E-TUTORIAL USE AND STUDENTS' EPISTEMIC AND ACHIEVEMENT LEARNING EMOTIONS

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ABSTRACT

This study explores the effect of epistemic and achievement learning emotions on student engagement and performance in a foundational business and economics course. We focus on the interaction between epistemic emotions, e-tutorial trace data, and achievement emotions within the context of a compulsory introductory mathematics and statistics course. Epistemic emotions, such as curiosity, confusion, frustration, and surprise, are crucial for cognitive engagement and learning retention but are often overlooked compared to achievement emotions like anxiety, boredom, hopelessness, and enjoyment. By employing dispositional learning analytics and analysing data from six cohorts of first-year students in the Netherlands, we examine how these emotions explain students' engagement with e-tutorials and subsequent academic performance. Our findings highlight the significant role of epistemic emotions in shaping students' learning behaviours and achievement emotions, which in turn affect their overall performance. Achievement emotions were measured using the Achievement Emotions Questionnaire (AEQ) and the Epistemic Emotion Scales (EES). Statistical analyses, including ANOVA and path modelling, show that epistemic emotions and behavioural data from e-tutorials are strong predictors of students' achievement emotions and performance. This research advocates for a more balanced approach in studying learning emotions, emphasizing the importance of both epistemic and achievement emotions in educational settings to improve academic outcomes and student well-being.

KEYWORDS

Learning Analytics, Dispositional Learning Analytics, Learning Emotions, E-Tutorials, Epistemic Emotions

1. INTRODUCTION

In the higher education world, particularly in demanding subjects like mathematics and statistics, understanding the role of emotions in student learning is crucial for enhancing both academic performance and student well-being. This study examines the interplay between epistemic learning emotions, e-tutorial trace data, and achievement learning emotions in a foundational business and economics course. By analysing the interactions among these elements, we aim to shed light on the often-underestimated role of epistemic emotions in the learning process. Epistemic emotions, which include curiosity, confusion, frustration, and surprise, are directly related to the cognitive aspects of learning tasks. These emotions are pivotal as they influence how students engage with, process, and retain new information. Despite their importance, epistemic emotions have historically received less attention compared to achievement emotions—such as anxiety, boredom, hopelessness, and enjoyment—which are more commonly associated with overall academic performance and motivation.

Our study utilizes dispositional learning analytics to examine a compulsory introductory mathematics and statistics course at a university in the Netherlands. We collected data from six cohorts of first-year business and economics students, encompassing e-tutorial system trace data and survey data on learning dispositions, including epistemic and achievement learning emotions. By analysing the interplay between epistemic emotion data, behavioural logs from e-tutorials, achievement emotion data, and course performance data, we aim to highlight the critical role of epistemic emotions in shaping students' engagement with e-tutorials. This engagement, in turn, influences their achievement emotions and overall performance. Our ultimate goal is to advocate for a more balanced approach in learning emotion research, recognizing the importance of both epistemic and achievement emotions in the educational experience.

2. LEARNING EMOTIONS: EPISTEMIC AND ACHIEVEMENT TYPES

"Over the past several decades, considerable research has indicated that students' emotions play a vital role in learning by modulating cognitive and motivational processes in multiple ways" (D'Mello, Moulder, Jensen, 2024, p. 1). At the same time, most of that research shared a common focus. "An overwhelming proportion of existing studies on emotions in education focuses on achievement emotions. … Epistemic emotions have recently started to play a major role in research." (Goetz et al., 2023, p. 150). Achievement emotions stem from engaging in learning activities, such as completing homework, while epistemic emotions pertain to the cognitive aspects of the task itself. Examples of prototypical epistemic emotions include curiosity and confusion.

Achievement emotions are defined as emotions directly related to achievement activities or their outcomes. Two types of achievement emotions can be distinguished based on their focus: activity emotions, which relate to ongoing achievement-related activities, and outcome emotions, which relate to the results of these activities. According to the control-value theory of achievement emotions, students' cognitive appraisals of an achievement outcome or activity are the proximal antecedents of emotions experienced in achievement-related situations. Two groups of appraisals are particularly relevant for achievement emotions: subjective control over achievement activities and their outcomes (e.g., the belief that persistence in studying can be maintained and will lead to success) and the subjective value of these activities and outcomes (e.g., the perceived importance of success) (Pekrun, 2000, 2006). Subjective value appraisals can be intrinsic (e.g., finding a learning activity valuable in itself) or extrinsic (e.g., valuing a learning activity because of its outcome) (Goetz et al., 2024). Although empirical studies typically estimate linear versions of control-value models, the framework suggests that control and value appraisals jointly determine the intensity of the emotional experience, implying a multiplicative model (Goetz et al., 2023). An additional non-linear element in the theory are the under- and over-challenge effects related to the boredom achievement emotion, indicating a curvilinear relationship between boredom and control (Goetz et al., 2024). In this study, achievement emotions were measured with the Achievement Emotions Questionnaire (AEQ: Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011).

Epistemic emotions do not refer to the learning activity, but to the cognitive aspects of learning knowledge. An example of a sequence of epistemic emotions when confronted with new knowledge incongruent with existing knowledge ranges from surprise to curiosity to confusion, anxiety and frustration when not successful, or enjoyment when successful (Goetz et al., 2023). In this study, epistemic emotions were measured with the Epistemic Emotion Scales (EES: Pekrun, Vogl, Muis, & Sinatra, 2017),

2.1 Dispositional Learning Analytics

Learning Analytics (LA, Ifenthaler, 2015) research primarily centred on constructing predictive models using data from institutional and digital learning platforms. The Dispositional Learning Analytics (DLA) infrastructure, introduced by Buckingham Shum and Deakin Crick (2012), combines learning data (trace data generated in logs of learning activities through technology-enhanced systems) with learner data (e.g., student dispositions, values, and attitudes measured through self-report surveys) (Tempelaar, 2024; Tempelaar, Rienties, & Giesbers, 2015). Learning dispositions represent individual differences that affect all learning processes and include affective, behavioural and cognitive facets (Rienties, Cross, & Zdrahal, 2017).

2.2 Research Aims

In this contribution, we aim to apply dispositional learning analytics to examine relationships between epistemic emotions, learning behaviours in the form of the use of e-tutorials, measuring both intensity and performance, as well as achievement emotions and course performance. In seeking better balance in the research community, this study emphasizes DLA over LA, and focuses on integrating epistemic emotions and achievement emotions. Our underlying hypothesis is that dispositions play a crucial role in LA studies, and epistemic emotions are essential in research on learning emotions. Additionally, since our data spans pre-pandemic, pandemic, and post-pandemic periods, a secondary objective is to explore the impact of the pandemic on students' learning emotions.

3. METHODS

3.1 Context and Setting

This research was conducted within an introductory mathematics and statistics course for first-year undergraduate students enrolled in a business and economics program in the Netherlands. The course demanded 20 hours of study per week over an eight-week period. It served as a compulsory foundational course, often proving challenging for students with limited mathematical aptitude. Employing a blended approach, the educational model followed the principles of flipped classroom design. The primary instructional method was Problem-Based Learning (PBL; Hmelo-Silver, 2004), conducted in small groups of 14 students each, guided by subject matter expert tutors. Attendance and participation in these tutorial groups were mandatory. Additionally, weekly lectures introduced fundamental concepts for that week's study. The remaining study hours were allocated for self-guided learning, facilitated by textbooks, along with access to two interactive e-tutorial platforms: Sowiso and MyStatLab, for mathematics and statistics, respectively. This educational framework emphasized student-centred learning, placing the responsibility for making educational choices primarily on the student. In student learning, we distinguish three phases. Phase 1 involved preparation for weekly tutorial sessions, where students engaged in discussions surrounding "advanced" mathematical and statistical problems. Successful participation in these discussions relied on prior self-study by the students. Phase 2 focused on preparing for bi-weekly quizzes, primarily serving as formative assessments to gauge students' comprehension of the weekly topics. Phase 3 encompassed preparation for the final exam in the eighth week, featuring formal, graded assessments. Consequently, students' study schedules were influenced by the varying demands of each phase, requiring different levels of preparation.

3.2 Participants

This study encompassed six cohorts of in total 6901 students spanning from the academic years 2018/2019 to 2023/2024. Within this sample, 38% were female, 62% were male, 18% possessed a Dutch high school diploma, while the remaining 82% were international students. Notably, among the international students, Germany (33%) and Belgium (20%) were well represented, with 7% of students from non-European countries. European high school systems exhibit significant variations in mathematics education, but all distinguish three tiers of math education in high school, tailored for sciences, social sciences, or humanities tracks. For admission to this international program, a background in mathematics geared towards social sciences is a prerequisite. Despite this, 37% of students pursued the highest academic track in high school, contributing to the diverse range of prior knowledge within the current sample. Given this diversity, the design of the first module for these students was pivotal. It necessitated flexibility, accommodating individual learning trajectories, and offering frequent, interactive feedback on students' learning strategies and tasks.

3.3 Data

In order to construct a longitudinal prediction model, our data is classified into six distinct time periods or intervals, as illustrated in Figure 1: demographic information obtained prior to the course commencement, epistemic emotions recorded during the initial week, e-tutorial trace data spanning the first four weeks, antecedents of achievement emotions along with the emotions themselves post the fourth week, and finally, course performance data at the conclusion of the course.

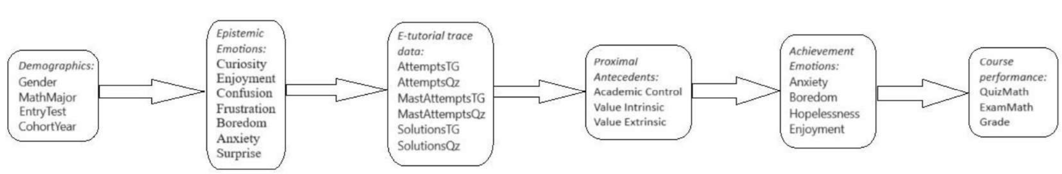

Figure 1. Data in this study, including temporal sequence

Demographics. This encompasses four key variables: Year indicator variables, Gender, indicating the gender of the student, MathMajor, indicating whether the student has previously studied mathematics at an advanced level, and EntryTest, which represents the score attained on a mathematics entry test.

Epistemic learning emotions. Epistemic emotions pertain to the cognitive facets of students' tasks. Characteristic epistemic emotions include curiosity and confusion. In this study, epistemic emotions were measured using the Epistemic Emotion Scales (EES) developed by Pekrun et al. (2017). The scales within the instrument can be categorized based on their valence (positive or negative) and activation component: either activating or deactivating. Positive, activating emotions comprise Curious and Excited, while negative, deactivating emotions encompass Confused, Frustrated, and Bored. Anxious represents a negative, activating emotion, while Surprised is classified as a neutral emotion.

E-tutorial log data were gathered from the Sowiso mathematics system, which is rooted in the instructional approach of mastery learning (Tempelaar et al., 2020). This methodology entails students progressively mastering mathematical concepts by successfully solving problems. Within Sowiso, students are provided with various scaffolding tools, including worked-out examples known as Solutions. The data includes information on Attempts, reflecting how many times a student has endeavoured to solve a problem, and Mastered Attempts, denoting the number of successful Attempts. In this study, we analyse trace data collected during the initial four weeks of the course. Specifically, this pertains to the recorded Attempts, Mastered Attempts, and Solutions during phase 1 learning (preparation for tutorial sessions, TG) for the first four weekly topics. Additionally, it includes data on Attempts, Mastered Attempts, and Solutions during phase 2 learning (preparation for quizzes, Qz) for the initial three weekly topics (with phase 3 extending beyond the fourth week).

Proximal antecedents of activity emotions. Academic Control, which reflects students' confidence in learning mathematics, was assessed using Perry, Hladkyj, Pekrun, & Pelletier's (2001) perceived Academic control scale. Value type of antecedents were determined using the SATS student attitudes toward learning quantitative topics questionnaire (Tempelaar, et al., 2007). Rooted in the expectancy-value theory proposed by Wigfield and Eccles (2000), this instrument incorporates two scales capturing the extrinsic and intrinsic aspects of valuing mathematics and statistics learning: Extrinsic Value assesses students' perceptions of the practical utility, while Intrinsic Value gauges their personal interest levels.

Learning Activity Emotions. The Control-Value Theory of Achievement Emotions (CVTAE), proposed by Pekrun (2000), asserts that emotions experienced during learning activities vary in terms of valence, focus, and activation. Emotional valence may be positive (e.g., enjoyment) or negative (e.g., anxiety). CVTAE delineates these emotions concerning an achievement activity (such as experiencing boredom while doing homework) or its outcome (such as feeling anxiety about an upcoming exam). The activation component characterizes emotions as either activating (prompting action, as in the case of anxiety) or deactivating (leading to disengagement, as with hopelessness). From the Achievement Emotions Questionnaire (AEQ) developed by Pekrun et al. (2011) to assess learning emotions, four scales were chosen: Enjoyment (LJO) representing a positive activating emotion, Anxiety (LAX) representing a negative activating emotion, and Boredom (LBO) and Hopelessness (LHL) representing negative deactivating emotions.

Course performance data. Student performance in the course is evaluated through three variables: QuizMath and ExamMath, which represent students' scores in mathematics quizzes and the final exam, respectively, and Grade, which encompasses scores from both mathematics and statistics exams and quizzes.

3.4 Procedure and Statistical Methods

Data collection occurred at various points in time, as depicted in Figure 1. Demographic information, along with epistemic emotions observed during the initial week of the very first university term, pertain to learning traits cultivated over six years of high school education. E-tutorial records were amassed within the first four weeks of the 8-weeks course, while achievement emotions and their proximal antecedents were assessed at the midpoint of the course, precisely four weeks into the course. In contrast to epistemic emotions, which focus on broader learning experiences, achievement emotions specifically target activities within the course, for clarification of the timing of data collection. Course performance data encompass the entirety of the course.

Statistical analyses were conducted using SPSS version 27 to compare groups through ANOVA, and MPlus version 8.11 for path modelling. In the path model, demographic factors and epistemic emotions act as exogeneous variables, e-tutorial trace data, achievement motivations and its antecedents, and course performance variables are endogenous. In line with previous studies into achievement emotions, we introduce quadratic and interaction terms in the estimation of activity emotions. Our goal is to develop a prediction model incrementally, aligned with the sequence of observations. Initially, exogenous demographic variables and epistemic emotions will predict learning activity. Next, control and value antecedents will be predicted using exogenous variables and learning activities as mediator. Following this, achievement emotions will be predicted by exogenous variables and both learning activity and control-value antecedents serving as mediators. Finally, in the fourth and final step, all these variables will be used to predict course performance.

4. RESULTS

4.1 Descriptives of Epistemic and Achievement Learning Emotions

Both epistemic and activity emotions demonstrate strong stability over years, as evidenced in Figure 2 and Table 1. Minor variations exist, with largest effect size for yearly differences being no more than 0.003.

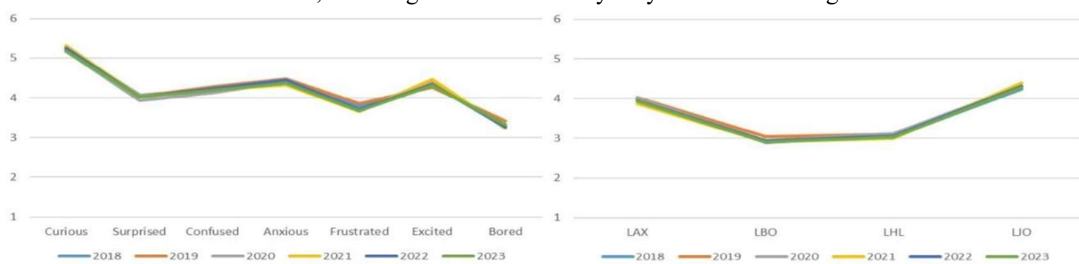

Figure 2. Yearly means of epistemic emotions, left panel, and achievement emotions, right panel

Table 1. Yearly means of epistemic emotions and achievement emotions

Year	Curious	Surprised	Confused	Anxious	Frustrated	Excited	Bored	LAX	LBO	LHL	LJO
18/19	5.24	4.06	4.22	4.4	3.78	4.35	3.27	3.96	2.89	3.05	4.24
19/20	5.18	4.03	4.27	4.47	3.85	4.27	3.42	4.02	3.05	3.11	4.29
20/21	5.18	3.93	4.13	4.4	3.68	4.38	3.26	4.01	2.94	3.12	4.31
21/22	5.31	4.04	4.20	4.33	3.66	4.46	3.24	3.87	2.91	3.00	4.38
22/23	5.25	4.02	4.23	4.44	3.70	4.34	3.27	3.95	2.93	3.06	4.31
23/24	5.17	4.02	4.18	4.37	3.68	4.31	3.32	3.93	2.92	3.02	4.28

Curiosity and Excitement, as epistemic emotions, consistently attain adaptive scores across all years, surpassing the neutral threshold of four. Conversely, negative epistemic emotions like Frustration and Boredom register scores below this neutral anchor, in accordance with adaptivity. However, both Confusion and Anxiety, also negative emotions, exhibit scores surpassing the neutral value, with Anxiety attaining the highest scores, the negative but activating emotion. The neutral emotion Surprise maintains neutral scores, displaying minor fluctuations around the neutral anchor.

Scores for achievement activity emotions tend to exhibit less deviation from the neutral anchor compared to epistemic emotion scores. Learning activity Anxiety (LAX) demonstrates minor fluctuation around the neutral anchor, while Boredom (LBO) and Hopelessness (LHL) consistently score below this neutral threshold. Conversely, Enjoyment (LJO) consistently registers scores above the neutral value.

4.2 Path Model

The scale and intricacy of the path model, in which the exogeneous variables, consisting of the demographic variables Year, Gender, MathMajor and EntryTest and the seven epistemic emotions Curiosity, Enjoyment, Confusion, Frustration, Boredom, Anxiety and Surprise explain the e-tutorial trace variables (Attempts, Mastered Attempts, Solutions, in first and second learning phase, registered in the first four weeks); trace variables together with exogeneous variables explain the proximal antecedents Academic control and Intrinsic and Extrinsic Value; all of these in turn explaining achievement emotions Anxiety, Boredom, Hopelessness and Enjoyment, and subsequently, all of these explaining the three course performance variables, prevents creating a diagram of the final path model. That final path model reaches adequate fit ($\chi^2 = 2570.735$ with df = 268, CFI = 0.983, TLI = 0.973, RMSEA [90% CI] = 0.035 [0.034-0.037], and SRMR = 0.047). In the following paragraphs, instead of using a diagram, the estimates of the several explanatory equations will be discussed.

In the explanation of the e-tutorial trace variables (as well as course performance variables), discrepancies among cohorts are significant, stemming from variations in assignment content and timing. Consequently, year indicator variables are integrated into the explanatory equations. However, these indicator variables will not be explicitly specified in the reporting. Estimated coefficients in explanatory equations are standardized. Starring of coefficient estimates indicates statistical significance (*: p<.05; **p<.01; ***p<.001).

AttemptsTG = 0.062***Surprise – 0.066***Confusion + 0.020***Frustration – 0.044***Boredom + 0.044***Female + 0.053***MathMajor + 0.037**EntryTest + YearIndicators; $R^2 = 0.095$

AttemptsQz = 0.032***Surprise + 0.030***Anxiety – 0.076***Boredom + 0.065***Female – 0.078***MathMajor – 0.029*EntryTest + YearIndicators; $R^2 = 0.054$

MasteredAttemptsTG = 0.053***Surprise – 0.062***Confusion – 0.046***Boredom + 0.073***Female + 0.088***MathMajor + 0.089**EntryTest + YearIndicators; $R^2 = 0.139$

MasteredAttemptsQz = 0.007**Curious – 0.079***Boredom + 0.121***Female + 0.071*EntryTest + YearIndicators; $R^2 = 0.048$

SolutionsTG = 0.063***Surprise – 0.059***Confusion + 0.038***Frustration – 0.037***Boredom - 0.033**EntryTest + YearIndicators; $R^2 = 0.047$

SolutionsQz = 0.045***Surprise + 0.043***Anxiety – 0.055***Boredom – 0.116***MathMajor - 0.093***EntryTest + YearIndicators; $R^2 = 0.076$

Between 4.7% and 13.9% of the variability in e-tutorial trace data can be accounted for by a combination of demographics and epistemic emotions. Regarding gender and previous education, we observe distinct patterns: students with greater prior knowledge (Math Major, high Entry Test score) engage in more preparation during the initial learning phase (Tutorial Group preparation), thus requiring less preparation during the subsequent learning phase (Quiz preparation). In contrast, coefficients for the Female indicator across all trace variables are positive, indicating that female students tend to prepare more intensively in both learning phases. Among epistemic emotions, Boredom consistently exerts a negative effect for all trace variables. Confusion plays a similar role but is specifically impactful on trace variables associated with learning during the initial phase, preparing tutorial group sessions. Anxiety confirms its status as a negative but activating emotion, but only for traces related to the learning in the second phase.

AcademicControl = 0.145***Curious – 0.074***Surprised – 0.111***Confused – 0.189***Anxious – 0.076***Frustrated – 0.050***Bored – 0.068***Female + 0.062***MathMajor + 0.074***EntryTest + 0.136***AttemptsQz + 0.041***MasteredAttemptsTG – 0.194***SolutionsQz; $R^2 = 0.216$

ExtrinsicValue = 0.246***Curious – 0.097***Confused – 0.142***Bored + 0.052***MathMajor + 0.057***EntryTest; $R^2 = 0.156$

IntrinsicValue = 0.369***Curious + 0.026***Surprised – 0.061***Confused + 0.053***Frustrated – 0.124***Bored + 0.131***Excited + 0.065***Female + 0.055***MathMajor + 0.041***EntryTest ; $R^2 = 0.312$

Epistemic emotions, particularly curiosity, are crucial in explaining the three proximal antecedents of achievement emotions. A consistent role is reserved for the two variables relating prior schooling, MathMajor and EntryTest. As anticipated, behavioural trace variables help explain Academic Control but not the two value constructs.

LAX, Anxiety = 0.440***Anxious + 0.079***Confused + 0.056***Frustrated + 0.122***Female – 0.175***AttemptsTG + 0.119***SolutionsTG – 0.310***AcademicControl – 0.049***AcademicControlSq; $R^2 = 0.528$

LBO, Boredom = 0.353***Bored – 0.097***Female + 0.033***MathMajor – 0.218***AttemptsTG + 0.138***SolutionsTG – 0.059***AttemptsQz – 0.229***AcademicControl – 0.031***AcademicControlSq – 0.060***ExtrinsicValue – 0.179***IntrinsicValue – 0.024***AcademicControlXIntrinsicValue; $R^2 = 0.384$

LHL, Hopelessness = 0.230***Anxious + 0.063***Confused + 0.085***Frustrated + 0.048***Bored + 0.062***Female – 0.033***EntryTest – 0.165***AttemptsTG + 0.127***SolutionsTG – 0.495***AcademicControl – 0.034***ExtrinsicValue – 0.056***IntrinsicValue; $R^2 = 0.590$

LJO, Enjoyment = 0.221^{***}Excited + 0.094^{***} Curious + 0.094^{***}Surprised – 0.066^{***}Bored + 0.085^{***}EntryTest + 0.068^{***}MasteredAttemptsTG + 0.161^{***}AcademicControl + 0.276^{***}IntrinsicValue + 0.039^{***} AcademicControlXIntrinsicValue; $R^2 = 0.427$

Both LAX and LBO are primarily explained not by the proximal antecedents from the CVTAE model but by their corresponding epistemic emotions: Anxious and Bored. LHL is best explained by a lack of Academic Control, while LJO is mainly explained by the epistemic emotion Excited, along with Academic Control and Intrinsic Value. Gender effects are evident in predicting Anxiety and Hopelessness. E-tutorial trace data follows a consistent pattern: students with more attempts during the initial learning phase (AttemptsTG) tend to have lower levels of negative achievement emotions, while students who only review worked examples during this phase (SolutionsTG) tend to have higher levels of negative achievement emotions. The quadratic term of Academic Control is significant only for explaining Anxiety, while the interaction between Academic Control and Intrinsic Value is significant for explaining both Boredom and Enjoyment.

MathExam = 0.153^{***}MathMajor + 0.074^{***}EntryTest + 0.235^{***}MasteredAttemptsTG + 0.364^{***}MasteredAttemptsQz – 0.298^{***}AttemptsQz + 0.073^{***}AcademicControl – 0.104^{***}LHL + YearIndicators; $R^2 = 0.460$
MathQz = 0.054^{***}MathMajor + 0.086^{***}EntryTest + 0.188^{***}MasteredAttemptsTG + 0.231^{***}MasteredAttemptsQz – 0.050^{***}SolutionsQz + 0.056^{***}AcademicControl – 0.036^{***}LHL + YearIndicators; $R^2 = 0.738$
Grade = 0.132^{***}MathMajor + 0.058^{***}EntryTest + 0.320^{***}MasteredAttemptsTG + 0.344^{***}MasteredAttemptsQz – 0.214^{***}SolutionsQz + 0.127^{***}AcademicControl – 0.122^{***}LHL – 0.014^{***}LBO – 0.053^{***}LJO + YearIndicators; $R^2 = 0.338$

E-tutorial trace data is the primary factor in explaining all three course performance measures. The key is the number of successful problem-solving attempts during the first two learning phases—Mastered Attempts to prepare for tutorial sessions and quizzes—adjusted for either the total number of attempts or the number of solution views. Achievement emotions play a minor role, with only LHL (Hopelessness) consistently appearing in all explanatory equations.

5. DISCUSSION AND CONCLUSIONS

Achievement emotions are crucial in any learning process, particularly for challenging subjects like mathematics and statistics in business and economics programs. Therefore, assessing and, where possible, influencing these emotions is important for both learning outcomes and student well-being. The control-value model is the most well-known theoretical framework for explaining levels of achievement emotions, focusing on three proximal antecedents: academic control, and extrinsic and intrinsic value. In this empirical study, we have shown that, beyond these proximal antecedents, distal antecedents in the form of epistemic emotions are equally important in understanding achievement emotions. For Anxiety and Boredom, these epistemic emotions, shaped by high school learning experiences, are even the dominant explanatory factors.

An additional note on control-value theory concerns the role of quadratic factors and interactions. The under- and over-challenge of students is expected to manifest in the negative emotion of Boredom. To demonstrate this, a quadratic term for Academic Control would be anticipated to have a positive coefficient. However, this term appears in the Anxiety and Boredom equations with a negative coefficient, indicating a levelling off at both high and low levels of academic control, in contrast to the hypothesis of under- and over-challenge. The interaction term between academic control and intrinsic value appears in the explanatory equations for two achievement emotions: Boredom and Enjoyment. The signs of the estimated coefficients are negative for Boredom and positive for Enjoyment, aligning with the control-value theory's assumption that strong achievement emotions develop when both control and value are high.

The most remarkable finding is however the interplay between epistemic emotions, students' e-tutorial activity, achievement emotions, and course performance. The only achievement emotion with a noticeable, though modest, effect on course performance is learning hopelessness. The primary factors explaining course performance are the counts of successful e-tutorial problem-solving attempts in the first and second learning phases, adjusted for unsuccessful attempts or simple solution views. These behavioural traces are in turn explained by epistemic emotions and demographics. Additionally, these same factors, along with trace variables, partially explain Hopelessness. This indicates that future research on learning emotions should prioritize epistemic emotions over achievement emotions. Moreover, it implies that educational practices should address maladaptive learning emotions that have emerged well before the class begins, rather than concentrating mainly on emotions that arise during in-class learning activities.

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