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Exploring links between feedback, emotions, and behavioral engagement in secondary school Singaporean students

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Abstract
In the current study, we examined the longitudinal relations among emotions, appraisals, and behavioral engagement with feedback in a sample of 314 Singaporean secondary school students. Students worked on writing assignments, and teachers gave feedback in the form of grades and comments. Students' emotions, appraisals, and receptivity to instructional feedback were assessed using a number of self-report instruments administered at four points in time, including the baseline and three additional waves. Repeated Measures ANOVA has shown variations in enjoyment, pride, excitement, anxiety, and shame, whereas non-significant differences were found for behavioral engagement, and aggregates of positive and negative affect over time. The latent growth modeling results have shown a steady decrease in enjoyment, pride, hope, and excitement, while the decline in anxiety and shame differed over time depending on the level of those emotions. Additionally, gender differences and changes in receptivity to instructional feedback were revealed. Cross-lagged panel model analysis also showed non-significant cross-paths, indicating high stability for the reciprocal influence of emotions and behavioral engagement over time. The findings provide insights about links among emotions, appraisals, and behavioral engagement and how these are forged by how students deal with the feedback.

Keywords Feedback · Emotions · Appraisal · Behavioral engagement · Longitudinal research · Secondary school

Introduction

In the context of education, feedback stands as a fundamental catalyst for learning and improvement and a critical component of the teaching and learning processes (Smith & Lipnevich, 2018). Despite its recognized significance, the effectiveness of feedback is not universally guaranteed and is determined by a wide range of factors. In this longitudinal study, we examine relations among emotions, cognitive appraisals, and behavioral engagement with feedback, while also considering variables that may explain the differential effects of feedback on meaningful educational outcomes.

Student processing of feedback

Undoubtedly, feedback processing is crucial for the efficiency of the feedback. No matter how perfect a feedback message is, if the students do not want or cannot use it, they will miss the opportunity to benefit from its formative potential (Jonsson, 2013). To explain the interaction of components that contribute to the effective uptake of feedback, the Student-feedback interaction model (Lipnevich & Smith, 2022) provides a comprehensive framework for understanding feedback dynamics, with a particular focus on how students interact with the feedback provided to them by one of the many sources. The model describes the context, the source, the feedback message, learners' characteristics,

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as well as processing (cognitive, affective, and behavioral) and how these variables may contribute to the key student outcomes.

To start our brief overview of the model, we must turn to context. Several studies have highlighted the importance of the context in cultural, environmental, and structural factors that relate to feedback. For example, Arimoto and Clark (2018) examined differential interpretations and responses to feedback of individuals coming from Western and non-Western cultural backgrounds. Korn et al. (2014) clearly illustrate that Western culture emphasizes individualism, while East Asian culture prioritizes interconnectedness. This fundamental difference might also influence how individuals from these cultures process feedback. In line with this hypothesis, Eriksson et al. (2020) examined the role of culture on the effectiveness of mistake-based feedback. To achieve this, students in 4th and 8th grades from 49 different countries participating in the 2015 TIMMS assessment were surveyed about whether their mathematics and science teachers informed them on how to improve after they made a mistake. The effect of mistake-based feedback was found positive in several countries which exhibited high levels of power distance and religiosity, with the exception of two countries, Malaysia and Singapore. Therefore, caution is warranted when making cross-context generalizations of feedback effects. In our study, we will consider feedback within the unique educational landscape of Singapore.

The effectiveness of feedback is not only affected by contextual factors but also by its sources (Lipnevich & Smith, 2022; Panadero & Lipnevich, 2022). Student responses to the identical message may differ depending on whether it came from teachers, peers, or technology-based systems (e.g., Reed, 2018; Zou et al., 2023). A study by Ruegg (2015) explored how teacher and peer feedback influenced students' writing skills. The findings highlighted that feedback from teachers was more effective than peer feedback in addressing concerns about meaning and content. Contrary to this finding, Cui et al. (2022) found that EFL peers could provide more meaning-level feedback than teachers provide. In another study by Zeevy-Solovey (2024), the perceptions and preferences of EFL students regarding teacher feedback, peer feedback, and feedback provided by an artificial intelligence (AI) tool were investigated. The findings indicated that teacher feedback and ChatGPT were viewed as effective, with students showing a preference for teacher-written corrective feedback (WCF) alongside a blend of this feedback with ChatGPT WCF. Therefore, the research has shown the differential effects of feedback from different sources, highlighting the importance of considering where feedback originates. Various aspects of the feedback message, including timeliness, accuracy, level of detail, comprehensibility, focus, function, and tone, also play crucial roles in effective feedback processing (Fyfe et al., 2021; Lipnevich & Smith, 2022; Nash et al., 2021).

In addition, the learner's characteristics are essential in shaping their interaction with feedback. Students' ability, congruency of expectations with feedback, self-efficacy beliefs, motivation, personality traits, and receptivity to feedback all influence how they engage with the feedback (Fong et al., 2021; Laudel & Narciss, 2023; Lipnevich & Smith, 2022). Student ability influences the way feedback is crafted and adjusted based on their current performance, as well as how students interpret this feedback (Lipnevich & Smith, 2022; Winstone et al., 2017). For example, a study conducted by Chong (2017) with secondary school students in Hong Kong found a strong relation between students' writing abilities and the relevance and accuracy of the feedback they provide to their peers. Any possible alignment or discrepancy between what students expect and their experience may cause them to respond to the feedback differently (e.g., Baadte & Kurenbach, 2017; Eva et al., 2012; To et al., 2023). Besides, students' self-efficacy beliefs influence students' responses to the feedback. For example, Adams et al. (2020) demonstrated positive relations between academic self-efficacy and students' perceptions of feedback. In fact, students' academic self-efficacy served as a mediator in the relationship between their perceptions of feedback and their academic attainment. Instead of demonstrating outright resistance, people with a strong sense of self-efficacy may also accept feedback, even when it contradicts their expectations (To et al., 2023). Besides, motivation might be influential in shaping students' reactions toward feedback. A study by Gan et al. (2021) found that when students' motivation regarding the perceived usefulness and interest in feedback increased, they showed higher engagement with teacher feedback and generated internal feedback more frequently. Personality traits are also essential for effectively addressing how students respond to feedback. As supported by varying studies (e.g., Linvill, 2019; Lipnevich et al., 2021), Dawson et al. (2024), for example, confirmed the strong bonds between personality traits and student feedback orientations. Specifically, students demonstrating high levels of conscientiousness—characterized by achievement orientation and discipline—along with those exhibiting openness and a keen desire for new information consistently showed higher behavioral engagement with feedback. Furthermore, students who were cooperative and trusting, with high scores in agreeableness, actively sought, utilized, and provided feedback. Last, receptivity to instructional feedback, as a learner characteristic, refers to individuals' readiness and willingness to accept feedback and includes four essential dimensions: instrumental attitudes (feedback utility), experiential attitudes (affect toward feedback), cognitive engagement (cognitive processing of feedback),

and behavioral engagement (feedback use) (Lipnevich & Lopera-Oquendo, 2022; Lipnevich et al., 2021). Recent studies have shown that college students who demonstrate higher receptivity to instructional feedback across various dimensions tend to perform better (Bahr et al., 2024) and experience more positive emotions and fewer negative emotions, underscoring the profound impact of feedback capabilities on students' emotional well-being (Calik, 2024).

In alignment with the Student-feedback interaction model, for feedback to be effective, students must engage in its cognitive, affective, and behavioral processing. Cognitive processing involves understanding the feedback and determining how to apply it further, often incorporating metacognitive elements where students internally evaluate their performance against criteria like rubrics or teacher comments (Nicol, 2021). Affective processing emphasizes students' emotional reactions to the feedback, which may influence how they use it (Pitt & Norton, 2016; Robinson et al., 2013). Behavioral processing encompasses the actions students take upon receiving feedback, such as seeking help or revisiting materials. These components are intertwined, as research shows that affective engagement can impact cognitive and behavioral engagement (Yu et al., 2019). For instance, negative reactions to feedback may lead to reduced behavioral engagement, as seen in studies of foreign language learners (Lira-Gonzales et al., 2021). Similarly, Zhang and Hyland (2018) explored Chinese university students' responses to teacher and automated writing feedback and showed that high cognitive engagement correlated with greater willingness to use feedback-enhanced positive attitudes, and increased time spent on revisions compared to moderately engaged peers. Further, Cheng and Liu (2022) observed disparities in engagement levels among Chinese EFL learners based on proficiency, with high-proficiency students demonstrating deeper engagement and more positive emotions. Zheng and Yu (2018), focusing on lower proficiency-level students, noted limited cognitive and behavioral engagement despite positive affective responses, highlighting the complexity of feedback engagement, while Zheng et al. (2023) underscored the role of student beliefs, goals, and teacher–student relationships in shaping engagement types. In sum, feedback processing encompasses behavioral, cognitive, and affective dimensions. In our study, we aim to examine these dimensions, exploring their interactions with student variables in the specific context of our research.

Emotions and feedback

Given the significant role of emotions in response to feedback (To, 2016), it is imperative to closely examine their impact. Achievement emotions refer to the psychological processes tied directly to learning activities or outcomes (Pekrun, 2006, 2018). In Pekrun's (2006) control-value theory (CVT), there is a dynamic relationship between the antecedents and consequences of achievement emotions. Different antecedents become influential in triggering distinct emotions, which, in return, directly or indirectly affect many learning outcomes, including the use of learning strategies, motivation to learn, self-regulated learning, and, ultimately, academic achievement (Pekrun, 2006, 2018). Cognitive antecedents involve individuals' interpretations of situations, known as appraisals, which include subjective control (i.e., attributional beliefs and self-efficacy) and value (i.e., intrinsic or extrinsic) appraisals. Different emotions can be activated by different levels of perceived control, perceived value, or the interplay between the two (for an overview, see Pekrun, 2006, 2018). Research has also shown significant relationships between cognitive appraisals and distinct emotions (e.g., Bieg et al., 2013; Forsblom et al., 2022; Goetz et al., 2010; Peixoto et al., 2017), and this is the link that we will consider longitudinally in the context of secondary education.

According to the CVT model, cognitive appraisals are influenced by several environmental and individual antecedents, with feedback being one of them (Pekrun, 2006). For example, the feedback students receive may affect the way they feel about an academic task, leading to improved (or hindered) academic performance and their receptivity to additional feedback in the future. In particular, positive or negative feedback might influence students' cognitive appraisals, such that receiving positive feedback might foster subjective control beliefs and trigger positive emotions, such as enjoyment and pride. However, receiving negative feedback might diminish the perceived control beliefs of students, which might boost their negative emotions (Pekrun et al., 2023). Although several studies have shown that positive feedback tends to evoke positive academic emotions, either directly or indirectly, while negative feedback tends to elicit negative academic emotions (Goetz & Hall, 2020; Sargeant et al., 2008; Vogl & Pekrun, 2016), drawing conclusions about this relationship is still not so simple. Perhaps, the important consideration is what positive and negative feedback means. Indeed, context, student characteristics, teacher expectations, and past performance, some of which represent important elements of the Student-feedback interaction model, might be considered when perceiving feedback as positive or negative. For example, while receiving 80 out of 100 may be considered a great success for one student and thus will trigger positive emotions, another student may perceive this outcome as a complete failure and thus experience negative emotions (Goetz et al., 2018; Lipnevich et al., 2021). Thus, further studying these links is of key importance, which is what we did in the current study.

Pekrun (2006) discusses the relative universality of achievement emotions across different cultures and genders. Namely, achievement emotions, control-value appraisals, and achievement linkage are virtually equivalent across genders, academic domains, and cultural contexts (Pekrun & Goetz, 2024). However, the specific elements of appraisals may vary across individuals, and those differences in appraisals can lead to variations in emotional responses. Moreover, individual factors in control-value theory, such as performance and achievement goals, are influenced by gender, race, and social class (Pekrun, 2024). Therefore, gender and culture play salient roles in portraying achievement emotions, with studies showing disparities in the types and intensity of emotions students experience across genders and in different cultures. For instance, Frenzel et al. (2007a) investigated the emotion profiles of 5th-grade German students, revealing lower enjoyment and pride but higher anxiety, hopelessness, and shame among female students in mathematics. Similarly, Reilly and Sánchez-Rosas (2021) explored gender variations in university-level students' emotions during second language testing in Mexico, noting that male students exhibited more frequent enjoyment, hope, relief, pride, and anger, while anxiety, shame, and hopelessness were non-significant. In another study, Fierro-Suero et al. (2022) assessed achievement emotions among Spanish secondary education students in physical education, finding higher negative emotions and lower positive emotions among girls. However, the consistency of these emotional patterns across genders and cultures remains uncertain, highlighting the importance of considering individual differences in emotion research.

Given the propositions set by the CVT (Pekrun, 2006) and the Student-feedback interaction model (Lipnevich & Smith, 2022), students' interactions with the feedback may influence their emotions, appraisals, reactions, and participation in the feedback. There is a need for studies that explore these constructs, particularly in longitudinal studies, which is what we attempted to accomplish in our study.

Context

In Singapore, children enter secondary school at age thirteen. Depending on their performance at the national Primary School Leaving Examinations (PSLE), they are channeled into the Normal (Technical) course which leads to a more vocational pathway or to 5-year Normal (Academic) course or a 4-year Express course which leads to General Certificate of Education (GCE) certificates that qualify them for post-secondary education. It has often been reported that Singaporean secondary school students perform well against their global counterparts. The Organization for Economic Cooperation and Development (OECD) has consistently rated Singaporean 15-year-olds among the top performers in Programme for International Student Assessment (PISA) study in mathematics, science, and reading (OECD, 2019a). However, the same report shows that they are also more afraid of failure (72% compared to OECD average of 56%).

The students' sterling performance could be due to the pervasive in-service training with 98% teachers attending at least one professional development activity in the past year (OECD, 2019b). This may be due to the government's commitment to ensuring teachers constantly upgrade their competencies. Lately, in 2020, the Ministry of Education (MOE) announced an initiative to map out the training route for all teachers in the following five years. Termed "Skills Future for Educators" (SFEd), it identified six prioritized areas (MOE, 2020), one of which being assessment literacy. To be assessment literate, teachers must be able to plan and design assessments to assess student learning, communicate purpose and criteria of assessment, use assessment information and involve the learner in assessment, especially through feedback and self-assessment. Teachers can sign on to various workshops mounted by MOE or other agencies such as the National Institute of Education (NIE). In other words, it is safe to state that Singaporean teachers have substantial exposure to feedback-related training. Hence, we used feedback as a constant without varying its nature.

The current study

This study aimed to explore the longitudinal relations between emotions, appraisals, and behavioral engagement with feedback in a sample of secondary students in Singapore. Previous literature has generally employed cross-sectional designs to investigate the links between feedback and emotions (e.g., Pekrun et al., 2014) and examination of student responses to feedback in non-western context has been scarce. Therefore, we will extend previous research and contribute to the literature by examining the following research questions:

1. Do emotions, appraisals, and behavioral engagement with feedback have a significant variation across time in a sample of secondary school students in Singapore?
2. What is the reciprocal influence of emotions and behavioral engagement over time?
3. Are there differences in key variables and trends between female and male students?

Method

Participants

Participants in this study were $N = 314$ secondary students (aged 15 years, $M = 15$, $SD = .3$) from Singapore enrolled

in five schools. These schools were drawn from a diverse range of educational contexts in the system. An autonomous school, similar to U.S. private schools, operates with greater independence in curriculum and funding while maintaining higher academic standards. Government schools, akin to U.S. public schools, are fully funded and managed by the state, offering standard curricula accessible to all students. A government-aided school, also comparable to U.S. public schools, receives substantial government funding but is independently managed, often by religious or community organizations. In each school, three distinct academic tracks were represented: Normal (Technical) classes focus on hands-on, vocationally oriented education; Normal (Academic) classes emphasize a broader academic curriculum preparing students for higher education; and Express classes cater to high-performing students with an accelerated curriculum. Among the participants, 54.1% ($n = 170$) were self-identified as girls and 45.9% ($n = 144$) as boys.[1]

Procedure

At baseline, participants completed the questionnaire assessing their emotions, appraisal, and receptivity to feedback when getting grades and teachers' comments. Following the three-week baseline data collection period, students worked on writing assignments, with teachers providing feedback after each assignment. Immediately after receiving feedback, consisting of grades (numerical scores) and comments, students reported their emotions, appraisals, and behavioral engagement with the feedback. The teacher feedback in this context was exclusively written, provided as annotated comments on students' work. This approach allows for detailed, contextualized guidance, helping students understand specific areas for improvement directly in relation to their performance. Annotated feedback is particularly effective for fostering reflection, as students can connect the feedback to precise elements of their work. Additionally, the focus on identifying opportunities for improvement highlights a formative orientation, aiming to enhance learning and skill development.

Data collection was conducted online, except in one classroom where the teacher distributed the surveys in a paper-and-pencil format. In this case, a research assistant manually entered the data into the system. The study included three waves of writing assignments and feedback, with approximately three weeks between wave 1 and wave 2, depending on the schools' writing schedules. Between waves 2 and 3, all schools transitioned to home-based learning, causing a delay in the writing tasks. Schools resumed one month later, at which point data for wave 3 were collected. The items collected during baseline and subsequent waves are detailed in Table A1 (Supplementary Material).

An application for ethics clearance was submitted to the Nanyang Technological University Institutional Review Board (NTU-IRB) before the start of data collection. Consent forms, information sheets, study procedures, as well as instruments, received approval from the NTU-IRB. Students and their parents gave consent to participate in the study by signing the same form, accompanied by an information sheet that was also approved by the institutional review board.

Measures

Receptivity to instructional feedback (RIF)

The receptivity to instructional feedback (RIF) is a self-report instrument designed to measure students' acceptance of instructional feedback (Lipnevich et al., 2021), which was validated in the same sample of secondary school students from Singapore used in this current research (Lipnevich & Lopera-Oquendo, 2022). A total of 24 Likert-type items measured on a 5-point scale (1 = strongly disagree and 5 = strongly agree) was generated under four receptivity scales: (1) experiential attitudes toward feedback, or affective engagement with feedback (e.g., I look forward to receiving the instructor's comments on my work); (2) instrumental attitudes toward feedback (i.e., value for feedback; e.g., I find the comments I get on my assignment to be very helpful); (3) cognitive engagement with feedback (e.g., I know how to use feedback comments to improve my work); and (4) behavioral engagement (e.g., When I receive feedback, I carefully read every comment). The finding of the validation study supported configural, metric, partial scalar, partial strict, variance, and covariance invariance across gender groups. Moreover, after controlling for gender, cognitive engagement and experiential attitudes predicted increments in grades, suggesting evidence for discriminant validity among the receptivity factors and their relevance for predicting meaningful educational outcomes.

Individual scores for each RIF scale were estimated using a Graded Response Model (GRM, Samejima, 1969), which is appropriate for the polytomous and ordinal nature of the

[1] The percentage of omissions across all items and waves ranged from 2.5% to 7.6%. These low omission rates indicate that most participants provided complete responses, minimizing the potential for selection bias. While some variation in omissions was observed, particularly in Wave 3, this was likely influenced by external factors such as changes in school schedules. Overall, the consistent pattern of low omission rates across key measures suggests that the findings are based on a representative subset of the sample.

items categories of responses (Kolen & Brennan, 2014) following the recommendation of the technical report of these constructs (Lipnevich & Lopera-Oquendo, 2022).[2] Individual scores derived from model estimation were transformed to have a mean of 0 and a standard deviation of 1. The internal consistency reliability statistics (Cronbach's α) across the four scales for baseline ranged from $.74 < \alpha < .86$ (Table A2, Supplementary Materials).

Behavioral engagement after feedback

The Behavioral Engagement with Feedback Scale is a self-report instrument designed to assess the degree to which students actively and thoughtfully engage with academic tasks following feedback from their teachers. This scale evaluates actions and attitudes that demonstrate deliberate attention to feedback (e.g., "I carefully read every comment," "I will go over my teacher's comments several times"), efforts to understand and apply it (e.g., "I will make sure I understand my mistakes"), and a proactive behavior and willingness to seek clarification when necessary (e.g., "I will try to address every comment that my teacher made," "I will ask my teacher to explain comments I do not understand"). (Lipnevich & Lopera-Oquendo, 2022). A total of 9 Likert-type items measured on a 5-point scale (1 = strongly disagree and 5 = strongly agree) were administered in three subsequent points of data collection (waves 1 thru 3). Individual scores for each this scale in each data collection point were estimated using a Graded Response Model (GRM, Samejima, 1969), following the recommendation of the technical report of these construct (Lipnevich & Lopera-Oquendo, 2022). Behavioral Engagement after Feedback had an internal consistency reliability Cronbach's α range from $.84 < \alpha < .89$ (Table A2, Supplemental Materials).

Positive (PA) and negative affect (NA)

Students responded to a self-report questionnaire gauging their emotions using eight discrete emotions measured using a reduced version of the Positive and Negative Affect Schedule (PANAS; Watson et al., 1988). The items prompted students to report how they felt after receiving teachers' feedback, using a Likert scale that ranged from 1 (very slightly or not at all) to 5 (extremely). In order to check the dimensions of positive affect (PA) and negative affect (NA) as two independent factors, an Exploratory (EFA) and Confirmatory Factor Analysis were conducted (CFA). (Table A1, Supplementary Materials). Single emotions were collected during baseline (trait) and in subsequent waves (waves 1 through 3) after receiving feedback from teachers (state). Individual scores for positive affect and negative affect scales, as well as discrete scores for single emotions, were used in the current analysis.

Appraisal

Two single items, using a Likert scale that ranged from 1 (Strongly disagree) to 5 (Strongly agree") were used to measure students' appraisals "*Doing well on assignments is important to me, no matter what mark I get*" and "*It is important for me to get a good mark on* assignments," which serve as indicators for intrinsic and extrinsic value. Individual scores for discrete emotions were used in the current analysis.

Analytic plan

Descriptive and psychometric analyses were conducted initially to evaluate the reliability and validity of multi-item scale measures. First, exploratory Factor Analysis (EFA), using parallel analysis and oblimin rotation of polychoric correlation matrix, as well as Confirmatory Factor Analysis (CFA) through Structural Equation Modeling (SEM) with Weighted Least Squares Mean and the Variance Adjusted (WLSMV) estimator (Sass et al., 2014) was conducted to examine the factor structure of positive (PA) and negative affect (NA) scales. We used the following indices to assess the overall fit model good fit: (1) the Root Mean Square Error of Approximation (RMSEA) with values $< .08$ being indicative of reasonable fit and values $< .05$ indicating a good fit; (2) the Comparative Fit Index (CFI) and Tucker–Lewis Index (TLI) with values $> .90$ indicating an acceptable fit and values $> .95$ indicating a good fit; and (3) the Standardized Root Mean Square Residual (SRMR) with values $< .05$ being indicative of good fit (Brown et al., 2014; Browne & Cudeck, 1992; Hair et al., 2010; Hu & Bentler, 1998, 1999; MacCallum et al., 1996; Yu, 2002).

Second, we conducted a set of nested hierarchical models to test hypotheses about CFA data fit, including the configural, metric, scalar, partial scalar, and partial strict factorial invariance models, as well as equal means, variance and covariance factor models (Gregorich, 2006; Lugtig et al., 2011; Milfont & Fischer, 2010; Millsap & Yun-Tein, 2004; Schoot et al., 2012; Vandenberg & Lance, 2000), for addressing the time and gender invariance of behavioral engagement after feedback and positive (PA) and negative affect (NA). Measurement invariance was tested by evaluating how well the models fit the observed data. Configural invariance was tested by evaluating the overall fit of the models. Moreover, the comparison of nested models, that

[2] Technical manual containing R code, data, codebook, and additional information for scoring Receptivity to Instructional Feedback scales is available in https://osf.io/5xnz7/ (Lipnevich & Lopera-Oquendo, 2022).

is, models that are identical except for a target set of restrictions in one, was evaluated by comparing the differences in fit statistics for the two models. Specifically, Satorra–Bentler (SB) scaled statistics ($\Delta\chi^2$) and differences in model degrees of freedom (Δdf) were computed to test whether the more constrained model resulted in a significantly weaker fit. We considered a violation of invariance when comparing one level of analysis to the next more stringent level; we found a change in CFI greater than .01 together with a change in RMSEA greater than .015 (Chen, 2007; French & Finch, 2006; Putnick & Bornstein, 2016). Additionally, for descriptive analysis, Pearson correlations were calculated for all scale scores in the study.

To address the first research question, two approaches were employed. Firstly, an ANOVA Repeated Measure with Huynh–Feldt sphericity correction was conducted to identify significant variations across time for individual emotions, positive affect, negative affect, and behavioral engagement. Post hoc analyses, using the Benjamini–Hochberg method to adjust p-values for multiple comparisons, were also carried out. Secondly, Linear Latent Growth Models (LGM) were used to investigate the trajectories of single emotions and scales over time, using a structural equation model approach. In LGM, the measured variables (Y) are repeated measures of the same variable. In a basic LGM, two factors were specified to represent aspects of change: an intercept (η_1) representing the level of the outcome measure at initial time point, and the slope factor (η_2) representing the rate at which the outcome measure changes (growth) (Preacher et al., 2008). Figure 1 depicts the path diagram of the factor model underlying the linear Latent Growth Model (LGM).

A series of theoretically plausible models were specified and tested to identify the most acceptable model for explaining the trajectories (intercepts and slopes) of variables across participants. In model 0 (null model), there is no change over time and no overall variability in mean level (Widaman & Thompson, 2003). Therefore, only the mean level (intercept; α1) and a common disturbance variance (θ_ε) were estimated. Model 1 (Random Intercept), all factor loadings for intercept are fixed to 1.0 and disturbance or unexplained individual variances constrained to equality (θ_ε), while the interindividual variance (ψ_{11}) can be higher than 0. Model 3 (Fixed Intercept, Fixed slope), intercept and the slope are fixed, meaning that a single, average intercept parameter (α_1) and linear slope parameter (α_2) are estimated, ignoring any correlation between slope and intercept ($\psi_{21}=0$) as well as

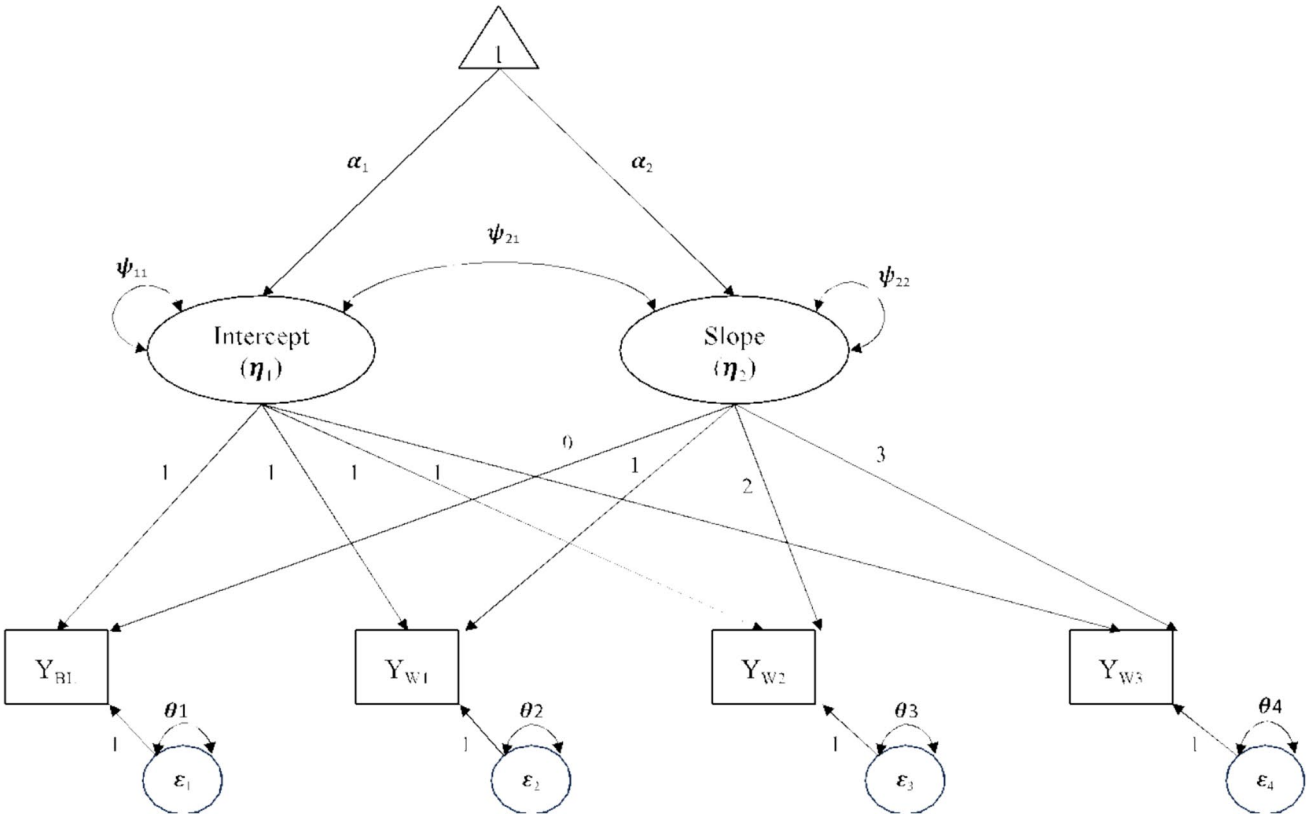

Fig. 1 Path diagram for a typical Latent Growth Curve Model. Note: α = Latent construct mean; ψ = variance and covariance; θ = indicator residual variance; ε = residual variance, Y_{BL} = outcome variable (i.e., individual emotions, positive affect, negative affect, and behavioral engagement) measure at baseline, Y_{wi} repeated measure outcome variables time i (i = 1 to 3)

unexplained individual variances constrained to equality (θ_ε). Model 4 (Random Intercept, Random Slope), every individual is allowed to have a different slope and intercept and also allows estimation of the intercept–slope covariance (ψ_{21}). Finally, Model 5 (Unconstrained) allows variating the disturbance or unexplained individual variances constrained to equality (θ_ε) across times. Moreover, for those variables where trajectories (intercepts and slopes) varied significantly across participants, a conditional model was checked to analyze whether gender and RIF at baseline explained some of that interindividual variability. Maximum likelihood (ML) estimation was used to fit all statistical models to the data because the initial evaluation of the data did not show major violations of normality.

To answer the second research question, a Cross-Lagged Panel Model (CLPM) was used to examine the reciprocal influences between single emotions and behavioral engagement with feedback over time (Mund et al., 2021). Figure 2 shows a bivariate CLPM with four measurement occasions. In the first model, autoregressive paths (a_1 and a_2) were constrained to be equal across time and indicate to what extent the rank order of individuals remains stable for emotions and behavioral engagement, respectively. The cross-lagged paths (c_1 and c_2) represent the strength of the reciprocal influences between emotions (x) and behavioral engagement (y) over

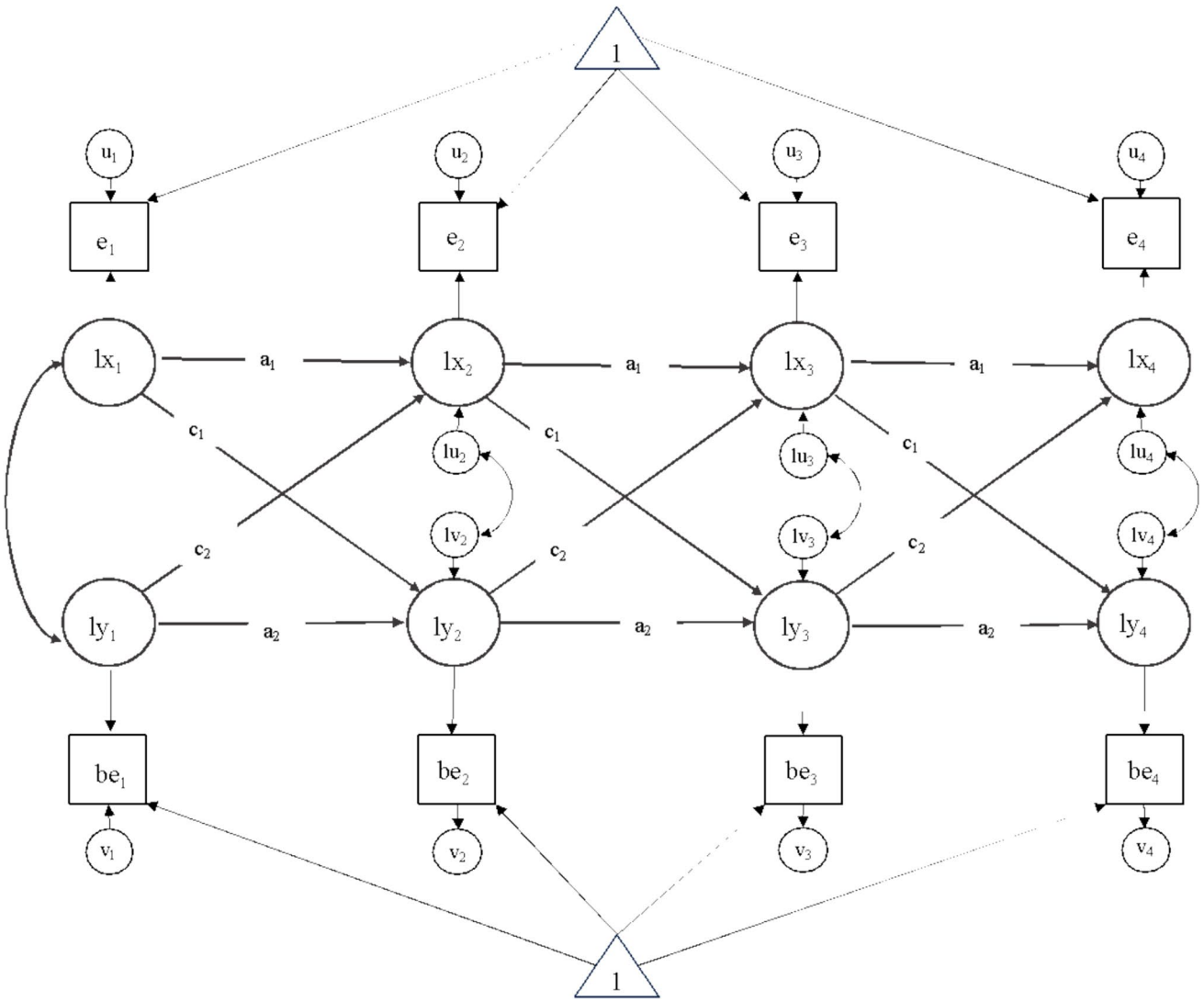

Fig. 2 Cross-Lagged Panel Model. Note: Squares represent observed variables for single emotions (e) and behavioral engagement scores (be_i), circles indicate latent variables, equivalents to observed variables. Triangles refer to intercepts. Directional arrows indicate regressions, double-headed arrows indicate correlations. Equal path labels (a1 and a2) and cross-lagged parameter (c1 and c2) were constrained to be equal across time. Figure has been published in Mund and Nestler (2019) under a CC-BY 4.0 license and is available at https://osf.io/sjph7/

time, that is, to what extent scores on emotions (behavioral engagement) at time point t are prospectively associated with scores on behavioral engagement (emotions) at the subsequent time point $t+1$. A second model where autoregressive effects, cross-lagged effects, and factor residual invariances were freely estimated was also estimated to provide the invariance of parameters, which means to identify whether imposing constraints on the models did not significantly worsen fit. The third research question, concerning the gender comparison of results, has been addressed through the analyses conducted in the preceding research questions.

A set of nine different models were estimated, including eight separate models for the discrete emotions and one integrative model combining all emotions into two positive and negative affect factors. We estimated two versions for all models. In the first version, autoregressive coefficients, cross-paths, and factor residual variances were freely estimated. In the second version, these parameters were constrained to be equal over time. Satorra–Bentler (SB) scaled χ^2 statistics ($\Delta\chi^2$) were computed to test whether the more constrained models result in a significant worsening of fit (Chen, 2007; French & Finch, 2006).

The following indices and their cut-offs to assess an 'acceptable' or 'good' fit were used (Brown et al., 2014; Browne & Cudeck, 1992; Hair et al., 2010; Hu & Bentler, 1998, 1999; MacCallum et al., 1996; Yu, 2002): (1) the Root Mean Square Error of Approximation (RMSEA) with values $< .08$ being indicative of reasonable fit and values $< .05$ indicating a good fit; (2) the Comparative Fit Index (CFI) and Tucker–Lewis index (TLI) with values $> .90$ indicating an acceptable fit and values $> .95$ indicating a good fit; and (3) the standardized root mean square residual (SRMR) with values $< .05$ being indicative of good fit. All analyses used R software version 4.1.2 (R Core Team, 2021).

Results

Measurement of positive (PA) and negative affect (NA)

First, we evaluate the goodness-of-fit of alternative models to understand and provide a valid latent variable for emotions. Based on the original instrument we first hypothesized, based on the original instrument, that single items would load onto two independent factors: positive affect (PA) and negative affect (NA) by each item administration. An Exploratory Factor Analysis (EFA) was conducted on a randomly selected half of the sample to identify the underlying factor structure of the emotional items. The EFA revealed that an 8-factor solution accounted for 69.1% of the variance. Subsequently, a Confirmatory Factor Analysis (CFA) was performed to test the hypothesized factor structure. The analysis indicated that the 2-factor correlated structure, with four items per scale across each time point, demonstrated acceptable model fit: RMSEA = 0.056 (90% CI: 0.050, 0.062), CFI = 0.984, TLI = 0.981, and SRMR = 0.076). The correlations between the factors ranged from −0.1187 to 0.7088, indicating acceptable discriminant validity. The internal consistency (Cronbach's α) for the positive affect (PA) scale ranged from $.779 < \alpha < .873$ across the baseline and three subsequent waves, while the negative affect (NA) scale exhibited reliability ranging from $.726 < \alpha < .811$. Tables B1 to B3 (Appendix B Supplementary Materials) provide details of loading factors for EFA, model fit indices of the CFA models, and reliability statistics.

The invariance analysis indicates that the positive affect (PA) and negative affect (NA) factors supported configural, metric, scalar, strict, variance, and covariance invariance across data collection points (Table B4, Supplementary Material). Additionally, the invariance analysis by gender supports both configural and metric equivalence of the measures (Table B5, Supplementary Material), suggesting that the basic factor structure and factor loadings of the model remain consistent across different genders. Individual scores for PA and NA scales at each time were estimated using the GRM-IRT model (Table B6, Supplementary Material). Individual scores derived from model estimation were transformed to have a mean of 0 and a standard deviation of 1. Scores for PA and NA scales, and also discrete emotions scores, were used in the current analysis.

Behavioral engagement after feedback

The invariance analysis of the measure across time of administration (waves 1 through 3) was also conducted. Findings supported configural, metric, partial strict, scalar, and variance and covariance equivalence of behavioral engagement after feedback scale by waves as well as configural, metric, and partial strict variance by gender. These results indicate that the behavioral engagement measure is robust and maintains its structural validity across time and between genders, ensuring the quality and comparability of the assessments. Tables C1 to C3 (Appendix C, Supplementary Material) present the nested Invariance models comparison by time and gender, as well as additional indicators of scale reliability.

Descriptive analysis

Descriptive statistics and correlations for all variables of interest in this study (discrete emotions, intrinsic and extrinsic value, behavioral engagement, and positive and negative affect) are presented in Tables A3 and A4 (Supplemental Materials), all of which followed a univariate normal distribution. Additionally, Tables 1 and 2 contain descriptive statistics and correlations between discrete items and scales

with behavioral engagement after feedback across all waves, respectively. Results indicated a moderate positive correlation between behavioral engagement with RIF scales at baseline ($.411 < r < .700$), as well as a weak-to-moderate positive correlation with PA ($.130 < r < .324$) across all waves. In contrast, NA showed a weak negative correlation with concurrent measures of behavioral engagement. Pearson correlation between scales by waves is presented in supplemental materials (Table A5).

Table 1 Descriptive statistics and correlation between behavioral engagement and discrete emotions, intrinsic and extrinsic values across waves

Wave	Variable	Mean	SD	Behavioral engagement			
				Baseline	Wave 1	Wave 2	Wave 3
Baseline	Enjoyment	3.177	(1.036)	**0.307**	**0.329**	**0.227**	**0.245**
	Pride	2.833	(1.031)	**0.114**	**0.157**	**0.138**	**0.137**
	Anger	1.636	(0.915)	**−0.225**	**−0.270**	**−0.204**	**−0.243**
	Hope	3.115	(1.062)	**0.285**	**0.246**	**0.227**	**0.211**
	Anxiety	2.902	(1.297)	0.017	0.013	0.011	−0.036
	Shame	2.305	(1.220)	−0.076	−0.083	−0.100	−0.091
	Hopelessness	1.954	(1.099)	**−0.160**	**−0.146**	**−0.161**	**−0.179**
	Excitement	2.761	(1.163)	**0.229**	**0.259**	**0.192**	**0.182**
	Intrinsic value	3.974	(0.961)	**0.324**	**0.331**	**0.393**	**0.271**
	Extrinsic value	3.933	(0.887)	**0.146**	**0.117**	**0.185**	**0.159**
Wave 1	Enjoyment	3.020	(1.116)	**0.213**	**0.244**	**0.161**	**0.131**
	Pride	2.724	(1.144)	0.076	**0.175**	0.076	0.052
	Anger	1.751	(1.055)	**−0.152**	**−0.194**	**−0.162**	−0.100
	Hope	2.956	(1.169)	**0.315**	**0.307**	**0.311**	**0.232**
	Anxiety	2.475	(1.194)	0.021	−0.006	−0.046	−0.047
	Shame	1.960	(1.144)	−0.062	−0.037	−0.076	−0.014
	Hopelessness	1.919	(1.142)	**−0.136**	**−0.280**	**−0.219**	**−0.205**
	Excitement	2.785	(1.163)	**0.154**	**0.241**	**0.119**	0.077
	Intrinsic value	4.109	(0.874)	**0.285**	**0.390**	**0.386**	**0.346**
	Extrinsic value	4.030	(0.865)	**0.151**	**0.220**	**0.253**	**0.221**
Wave 2	Enjoyment	2.906	(1.077)	**0.212**	**0.160**	**0.184**	**0.171**
	Pride	2.614	(1.170)	0.093	0.103	**0.146**	**0.163**
	Anger	1.678	(0.973)	−0.061	**−0.194**	**−0.123**	−0.041
	Hope	2.892	(1.063)	**0.170**	**0.153**	**0.244**	**0.182**
	Anxiety	2.329	(1.186)	0.040	−0.040	−0.036	0.001
	Shame	1.859	(1.051)	−0.009	−0.115	−0.084	−0.108
	Hopelessness	1.919	(1.070)	**−0.139**	**−0.238**	**−0.214**	**−0.152**
	Excitement	2.649	(1.173)	**0.127**	0.114	**0.148**	**0.128**
	Intrinsic value	3.935	(0.959)	**0.273**	**0.333**	**0.441**	**0.369**
	Extrinsic value	3.976	(0.877)	**0.204**	**0.243**	**0.328**	**0.290**
Wave 3	Enjoyment	2.884	(1.075)	**0.200**	**0.222**	**0.188**	**0.258**
	Pride	2.515	(1.118)	**0.183**	**0.132**	**0.197**	**0.251**
	Anger	1.680	(0.978)	−0.013	**−0.127**	−0.079	−0.115
	Hope	2.914	(1.170)	**0.236**	**0.211**	**0.213**	**0.283**
	Anxiety	2.247	(1.157)	0.096	−0.045	0.021	−0.017
	Shame	1.904	(1.141)	0.007	−0.065	−0.059	−0.151
	Hopelessness	1.866	(1.153)	**−0.105**	**−0.144**	**−0.125**	**−0.179**
	Excitement	2.543	(1.212)	**0.154**	**0.132**	0.099	**0.209**
	Intrinsic value	3.997	(0.943)	**0.202**	**0.311**	**0.327**	**0.397**
	Extrinsic value	3.973	(0.913)	**0.133**	**0.170**	**0.196**	**0.345**

Note: Statistically significant correlations values at $\alpha = 0.05$ are bolded

Table 2 Correlation of behavioral engagement with receptivity of instructional feedback and positive and negative affect across waves

Wave	Variable	Behavioral engagement after feedback		
		Wave 1	Wave 2	Wave 3
Baseline	Cognitive Engagement	**0.530**	**0.462**	**0.487**
	Experiential Attitudes	**0.470**	**0.452**	**0.411**
	Instrumental Attitudes	**0.592**	**0.534**	**0.491**
	Behavioral Engagement	**0.629**	**0.651**	**0.580**
	Positive Affect	**0.324**	**0.235**	**0.250**
	Negative Affect	−0.108	**−0.121**	**−0.136**
Wave 1	Positive Affect	**0.269**	**0.176**	**0.130**
	Negative Affect	**−0.160**	**−0.153**	−0.114
Wave 2	Positive Affect	**0.146**	**0.200**	**0.179**
	Negative Affect	**−0.170**	**−0.129**	−0.085
Wave 3	Positive Affect	**0.190**	**0.205**	**0.284**
	Negative Affect	−0.097	−0.050	**−0.128**

Note: Statistically significant correlations values at $\alpha = 0.05$ are bolded. Individual scores for scales were transformed to have a mean of 0 and a standard deviation of 1

Changes in emotions, appraisal, and behavioral engagement across time

A repeated-measures ANOVA with Huynh–Feldt sphericity correction was conducted to determine whether or not there were differences in every single emotion, behavioral engagement, and positive and negative affect response to feedback across time (Table 3). Table A6 (Supplemental Materials) displays the results of Repeated Measure ANOVA without correction, Test Sphericity and Huynh–Feldt ε (HFε) for Sphericity Correction.

Results showed a statistically significant main effect of time on positive emotions measures for enjoyment (F (2.87, 772.17) = 6.752, $p < .001$), pride (F (2.96, 796.2) = 6.507, $p < .001$), and excitement (F (2.96, 796.33) = 4.048, $p = .007$), as well as negative emotion of anxiety (F (2.85 768.91) = 3.728, $p < .001$) and shame (F (2.85, 767.98) = 13.936, $p < .001$). Multiple comparisons using Benjamini–Hochberg (Table 4) indicated that positive and negative single emotions measures decreased in subsequent waves in comparison to baseline ($p < .05$). However, adjacent measurement occasions showed no significant difference with one another (e.g., wave 1 vs. wave 2, wave 2 vs. wave 3). There were no statistically significant effects across time for behavioral engagement, PA and NA.

Trajectories of emotions, appraisal, and behavioral engagement across time

Linear Latent Growth Models (LGM) were employed to explore the trajectories over time of variables of interest in this study. A chi-square difference test ($\Delta\chi^2$) showed that random intercept and random slope significantly improved fit over that of Model 3 (*fixed intercept, fixed slope model)* for enjoyment, pride, hope, excitement, anxiety, and shame, while the *fixed intercept, fixed slope model* (Model 3) is more suitable for hopelessness (Table A7,

Table 3 Repeated measure ANOVA. Within-subjects factor (time)

Variable	DF_n	DF_d	F	p	η^2
Enjoyment	2.87	772.17	6.752	0.000*	0.012
Pride	2.96	796.2	6.507	0.000*	0.011
Anger	2.92	785.24	0.962	0.409	0.002
Hope	2.9	776.71	2.606	0.052	0.004
Anxiety	2.85	768.91	22.694	0.000*	0.040
Shame	2.85	767.98	13.936	0.000*	0.024
Hopelessness	2.84	765.11	0.279	0.832	0.000
Excitement	2.96	796.33	4.048	0.007*	0.007
Intrinsic Motivation	2.78	731.56	0.548	0.638	0.001
Extrinsic Motivation	2.91	766.46	2.12	0.097	0.003
Behavioral Engagement	2.89	776.55	0.051	0.983	0.000
Negative Affect	2.81	756.37	0.152	0.919	0.000
Positive Affect	3.01	803.15	0.112	0.953	0.000

Note: η^2 (generalized η^2) represents the effect size is essentially the amount of variability due to the within-subjects factor ignoring the effect of the subjects

Huynh–Feldt sphericity correction (Girden, 1992) was applied for all within-subjects factors even if the assumption of sphericity was met, $\varepsilon > .75$ in all cases when sphericity correction was not met

*$p < .05$

Table 4 Summary of pairwise comparisons single emotions

Variable	Time	Baseline	Wave 1	Wave 2
Enjoyment	Wave 1	n.s (.127)		
	Wave 2	<* (.005)	n.s (.236)	
	Wave 3	<* (.004)	n.s (.186)	n.s (.797)
Pride	Wave 1	n.s (.277)		
	Wave 2	<* (.039)	n.s (.277)	
	Wave 3	<* (.002)	<* (.048)	n.s (.285)
Anxiety	Wave 1	<* (.000)		
	Wave 2	<* (.000)	n.s (.170)	
	Wave 3	<* (.000)	<* (.034)	n.s (.414)
Shame	Wave 1	<* (.000)		
	Wave 2	<* (.000)	n.s (.426)	
	Wave 3	<* (.000)	n.s (.635)	n.s (.635)
Excitement	Wave 1	n.s (.863)		
	Wave 2	n.s (.321)	n.s (.321)	
	Wave 3	n.s (.060)	n.s (.060)	n.s (.331)

Note: ns = not significant; >* mean in the row statistically significantly higher than the column, <* mean in the row statistically significantly lower than the column. *P*-values were adjusted using Benjamin–Hochberg correction. *P*-values in parenthesis ()

Supplemental Material). Fit indices exhibit good fit for selected models (Table A8, Supplemental Material). Furthermore, LGM for intrinsic and extrinsic control value, positive (PA) and negative (NA) affect, and behavioral engagement showed relatively poor fits and no significant coefficients.

Unstandardized parameter estimates for specific LGMs are reported in Table 5. For all emotions, positive mean intercept (α_1), negative mean slope (α_2), and intercept variance (ψ_{11}) are statistically significant ($p < .001$), indicating that single emotions decreased in subsequent waves in comparison to baseline and there is nontrivial variance between individuals in their initial status. The parameter estimates for mean intercepts ($\widehat{\alpha}_1$) vary between 1.913 (hopelessness) and 3.126 (enjoyment), while the mean slope ($\widehat{\alpha}_2$) ranged between −0.203 (anxiety) and −0.058 (hope). Moreover, the estimated slope variance ($\widehat{\psi}_{22}$) and intercept/slope covariance ($\widehat{\psi}_{21}$) for enjoyment, pride, hope, and excitement were non-statistically significant ($p > .05$), suggesting a constant decreasing rate of change over time of those emotions between participants, independent of the initial status. In contrast, for anxiety and shame the estimate parameter for intercept variance ($\widehat{\psi}_{21}$) is large relative to the slope variance ($\widehat{\psi}_{22}$), and the intercept–slope covariance is negative and significant ($\widehat{\psi}_{21}$). This suggests that students who initially have higher levels of anxiety and shame after receiving feedback at baseline exhibit a less steep decline slope, indicating a tendency to decrease these emotions at a lower rate over time compared to those with lower levels of anxiety and shame at baseline.

In these longitudinal models, time-invariant covariates were included to explain differences in the level of emotions (intercept) between gender and receptivity of instructional feedback students' characteristics. Tables A9 and A10 (Supplemental Material) present estimated unstandardized coefficients and fit indices for models. Findings showed a significant and negative effect of gender on the level at baseline (intercept) of emotions for enjoyment, pride, hope, and excitement ranged between $\beta = -0.627$ ($p < .001$) (excitement) and $\beta = -0.308$ ($p < .001$) (enjoyment), indicating that positive emotions for boys are significantly lower than girls on baseline. In contrast, negative emotions, such as anxiety and shame, did not show a significant gender effect. Regarding receptivity to instructional feedback, more positive experiential attitudes toward feedback predicted a positive and significant effect on enjoyment ($\beta = 0.232$, $p < .001$), pride ($\beta = -0.280$, $p < .001$), hope ($\beta = -0.248$, $p < .001$), and excitement ($\beta = 0.181$, $p = .01$) as well as predicted a decrease on shame ($\beta = -0.168$, $p < .03$), suggesting that affective engagement with feedback serves as a triggering factor in reducing negative emotion after receiving feedback. Furthermore, enhancing the perceived value of feedback

Table 5 Unstandardized coefficients. Latent Growth Models for single emotions

Coefficient	Enjoyment		Pride		Hope		Anxiety		Shame		Hopelessness		Excitement	
	β	p	β	p	β	P	β	p	β	p	β	p	β	p
Mean Intercept (α_1)	3.126 (0.06)	0.000	2.809 (0.06)	0.000	3.048 (0.06)	0.000	2.797 (0.07)	0.000	2.207 (0.07)	0.000	1.913 (0.05)	0.000	2.783 (0.06)	0.000
Mean Slope (α_2)	−0.096 (0.02)	0.000	−0.104 (0.02)	0.000	−0.058 (0.02)	0.016	−0.203 (0.03)	0.000	−0.126 (0.03)	0.000	–	–	−0.077 (0.03)	0.003
Intercept Variance (ψ_{11})	0.43 (0.08)	0.000	0.406 (0.09)	0.000	0.429 (0.09)	0.000	0.857 (0.13)	0.000	0.725 (0.11)	0.000	0.524 (0.06)	0.000	0.537 (0.10)	0.000
Slope Variance (ψ_{22})	0.03 (0.02)	0.062	0.014 (0.02)	0.380	0.011 (0.02)	0.508	0.084 (0.02)	0.000	0.063 (0.02)	0.002	0.022 (0.01)	0.043	0.023 (0.02)	0.196
Intercept/slope covariance (ψ_{21})	−0.017 (0.03)	0.558	0.012 (0.03)	0.695	0.019 (0.03)	0.511	−0.172 (0.05)	0.000	−0.123 (0.04)	0.002	–	–	−0.005 (0.03)	0.886
Disturbance variance (θ_ε)	0.656 (0.04)	0.000	0.735 (0.04)	0.000	0.716 (0.04)	0.000	0.839 (0.05)	0.000	0.74 (0.05)	0.000	0.651 (0.04)	0.000	0.77 (0.05)	0.000

Note: β represents the estimate effect and p the p-value. Standards errors in parenthesis

(instrumental attitudes) has a positive and significant effect on enjoyment ($\beta = 0.233$, $p < .001$) and excitement ($\beta = 0.187$, $p = .02$).

Reciprocal influence of emotions and behavioral engagement over time

Fit indices provide support for the cross-lagged structural equation models across all seven emotions, PA, NA, and behavioral engagement with feedback. In models where autoregressive effects, cross-lagged effects, and factor residual invariances were freely estimated, the Comparative Fit Index (CFI) exceeded.98, the Root Mean Square Error of Approximation (RMSEA) was below .06, and the Standardized Root Mean Residual (SRMR) was under.03 (Table A11, Supplemental Material). Scaled chi-square difference tests ($\Delta\chi^2$) indicated that imposing constraints on the models did not significantly worsen the fit; the loss of fit was $\Delta CFI \leq .009$, $\Delta RMSEA \leq .004$, and $\Delta SRMR \leq .019$ for all models, providing support for the invariance of parameters. Therefore, the results suggest autoregressive stability in the association of emotion and behavioral engagement across time. Standardized coefficients for constrained models were used for further interpretation, providing more robust and precise parameter estimates.

The standardized autoregressive coefficients, cross-lagged effects, residual variances, and covariances for the reciprocal effects models between emotions and behavioral engagement across time are presented in Table 6. Both emotion variables and behavioral engagement demonstrated strong and considerable stability over time, as evidenced by the statistically significant autoregressive effects for these variables ($p < .001$). Despite this autoregressive stability, the results revealed that changes in emotions and behavioral engagement at one point in time did not lead to significant changes in the other variable in subsequent waves, except for the relationship between anger and behavioral engagement. According to the findings, increases in anger at baseline were associated with an increase in behavioral engagement at the second point of data collection by 0.136 ($p < .0017$), and similar patterns were observed for subsequent waves. Despite significant autoregressive effects and non-significant cross-lagged effects, there were significant and positive concurrent correlations in both baseline and subsequent waves across all positive emotions and behavioral engagement. For negative emotions, the results indicated that anger was negatively correlated with behavioral engagement at baseline but not in subsequent waves. Overall, the findings suggest that emotions and behavioral engagement predict effects at subsequent points in time, demonstrating high stability in these measures. However, there are no significant cross paths between these variables, which is an expected result.

Discussion

In the current study, we sought to examine Singaporean secondary school students' emotions, appraisals, and behavioral engagement as they received feedback on their writing assignments across four points of data collection. The study was grounded in Control-Value theory (Pekrun, 2006) and the Student-Feedback Interaction model (Lipnevich & Smith, 2022). The study also explored how emotions and behavioral engagement influence each other over time. Lastly, we attempted to investigate the gender differences in students' emotions and how receptivity to instructional feedback changed among Singaporean secondary school students.

Links between emotions, appraisals, and behavioral engagement with feedback over time

The results considering the longitudinal relationships among emotions, appraisals, and behavioral engagement revealed that students' enjoyment, pride, excitement, anxiety, and shame have shown significant variation across time. Although those emotions fluctuated over time, enjoyment, pride, and excitement displayed constant decreases, whereas the decline in anxiety and shame depended on their initial levels.

These findings could be linked to the alignment of feedback with learners' expectations, a core aspect of the Student-feedback interaction model (Lipnevich & Smith, 2022). Such congruence or lack thereof can significantly influence emotional responses to feedback, as noted by Eva et al. (2012), who discussed the difficulties students face when self-assessments diverge from external feedback. Moreover, emotions can serve a protective role in feedback reception, supporting individuals in managing potentially negative impacts of critical feedback (Gilovich, 1991). Further, our results are consistent with Brown (2007) and Pekrun et al. (2023), who, respectively, found that expectations of grades influence the desire for feedback and that positive interpretations of feedback (as indicative of success) enhance positive emotional reactions while mitigating negative ones. Similarly, Holmes (2023) reported that students often reacted negatively to feedback unless it aligned well with their expectations.

The steady decline in students' enjoyment, pride, hope, and excitement, and the decreasing fall in anxiety and shame for students who had higher scores in these emotions described by the linear latent growth modeling might also be interpreted by the sociocultural context of the present study. In the context of Singapore's exam-focused educational system (Ratnam-Lim & Tan, 2015; Wong

Table 6 Reciprocal effects models for emotion and behavioral engagement: standardized factor loadings, path coefficients, and residual variances

	Shame		Behavioral engagement		Anxiety		Behavioral engagement		Hopelessness		Behavioral engagement		Anger		Behavioral engagement	
	β	*p*	*β*	*p*	*β*	*p*	*β*	*p*	*β*	*p*	*β*	*p*	*β*	*p*	*β*	*p*
Autoregressive effects																
BL → W1	0.786 (0.08)	0.000	0.984 (0.04)	0.000	0.764 (0.08)	0.000	0.989 (0.04)	0.000	0.837 (0.07)	0.000	0.982 (0.04)	0.000	0.988 (0.12)	0.000	0.999 (0.04)	0.000
W2 → W3	0.766 (0.08)	0.000	0.984 (0.04)	0.000	0.741 (0.08)	0.000	0.987 (0.04)	0.000	0.832 (0.07)	0.000	0.982 (0.04)	0.000	0.982 (0.12)	0.000	0.998 (0.04)	0.000
W3 → W4	0.753 (0.08)	0.000	0.983 (0.04)	0.000	0.727 (0.08)	0.000	0.985 (0.04)	0.000	0.829 (0.07)	0.000	0.981 (0.04)	0.000	0.978 (0.12)	0.000	0.997 (0.04)	0.000
Cross-lagged effects																
BL → W1	0.005 (0.03)	0.866	0.017 (0.04)	0.658	−0.037 (0.02)	0.241	0.027 (0.04)	0.466	0.001 (0.03)	0.976	−0.041 (0.04)	0.274	0.014 (0.05)	0.685	0.136 (0.04)	0.017
W2 → W3	0.005 (0.03)	0.866	0.017 (0.04)	0.658	−0.035 (0.02)	0.241	0.027 (0.04)	0.466	0.001 (0.03)	0.976	−0.04 (0.04)	0.274	0.016 (0.05)	0.685	0.122 (0.04)	0.017
W3 → W4	0.005 (0.03)	0.866	0.017 (0.04)	0.658	−0.034 (0.02)	0.241	0.028 (0.04)	0.466	0.001 (0.03)	0.976	−0.04 (0.04)	0.274	0.018 (0.05)	0.685	0.109 (0.04)	0.017
Residual variance																
W1	0.385 (0.11)	0.012	0.033 (0.03)	0.555	0.413 (0.13)	0.008	0.026 (0.03)	0.643	0.283 (0.09)	0.017	0.035 (0.03)	0.528	0.12 (0.06)	0.491	0.013 (0.03)	0.806
W2	0.417 (0.11)	0.012	0.033 (0.03)	0.555	0.449 (0.13)	0.008	0.026 (0.03)	0.643	0.288 (0.09)	0.017	0.036 (0.03)	0.528	0.099 (0.06)	0.491	0.014 (0.03)	0.806
W3	0.437 (0.11)	0.012	0.034 (0.03)	0.555	0.471 (0.13)	0.008	0.027 (0.03)	0.643	0.29 (0.09)	0.017	0.037 (0.03)	0.528	0.081 (0.06)	0.491	0.014 (0.03)	0.806
Covariance single emotions–behavioral engagement																
BL	−0.129 (0.06)	0.138			0.066 (0.06)	0.445			−0.224 (0.06)	0.007			−0.426 (0.04)	0.000		
W1 to W3	−0.49 (0.02)	0.079			−0.281 (0.02)	0.361			−0.527 (0.02)	0.078			−1.309 (0.02)	0.168		
	Enjoyment		Behavioral engagement		Excitement		Behavioral engagement		Pride		Behavioral engagement		Hope		Behavioral engagement	
	β	*p*	*β*	*p*	*β*	*p*	*β*	*p*	*β*	*p*	*β*	*p*	*β*	*p*	*β*	*p*
Autoregressive effects																
BL → W1	0.714 (0.11)	0.000	1.003 (0.04)	0.000	0.905 (0.09)	0.000	0.983 (0.04)	0.000	0.759 (0.09)	0.000	0.983 (0.04)	0.000	0.970 (0.10)	0.000	0.997 (0.05)	0.000
W2 → W3	0.748 (0.11)	0.000	1.002 (0.04)	0.000	0.910 (0.09)	0.000	0.983 (0.04)	0.000	0.794 (0.09)	0.000	0.983 (0.04)	0.000	0.973 (0.10)	0.000	0.996 (0.05)	0.000
W3 → W4	0.765 (0.11)	0.000	1.000 (0.04)	0.000	0.915 (0.09)	0.000	0.983 (0.04)	0.000	0.727 (0.08)	0.000	0.985 (0.04)	0.000	0.976 (0.10)	0.000	0.995 (0.05)	0.000
Cross-lagged effects																
BL → W1	−0.042 (0.04)	0.252	0.036 (0.06)	0.524	−0.048 (0.03)	0.170	0.032 (0.04)	0.458	−0.008 (0.03)	0.813	0.032 (0.04)	0.458	−0.057 (0.04)	0.129	−0.095 (0.06)	0.143
W2 → W3	−0.047 (0.04)	0.252	0.034 (0.06)	0.524	−0.05 (0.03)	0.170	0.029 (0.04)	0.458	−0.009 (0.03)	0.813	0.029 (0.04)	0.458	−0.062 (0.04)	0.129	−0.088 (0.06)	0.143
W3 → W4	−0.05 (0.04)	0.252	0.033 (0.06)	0.524	−0.053 (0.03)	0.170	0.028 (0.04)	0.458	−0.009 (0.03)	0.813	0.028 (0.04)	0.458	−0.067 (0.04)	0.129	−0.081 (0.06)	0.143

Table 6 (continued)

	Enjoyment		Behavioral engagement		Excitement		Behavioral engagement		Pride		Behavioral engagement		Hope		Behavioral engagement	
	β	p	β	p	β	p	β	p	β	p	β	p	β	p	β	p
Residual variance																
W1	0.462 (0.13)	0.014	0.035 (0.03)	0.505	0.237 (0.09)	0.090	0.032 (0.04)	0.458	0.41 (0.11)	0.023	0.038 (0.03)	0.486	0.155 (0.08)	0.274	0.067 (0.03)	0.215
W2	0.417 (0.13)	0.014	0.036 (0.03)	0.505	0.217 (0.09)	0.090	0.029 (0.04)	0.458	0.355 (0.11)	0.023	0.039 (0.03)	0.486	0.134 (0.08)	0.274	0.068 (0.03)	0.215
W3	0.394 (0.13)	0.014	0.037 (0.03)	0.505	0.201 (0.09)	0.090	0.028 (0.04)	0.458	0.323 (0.11)	0.023	0.04 (0.03)	0.486	0.117 (0.08)	0.274	0.069 (0.03)	0.215
Covariance emotion–behavioral engagement																
BL	0.519 (0.05)	0.000			0.466 (0.06)	0.000			0.261 (0.05)	0.006			0.564 (0.05)	0.000		
W1 to W3	0.506 (0.02)	0.049			0.967 (0.02)	0.004			0.692 (0.02)	0.023			1.241 (0.02)	0.000		

Note: β represents the estimate effect and p the p-value. Error standards in parenthesis

et al., 2020), where assessments determine educational and career paths, students may prioritize grades and competitiveness, leading to perfectionistic tendencies (Fong & Cai, 2019). This emphasis on achievement may dampen students' enjoyment, pride, hope, and excitement, particularly if feedback does not meet their high expectations.

To support the latter point, a study on Chinese students' achievement emotions emphasized how their assessment perceptions influenced their emotional responses (Chen & Brown, 2018). In Singapore, students may experience similar emotional fluctuations due to the pressure of exam-oriented education. Interestingly, in our study, students' anger, hope, hopelessness, internal and external motivation, and the aggregates of negative and positive emotions did not show significant variations over time. These findings contradict the studies analyzing the trajectories of emotions and their appraisals in time, especially in Western cultures (e.g., Forsblom et al., 2022; Sakaki et al., 2023). However, Singapore blends the Western cultural and institutional orientations and Confucian perspectives of East Asian societies, so collectivism and individualism co-occur in this country (Luo et al., 2014). While personal choices serve as driving forces for students in individualist cultures, students in collectivist cultures are usually motivated when their choices are made by some authority figures, such as teachers or parents (King & McInerney, 2014). For example, although mistake-based feedback was connected to higher achievement in East Asian cultures where the high-power distance and collectivism are inherently acknowledged elements, Singapore stood out as an exception in Eriksson et al.'s (2020) study, which involved 4th- and 5th-grade students from 49 countries participating in the 2015 TIMSS data on the effects of mistake-based feedback. That study also supported the diversifying role of Singapore among Eastern and Western cultures to examine the effect of mistake-based feedback regarding the power distance and authority profiles of participating countries. For the current study, it is essential to consider teachers' feedback practices within the cultural context to explain the reasons for the non-significant variations in appraisals and emotions in time. For instance, Schleppenbach et al. (2007) examined videorecorded lessons in elementary mathematics from China and the United States, focusing on how teachers addressed students' mistakes. Although the frequency of mistakes made by students was similar, the teachers' reactions differed between the two cultures. Chinese teachers tended to provide fewer comments about errors and asked more follow-up questions, expecting students to identify and correct their mistakes. In contrast, teachers in the United States leaned toward having students assess their own answers. Heng et al. (2021) demonstrated that context played a significant role in shaping teachers' beliefs and practices regarding assessment, learning, and teaching. Their findings revealed that Singaporean teachers frequently faced

internal conflicts when their personal beliefs and practices are at odds with their sociocultural and educational environments. Therefore, when discussing the differences in emotions and appraisals of students after receiving feedback in Singaporean culture, it is important to consider the common elements of both individualist and collectivist cultures.

Specifically, *hope* is influenced by the locus of control, with internal forces contributing to individualistic hope and external agency linked to collectivist hope (Bernardo, 2010). In Singapore, where both individualist and collectivist values are prominent, minimal changes in hope after feedback may be expected. Anger, often viewed as disruptive to social harmony, is less prevalent in collectivist cultures (Bierle et al., 2023; Frenzel et al., 2007b; Grimm et al., 1999), potentially explaining its stability in this study. Similarly, hopelessness may remain unchanged over time, consistent with previous findings (Marchetti et al., 2023), irrespective of cultural influences. However, factors such as personality traits, school environment, relationships, and family dynamics may also impact students' responses to feedback, warranting further investigation.

The study also revealed non-significant differences in behavioral engagement across waves, contrary to expectations in score-driven educational settings like those in East Asian countries. While feedback has been shown to enhance behavioral engagement and motivation among Chinese university students (Yu et al., 2020), it is possible that students responded to feedback consistently over time, leading to stable behavioral engagement. Moreover, individual differences, such as beliefs, goals, and prior knowledge, may play a significant role in shaping students' engagement with feedback, as highlighted in previous research (Cheng & Liu, 2022; Zheng & Yu, 2018; Zheng et al., 2023). For instance, Hafour and Alwaleedi (2022) observed no change in junior EFL college students' behavioral engagement after an eight-week intervention in collaborative writing, despite improvements in emotional engagement, underscoring the multifaceted nature of feedback engagement.

Above all, all schools in Singapore transitioned to home-based learning during COVID-19, known as the "Circuit Breaker," and reopened a month later with strict safety measures, including mask-wearing and maintaining physical distance. In the present study, this period corresponded with the time between waves 2 and 3. During the Circuit Breaker, students from disadvantaged families faced significant challenges due to the lack of resources for online education, and concerns about the quality of online instruction also arose (Ng, 2021). These inherent tensions may also have impacted the study's results. If teachers lack facilitative and lesson design skills for home-based or online learning, it could lead to confusion for students during home-based learning (Ng, 2021). Moreover, students lacked both teacher support and social-emotional assistance from peers at that time, expressing a strong need for self-directed learning. (Goh et al., 2023). In the present study, the challenges that students faced in accessing sources, as well as support from teachers and peers, may have influenced their emotion profiles and their engagement with feedback after the reopening of the schools, regardless of the study conditions. The decline in enjoyment from the initial levels to wave 3, along with the decrease in pride measured between the initial levels, wave 1 and wave 3, may be attributed to the academic-related stress students faced during home-based learning. Soon et al. (2023) also discuss the academic stress experienced by students during the transition to home-based learning, which led them to adopt various coping strategies.

The reciprocal influence of emotions and behavioral engagement over time

The results regarding the reciprocal influence of emotions and behavioral engagement over time indicate a high degree of stability, suggesting a closely intertwined relationship between emotions and the reception of feedback. The connections between engagement, feedback, and emotions are evident in various research studies. Quintero et al. (2022), for example, examined the relations between classroom engagement in terms of cognitive, behavioral, and emotional aspects and the US students' anxiety and achievement in mathematics. Considering students' achievement scores as performance feedback, it appears that students' engagement behaviors mediate the relationship between mathematics anxiety and achievement. Li and Jiang (2024) conducted a longitudinal qualitative study on English as a Foreign Language (EFL), and learners in China focused on their affective, behavioral, and cognitive engagement with peer feedback. The study found that positive affective engagement among learners encouraged both cognitive and behavioral engagement. Interestingly, negative emotions did not prevent improvements in cognitive and behavioral engagement. Additionally, the learners' cognitive and behavioral engagement with feedback could either enhance or serve as a barrier to their affective engagement. While focusing on the temporal dynamics of these constructs may pose challenges, the findings highlight enduring and significant associations between emotions and behavioral engagement with feedback. Moreover, it is important to underscore the impact of cultural, contextual, individual, and task-related factors, as delineated in the Student-feedback interaction model, to provide further clarification on the aforementioned mutual relationships.

The differences in key variables and trends between female and male students

Finally, our study showed gender differences in students' initial level of emotions. To this end, male students' enjoyment, pride, hope, and excitement were lower than those of female students. Although the findings contradict the existing literature (e.g., Fierro-Suero et al., 2022; Frenzel et al., 2007a), higher scores of female students on those emotions may be attributed to the common perception of greater emotional expressiveness and intensity among females compared to males (Sorić et al., 2013). On the other hand, anxiety and shame did not reveal any significant differences in gender. Shame has been viewed as a prominent emotion in East Asian cultures, regarded as a driver for students' learning and engagement (Fang et al., 2022). In cross-cultural research, Frenzel et al. (2007b) found that eighth-grade Chinese students experienced higher levels of shame, anxiety, enjoyment, and pride and lower levels of anger in mathematics than their German counterparts. Typically, much emphasis on achievement and the attribution of failure to the internal state might trigger feelings of shame and anxiety (Pekrun, 2018; Turner & Waugh, 2007), and the experience of those emotions might be more salient in East Asian cultures where achievement is highly valued, and failure is strongly avoided. In this context, the non-significant finding in this study suggests that there is no difference in the way students experience anxiety and shame, regardless of gender. This observation aligns with the findings of prior studies, such as Reilly and Sánchez-Rosas (2021). Concerning students' receptivity to instructional feedback, students with higher affect toward feedback (experiential attitudes) experienced more enjoyment, pride, hope, and excitement and less shame. Besides, when students perceived feedback as useful for their work (instrumental attitudes), they also felt more enjoyment and excitement. The findings corroborated Calik's (2024) research on the link between feedback receptivity and emotions. In it, students' interpretations of feedback appeared to play a crucial role in shaping their emotions. However, this assertion should be further examined in light of various individual, contextual, and task-related factors.

Limitations and future directions

This study has some limitations to report. Due to the design of this study, its generalizability is weak, and we cannot determine a causal relationship between feedback and behavior mediated by emotions. This study was conducted in Singapore, which is known for its exceptionally unique educational environment. This study should be replicated in other countries in order to provide a cross-cultural comparison and determine if findings are consistent across samples. The timing of the study occurred in conjunction with the COVID-19 pandemic, in which the study first began by using a traditional in-person model of implementation and pivoted to an online model as a result of the transition to online learning. Another limitation of the study is the inconsistent reporting of grades across different waves, which could lead to potential biases in understanding the relationship between feedback types, emotions, and behavioral engagement. This could also introduce the complexity in interpreting the causal relationship when doing quantitative analysis. Future studies should aim to consistently collect grades alongside emotional measures in all waves to ensure a more complete and accurate analysis. This would allow for a better understanding of how different types of feedback impact emotions and engagement. Additionally, incorporating consistent grade reporting could aid in developing more robust models that account for the dynamics of student performance, emotional states, and behavioral engagement over time. The longitudinal study, encompassing four waves of data collection, introduces a notable limitation due to the varying time between these waves. This inconsistency may lead to challenges in understanding whether the changes in emotion, feedback reception, and behavioral engagement are due to unequal intervals. This differing time may lead to the variability not due to the study variables but rather to the length of intervals themselves, potentially weakening the ability to draw definitive conclusions about the patterns and relationships observed. To address this design flaw in future studies, it would be beneficial to standardize the time between each wave, allowing for a clear understanding of the cause–effect relationship and strengthening the overall robustness of conclusions.

Conclusion

This study broke away from past research trends, which predominantly utilized cross-sectional designs in investigating feedback and emotions, often within Western contexts. Instead, it adopted a longitudinal approach to explore how the relationships among emotions, appraisals, and behavioral engagement with feedback evolved over time, specifically in a non-Western context. We found variations in enjoyment, pride, excitement, anxiety, and shame over time. These findings suggest that students have been using the feedback in their writing assignments, which elicited these emotions. Therefore, the reasons behind the changing emotions after receiving feedback and the development of capabilities and strategies of students to regulate those emotions might be a fruitful avenue for future research. Developing students' coping skills during the feedback process is also related to teachers' sensitivity to students' emotions, so teacher professional development might be designed to include those elements (To et al., 2023). Gender differences were also reported for some emotions in our study.

So, Singaporean boys seemed to experience less enjoyment, pride, hope, and excitement than Singaporean girls. Besides, students' experiential and instrumental attitudes toward feedback and affective engagement with feedback were likely to trigger positive emotions and/or reduce the experience of some negative emotions. In this respect, instructional interventions might be tailored to foster student feedback receptivity (Lipnevich et al., 2023). Lastly, there was a stability in the link between the emotions and behavioral engagement over time. This stability underscores the persistent connection between emotions and behavioral engagement over time, emphasizing the enduring link of emotional states and students' responses to feedback. In sum, our study provides a novel illustration of student emotions, appraisals, and behavioral engagement with feedback over time within the Singaporean educational context. This deeper understanding can inform more targeted interventions and support mechanisms to enhance students' learning experiences and outcomes.

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Declarations

Conflict of interest The authors declare that there are no conflicts of interest.

Ethics approval Research ethics approval was obtained by the Institutional Review Board of Nanyang Technological University.

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