Language Learning & Technology
ISSN 1094-3501 CC BY-NC-ND

June 2026, Volume 30, Issue 2
pp. 157–179

ARTICLE

The developmental trajectory of L2 students' positive achievement emotions and flow experience within AI-enhanced classrooms: A latent growth curve modeling (LGCM)

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Abstract

The integration of artificial intelligence (AI) in L2 classrooms has garnered remarkable attention due to its potential to enhance students' language achievements. While existing research has highlighted the implications of incorporating AI into L2 classrooms, there remains a gap in understanding how this incorporation may affect students' achievement emotions and flow experiences. To narrow this gap, this intervention study sought to assess the influence of AI-enhanced instruction on L2 students' positive achievement emotions: pride, hope, enjoyment, and their flow experiences. Furthermore, with the aid of latent growth curve modeling (LGCM), the study tried to track the developmental trajectory of L2 students' positive achievement emotions and flow experiences over the course of a semester. To these aims, a large sample of 217 L2 students was recruited and randomly divided into the control or experimental groups. To measure participants' flow and positive achievement emotions, two questionnaires were administered to them at distinct intervals throughout the intervention. The results evinced a notable enhancement in both the flow experience and positive achievement emotions of participants who were exposed to AI-enhanced instruction. This research underscores the critical role of AI-enhanced instruction in fostering students' positive achievement emotions and flow experiences within L2 classrooms.

Keywords: achievement emotions; AI-enhanced classrooms; enjoyment; flow; latent growth curve modeling

Language(s) Learned in This Study: *English*

APA Citation: Qin, L., & Derakhshan, A. (2026). The developmental trajectory of L2 students' positive achievement emotions and flow experience within AI-enhanced classrooms: A latent growth curve modeling (LGCM). *Language Learning & Technology*, *30*(2), 157–179.
https://doi.org/10.64152/10125/73685

Introduction

The advent of artificial intelligence (AI) in second language (L2) classrooms has revolutionized educational practices (Liu & Wang, 2024; Qin & Dong, 2025; Park & Derakhshan, 2026; Wang et al., 2025), offering unprecedented opportunities to improve students' learning experiences and outcomes (Dai & Liu, 2024; Derakhshan & Park, 2026a; Huang & Zou, 2024; Jeon, 2024; Teng & Huang, 2025). AI-driven technologies, such as adaptive learning platforms (ALPs), virtual tutors (VTs), and natural language processing applications (NLPAs), create dynamic, personalized, and immersive environments conducive to L2 acquisition (Xiu-Yi, 2024). These technologies can not only enhance students' L2 proficiency (Kruk & Kałużna, 2024) but also hold transformative potential for fostering students' emotional and psychological states (Derakhshan & Lalli, 2025; Derakhshan et al., 2026; Teng, 2026; Zhi

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& Wang, 2024; Zhou & Hou, 2024), including hope, pride, enjoyment, and flow. Hope, pride, and enjoyment, concomitantly known as positive achievement emotions, are the emotional reactions students experience in response to their advancement toward achieving academic goals (Chen et al., 2025; Li et al., 2024; Pekrun & Perry, 2014). In addition, flow as a positive psychological state pertains to a highly focused and immersive academic experience in which students become fully absorbed in a learning task or activity (Csikszentmihalyi et al., 2014; Liu & Song, 2021). Together, these emotional and psychological states play a crucial role in shaping students' attitudes, behaviors, and overall engagement within L2 learning contexts (Pawlak et al., 2024). Thus, delving into the developmental trajectory of these psycho-emotional states within AI-enhanced classrooms is vital for understanding how technological advancements can optimize L2 learning experiences.

The interplay between AI, positive achievement emotions, and flow states can be illuminated through the lens of Pekrun's (2006) control-value theory (CVT), which explains how students' control and value assessments influence their achievement emotions and overall engagement (Li et al., 2023). According to CVT, positive achievement emotions that arise from a sense of control and value are critical in promoting students' engagement levels within academic contexts (Pekrun & Linnenbrink-Garcia, 2012). When students believe they have the ability to influence their learning outcomes (control) and perceive their learning tasks as meaningful and significant (value), they are more likely to feel positive emotions (Pekrun, 2006). These positive emotions, including pride, enjoyment, and hope, enhance students' academic motivation and encourage them to become fully engaged in the learning process (Pekrun & Linnenbrink-Garcia, 2012). In AI-enhanced learning environments, AI tools and technologies can significantly shape students' control and value appraisals. AI-powered tools, such as intelligent tutoring systems (ITSs) and interactive learning apps (ILAs), can assess students' strengths and weaknesses and adjust the difficulty of learning tasks accordingly (Alam, 2023; Lin et al., 2023). This dynamic adaptability fosters a sense of control, as students feel that the system is responsive to their individual needs and desires (Loderer et al., 2020). By presenting classroom content in engaging, multimodal formats, AI-powered instruments also enhance the relevance and significance of learning tasks, which lead to an increased sense of value (Loderer et al., 2020). Through enhancing a perceived sense of control and value, AI technologies cultivate positive achievement emotions in classroom contexts (Loderer et al., 2020), which in turn increase students' engagement with learning tasks (Guo & Wang, 2025).

Despite the growing recognition of AI's transformative potential within L2 education contexts, several research gaps persist regarding its role in shaping students' emotional and psychological states. Most existing language studies on AI tools and technologies have focused predominantly on their effects on L2 students' language skills (Barrot, 2023; Fathi et al., 2024; Shafiee Rad, 2024; Wei, 2023; Yuan, 2024; Zhao, 2023), often overlooking their possible impact on students' emotional and psychological states within learning environments (Wang, 2026). While some research has probed the influences of AI on L2 students' emotional experiences (Xin & Derakhshan, 2025; Yang & Zhao, 2024), there remains a lack of understanding of how this advanced technology shapes students' positive achievement emotions, including pride, hope, and enjoyment (Derakhshan & Li, 2026; Derakhshan & Park, 2026b; Wang, Wang, et al., 2026; Yuan & Liu, 2025). Moreover, although some psychological states of students in AI-supported L2 classrooms have been investigated (Huang et al., 2024; Sayed et al., 2024; Zong & Yang, 2025), the state of flow and its connection to emotional dynamics have remained largely unexplored (Çelik & Aşık, 2023; Lu, 2025). Additionally, almost all studies in this domain have been cross-sectional, offering static snapshots rather than dynamic insights into the temporal evolution of students' emotional and psychological states. To address these lacunas, the present study sets out to assess the long-term impact of AI on L2 students' flow and positive achievement emotions through latent growth curve modeling (LGCM). In contrast to traditional statistical techniques such as structural equation modeling (SEM) and regression analysis (RA) that primarily capture static relationships or cross-sectional patterns, LGCM enables researchers to model intra-individual change and inter-individual variability in the developmental trajectories of the variables under investigation (Rovine & McDermott, 2018), making it a more suitable approach for our longitudinal study. Using this approach, the study also intends to capture

the developmental trajectory of these psycho-emotional states within AI-enhanced L2 classrooms. This intervention study provides a nuanced and evidence-based understanding of how AI technologies can be leveraged to create emotionally supportive and engaging learning environments for L2 learners.

Literature Review

Theoretical Underpinning: Control-Value Theory (CVT)

Control-value theory (CVT), introduced by Pekrun (2006), is a widely recognized framework for understanding students' control-value appraisals and their impact on their emotional experiences and overall engagement within academic contexts. Control appraisals refer to students' perceptions of their ability to influence learning outcomes, while value appraisals relate to the perceived importance and relevance of a learning task or activity (Pekrun et al., 2010). Students who perceive high control over their learning outcomes and assign significant value to their learning activities typically experience positive achievement emotions (Pekrun et al., 2011). These emotions, in turn, contribute to enhanced attention, perseverance, and effort, forming a reciprocal cycle that supports students' sustained engagement (Pekrun & Linnenbrink-Garcia, 2012).

As put by Huang et al. (2023), the integration of AI in language education contexts may offer new opportunities to influence control and value appraisals, thereby shaping students' achievement emotions and academic engagement (Shao et al., 2020). AI-powered tools provide adaptive learning experiences that can enhance students' sense of control by matching task difficulty to their proficiency levels and offering immediate, constructive feedback (Bachiri et al., 2023). These features help students feel capable of succeeding and making meaningful progress, which strengthens their control appraisals (Bakare & Jatto, 2023). Simultaneously, AI can increase the value students attribute to learning tasks by presenting them in engaging and contextually relevant formats that align with their academic goals and interests (Huang et al., 2022).

Artificial Intelligence and L2 Learning

The use of AI in L2 learning environments has grown rapidly in recent years. In these classrooms, AI-driven tools such as intelligent tutoring systems (ITSs) and speech recognition software (SRS) have been deployed to facilitate personalized learning and offer real-time feedback (Huang et al., 2022). These technologies, by their nature, allow for tailored learning experiences that address individual student profiles (Derakhshan & Taghizadeh, 2025; Huang et al., 2023), including their strengths, weaknesses, and preferences, which are not always achievable through traditional pedagogical methods.

One of the most prominent applications of AI in L2 learning is ITSs, which use algorithms to personalize language instruction based on students' progress and performance (Mousavinasab et al., 2018). These systems can adjust the difficulty of learning tasks, suggest targeted exercises, and provide feedback on pronunciation, grammar, and vocabulary (Lin et al., 2023). For instance, platforms like Duolingo and Babbel feature adaptive learning pathways that adjust according to students' progress, ensuring they remain consistently challenged within their zone of proximal development (Kessler et al., 2023). Likewise, SRS, like Rosetta Stone and Google's speech-to-text, helps students refine their pronunciation and fluency. These AI-powered systems allow students to practice speaking and receive instant corrective feedback, which not only improves their language skills but also boosts their confidence in using the target language (Chen, 2022; Lord, 2016).

In addition to enhancing language proficiency, AI technologies are also promising in shaping students' emotional experiences and their cognitive investment in the learning process (Guo & Wang, 2025). AI technologies, with their ability to deliver educational content in varied multimodal formats, can make learning more enjoyable (Xiao et al., 2024), which cultivates positive emotions among students. Moreover, through the integration of gamified elements, virtual assistants, and interactive chatbots, these technologies can create dynamic and interactive learning environments that hold students'

attention and inspire them to immerse themselves in classroom activities (Bachiri et al., 2023). Despite these promising potentials, few language researchers have inspected the impact of AI resources and technologies on L2 students' emotions (Dai & Wang, 2024; Yang & Zhao, 2024; Zhao, 2024) and overall engagement (Shafiee Rad et al., 2023; Wang & Xue, 2024).

For instance, in a qualitative inquiry, Yang and Zhao (2024) addressed the role of AI-assisted language teaching in Chinese L2 learners' classroom emotions. Their findings highlighted the important role of AI technologies in cultivating positive feelings like enjoyment, inspiration, interest, pride, and happiness among L2 students. Moreover, in a quantitative study, Zhao (2024) assessed the effect of AI-mediated teaching on Chinese L2 students' classroom enjoyment. The results revealed that AI technologies significantly enhanced L2 students' classroom enjoyment by offering personalized learning experiences and timely feedback. Furthermore, to unravel the role of AI in shaping student engagement, Shafiee Rad et al. (2023) examined the impact of the Wordtune application on Iranian L2 students' academic engagement. Their study revealed that the use of Wordtune, with its AI-powered writing assistance and real-time feedback, led students to deeper academic engagement. Likewise, Wang and Xue (2024) scrutinized the effect of AI-driven chatbots on the engagement levels of Chinese L2 students. They found that AI-driven chatbots encouraged students' emotional and cognitive involvement in classroom activities.

Positive Achievement Emotions: Hope, Pride, and Enjoyment

Achievement emotions include the positive or negative feelings triggered by academic activities or the outcomes tied to them (Pekrun, 2006). These feelings are instrumental in shaping students' learning trajectories and overall success (Pekrun & Stephens, 2010). Among the positive achievement emotions, hope, pride, and enjoyment hold particular importance due to their profound impact on students' motivation and overall engagement within academic contexts (Alrabai, 2024; Pekrun et al., 2017; Pekrun & Linnenbrink-Garcia, 2012; Shakki, 2023; Shao et al., 2020). In L2 learning environments, where sustained motivation and engagement are integral to learning success, these emotions play a vital role in supporting students' academic growth (Shao et al., 2020).

Hope has been generally characterized as students' optimistic outlook on achieving desired goals (Pekrun et al., 2010). For L2 students, this positive achievement emotion acts as a driving force, inspiring them to persevere in the face of learning adversities (Shao et al., 2020). Pride, another key positive achievement emotion, emerges when students recognize their academic accomplishments (Pekrun et al., 2011). In L2 learning contexts, pride may result from mastering a difficult grammatical structure, delivering a successful presentation, or achieving a high score on a language test. This positive emotion reinforces L2 students' sense of competence and motivates them to strive for further language achievements (Shao et al., 2020). Finally, enjoyment encompasses the sense of pleasure and satisfaction students feel during meaningful and stimulating learning activities (Pekrun et al., 2017). In L2 classrooms, this positive achievement emotion often stems from interactive tasks, collaborative discussions, and opportunities for cultural exploration (Kirkpatrick et al., 2025; Shao et al., 2020).

Previous studies on positive achievement emotions have consistently demonstrated the influence of these desirable feelings on students' classroom performance (Csizér et al., 2024; Kruk & Pawlak, 2022; Li et al., 2023; Wu & Yu, 2022; Xing et al., 2019). Research has shown that positive achievement emotions like hope, pride, and enjoyment trigger students to immerse themselves in the learning process (Bakır-Yalçın & Usluel, 2024; Shakki, 2023; Wang et al., 2024).

Flow Experience

Flow is a highly focused and intrinsically rewarding state that occurs when individuals deeply engage in a particular task or activity (Csikszentmihalyi et al., 2014). Originally introduced by Csikszentmihalyi (1990), the concept of flow has become central to the study of human engagement in learning environments. It is characterized by several key features, namely a sense of control over the activity, a loss of self-consciousness, and complete concentration (Nakamura & Csikszentmihalyi, 2009). In

educational contexts, flow is particularly relevant as it reflects an optimal learning state where students experience intrinsic motivation and become fully absorbed in the learning process (Csikszentmihalyi et al., 2014).

In L2 classrooms, flow is often achieved when learners feel a sense of control over L2 tasks or activities (Liu & Song, 2021). This sense of control emerges when learning tasks are appropriately challenging and aligning with students' current skill levels (Csikszentmihalyi, 2014). Activities that foster flow among students typically provide them with opportunities to make choices, solve problems, and actively engage with learning materials in meaningful ways (Csikszentmihalyi, 2014). For example, personalized speaking exercises, creative storytelling tasks, or simulations of real-world scenarios can encourage L2 students to immerse themselves in the learning process (Lu, 2025).

Understanding how flow operates within L2 classrooms, particularly in AI-enhanced environments, offers significant potential for improving learning outcomes. AI technologies, with their ability to adapt to learners' skill levels and provide real-time feedback, can facilitate the conditions necessary for flow by creating a balanced challenge and skill experience (Alam, 2023; Lin et al., 2023). As such, the study of flow in L2 learning contexts is crucial for developing instructional strategies and AI tools that not only facilitate language acquisition but also promote deep, sustained engagement in the learning process.

Present Study

Drawing on the main tenets of the CVT (Pekrun, 2006), the present study assessed the potential of AI in shaping students' positive achievement emotions and flow experiences within L2 classrooms. Furthermore, with the aid of LGCM, the study traced the developmental trajectory of L2 students' positive achievement, emotions and their flow experiences within these AI-augmented learning contexts. More precisely, this longitudinal research strived to answer two research questions (RQ), as follows:

RQ1. How does AI-mediated instruction affect L2 students' positive achievement emotions and flow state?

RQ2. In what direction do L2 students' positive achievement emotions and flow state change during the semester?

Methods

This study used a repeated measures design (RMD) to measure the impact of AI-mediated instruction on participants' positive achievement emotions and flow experiences and trace the developmental trajectory of these psycho-emotional states throughout the course of the intervention. RMD involves "gathering data from the same participants at multiple time points" (Cunningham et al., 2013, p. 367), allowing researchers to observe changes and patterns within individuals over time. This design is particularly effective for assessing intervention impacts, examining developmental trends, or capturing within-subject variations in longitudinal studies (Verma, 2015).

Research Context and Participants

This longitudinal research was carried out at a state university in Iran, targeting students enrolled in English-related programs. This context was selected due to its alignment with the study's objective of examining the emotional and psychological states of students within L2 classrooms. The sample consisted of 217 undergraduate students majoring in Applied Linguistics (AL) and English Language and Literature (ELL). The participants were 131 females and 86 males, with ages ranging from 18 to 22 years (M= 20, SD = 0.63). The participants in this study were randomly divided into two groups: an experimental group comprising 117 students who were subjected to AI-mediated instruction and a control group consisting of 100 students who followed traditional, teacher-led instruction. By randomly assigning participants, the study sought to create equivalent groups in terms of demographic variables such as gender, age, and

academic major. This sampling approach helped researchers to ensure that any differences in the results could be attributed to the instructional method rather than to pre-existing individual differences.

Measures and Instruments

AI-Powered Tools: Speeko and Quillbot

To implement AI-mediated instruction in the experimental group, two AI-powered tools, Speeko and QuillBot, were utilized. These tools were selected based on their capabilities to support various aspects of L2 learning. Speeko is a speech coaching software designed to improve oral communication skills. It delivers real-time feedback on pronunciation, fluency, and clarity, along with tailored recommendations for improvement. By integrating advanced speech recognition technology (SRT), Speeko enables individuals to practice speaking in a low-stakes, self-paced environment. QuillBot, on the other hand, is a writing assistant software designed to support individuals' writing skills. Using natural language processing (NLP) algorithms, QuillBot helps users refine their writing by providing suggestions for improved vocabulary, grammar, and sentence structure.

Flow Scale

The flow scale, developed by Mayers (1978), was employed to measure the participants' flow experiences within L2 classrooms. This scale assesses the multidimensional construct of flow, which encompasses the optimal psychological state where students are fully immersed in and deeply engaged with a task. The robust psychometric properties of this scale in language education contexts make it a reliable tool for assessing the intensity and quality of students' flow experiences within L2 learning environments (Zuniga, 2023). The scale consists of 12 items scored on an 8-point frequency rating scale (Appendix A). Some items on the flow scale are: "I clearly know what I am supposed to do" (item 3), "I would do it even if I didn't have to" (item 9), and "I enjoy the experience and the use of my skills" (item 12). In the current study, the flow scale exhibited a high-reliability index ($\alpha = 0.90$).

Achievement Emotions Questionnaire (AEQ)

To assess participants' positive achievement emotions, the study employed the Achievement Emotions Questionnaire (AEQ) developed by Pekrun et al. (2005). This self-report instrument is designed to measure students' academic emotions, such as pride, hope, and enjoyment, which were the focus of the present study. The AEQ comprises 27 items rated on a 5-point frequency rating scale (Appendix B). These items include: "I am proud of myself" (item 1, pride), "I am optimistic that I will be able to keep up with the material" (item 12, hope), and "My enjoyment of this class makes me want to participate" (item 25, enjoyment). With a Cronbach's alpha of 0.93, the AEQ was found to be a highly reliable measure of L2 students' pride, hope, and enjoyment.

Procedure

The study began with the distribution of consent letters among participants, ensuring that they were fully informed about their rights and the study's objectives. Following the consent process, the study proceeded with the pre-intervention assessment. After the initial assessment, the experimental group began using the AI tools (Speeko and QuillBot) during their regular language activities. These tools were used for approximately 45 minutes per session, twice a week. Meanwhile, the control group continued with traditional language instruction, receiving feedback from the instructor without the use of AI technologies. Both groups were given equal instructional time, and the activities covered were similar, ensuring that the primary difference between the groups was the use of AI-enhanced instruction.

For the experimental group, which engaged with AI-powered tools, the questionnaires (AEQ and flow scale) were distributed three times during the study: at the beginning (pre-test), after six weeks (mid-test), and at the end of the semester (post-test). This repeated measure helped track changes in participants' achievement emotions (hope, pride, and enjoyment) and flow experiences over time, capturing the potential influence of AI-assisted teaching. The control group, which continued with traditional, teacher-

led instruction, completed the same questionnaires at two-time points: before the intervention (pre-test) and at the end of the semester (post-test). While the control group did not use AI tools, their responses provided a comparative baseline for understanding the effects of AI integration in the experimental group.

Data Analysis

To examine the effects of the AI intervention, two sets of Analysis of Covariance (ANCOVA) were conducted. The first ANCOVA focused on comparing the post-test scores of the experimental and control groups for the positive achievement emotions (pride, hope, and enjoyment), while the second ANCOVA targeted the participants' flow states. For each analysis, the pre-test scores were used as covariates to control for initial differences between the groups, allowing for a more accurate estimation of the impact of AI-mediated instruction. Furthermore, to examine the intensity and direction of changes in the positive achievement emotions and flow state of the experimental group, a Latent Growth Curve Model (LGCM) was created via IBM AMOS (v. 27). LGCM is "a robust statistical method that allows for the modeling of individual trajectories and group-level trends over multiple time points" (Rovine & McDermott, 2018, p. 93). In this longitudinal research, the LGCM provided insights into the developmental patterns of L2 students' emotional and psychological states throughout a twelve-week semester.

Results

Descriptive Statistics

Data collection for this study followed a structured timeline, with variations between the experimental and control groups. In the control group, data were gathered in two distinct phases: a pre-test conducted at the beginning of the semester and a post-test administered at the end. Conversely, the experimental group underwent a more detailed assessment process, with data collected at three key intervals: the onset of the intervention (pre-test), midway through the semester (mid-test), and at the conclusion of the study (post-test). The descriptive statistics for the collected data, including means and standard deviations, are summarized in Table 1.

As shown in the table above, the mean scores for achievement emotions (pride, hope, and enjoyment) and flow states differed between the experimental and control groups at both the pre-test and the post-test. However, both groups exhibited positive changes in these variables over the course of the semester. Additionally, the examination of the skewness values confirmed the normality of all distributions across both groups and time points. This verification of normality ensured the suitability of the data for subsequent parametric analyses, including ANCOVA and LGCM.

Impact of Treatment on Participants' Positive Achievement Emotions and Flow State

To determine whether the treatment had a significant effect on students' achievement emotions and flow states, two sets of ANCOVA were conducted. Prior to running the analyses, the necessary assumptions for ANCOVA were checked to ensure the validity of the results. As outlined earlier in Table 1, the normality assumption was met for all variables. Additionally, the linear relationships between the covariates and the dependent variables were evaluated using two scatterplots (see Figure 1). Both scatterplots indicated that the relationships were approximately linear, thereby satisfying the assumption of linearity. Furthermore, the homogeneity assumption of regression slopes was assessed by creating two interaction models. These models tested the interaction between the pre-test scores and the type of treatment (AI-mediated instruction vs. traditional instruction) for both achievement emotions and flow state scores. The results indicated that the interaction effects were non-significant (see Table 2), suggesting that the association between the covariate and the dependent variables did not differ across the experimental and control groups.

Table 1

Descriptive Statistics

			Minimum	Maximum	Mean	SD	Skewness
Control Group (N = 100)	Flow	Pretest	58.00	80.00	67.51	4.56	.237
		Posttest	58.00	85.00	69.72	5.14	.298
	Pride	Pretest	13.00	39.00	20.58	5.58	.947
		Posttest	13.00	39.00	21.86	5.87	.823
	Hope	Pretest	9.00	36.00	22.62	7.68	–.028
		Posttest	9.00	39.00	23.69	8.03	–.085
	Enjoyment	Pretest	8.00	37.00	22.64	7.14	–.056
		Posttest	9.00	42.00	23.30	7.61	.250
	Achievement Emotions	Pretest	30.00	106.00	65.84	17.61	.224
		Posttest	32.00	109.00	68.85	18.38	.297
Experimental Group (N = 117)	Flow	Time1	31.00	84.00	61.09	9.13	–.244
		Time2	32.00	89.00	64.73	9.98	–.371
		Time3	32.00	90.00	65.15	10.23	–.355
	Pride	Time1	10.00	39.00	24.11	6.87	–.098
		Time2	11.00	42.00	25.57	7.42	–.127
		Time3	11.00	42.00	25.98	7.56	–.122
	Hope	Time1	11.00	35.00	24.95	5.77	–.020
		Time2	11.00	39.00	26.54	6.30	–.023
		Time3	11.00	40.00	26.95	6.57	.026
	Enjoyment	Time1	14.00	35.00	24.78	5.22	.089
		Time2	16.00	41.00	27.91	6.18	.144
		Time3	16.00	42.00	28.36	6.46	.195
	Achievement Emotions	Time1	40.00	109.00	73.84	16.24	.071
		Time2	41.00	119.00	80.03	17.78	.010
		Time3	43.00	122.00	81.29	18.50	.064

Figure 1

Relationship between Covariates and Dependent Variables

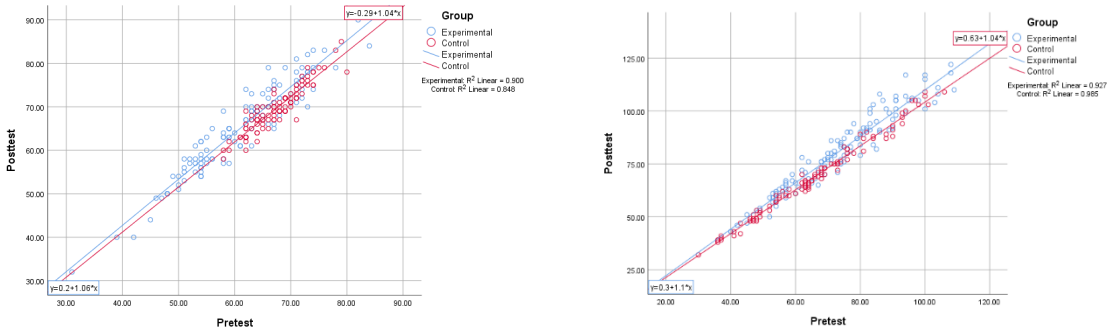


Table 2

Homogeneity of Regression Slopes

	Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Flow	Corrected Model	14267.265[a]	3	4755.755	626.146	.000
	Intercept	.003	1	.003	.000	.984
	Group	.093	1	.093	.012	.912
	Flow1	7486.969	1	7486.969	985.740	.000
	Group * Pretest	1.157	1	1.157	.152	.697
	Error	1617.795	213	7.595		
	Total	997382.000	217			
	Corrected Total	15885.060	216			
Achievement Emotions	Corrected Model	78102.958[a]	3	26034.319	1634.544	.000
	Intercept	2.562	1	2.562	.161	.689
	Group	.341	1	.341	.021	.884
	Total1	69707.701	1	69707.701	4376.544	.000
	Group * Pretest	56.750	1	56.750	3.563	.060
	Error	3392.572	213	15.928		
	Total	1320338.000	217			
	Corrected Total	81495.530	216			

Finally, through Levene's test, the assumption of homogeneity of error variances was evaluated. The results revealed significant outcomes for both flow scores ($F = 19.932$, $p = .000$) and achievement emotions scores ($F = 36.493$, $p = 0.000$), indicating that this assumption was violated. To mitigate the effects of this violation, a more conservative alpha level ($\alpha = 0.01$) was adopted for the ANCOVA analyses. This adjustment aimed to reduce the likelihood of Type I errors and to ensure that the results remained robust despite the lack of homogeneity in error variances. The ANCOVA results, presented in Table 3, were interpreted with this adjusted threshold to maintain methodological rigor.

Table 3

ANCOVA Results

	Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Flow	Corrected Model	14266.109[a]	2	7133.054	942.878	.000	.898
	Intercept	1.115	1	1.115	.147	.701	.001
	Flow1	13137.739	1	13137.739	1736.603	.000	.890
	Group	224.566	1	224.566	29.684	.000	.122
	Error	1618.951	214	7.565			
	Total	997382.000	217				
	Corrected Total	15885.060	216				
Achievement Emotions	Corrected Model	78046.207[a]	2	39023.104	2421.039	.000	.958
	Intercept	4.137	1	4.137	.257	.613	.001
	Total1	69701.547	1	69701.547	4324.365	.000	.953
	Group	780.977	1	780.977	48.453	.000	.185
	Error	3449.323	214	16.118			
	Total	1320338.000	217				
	Corrected Total	81495.530	216				

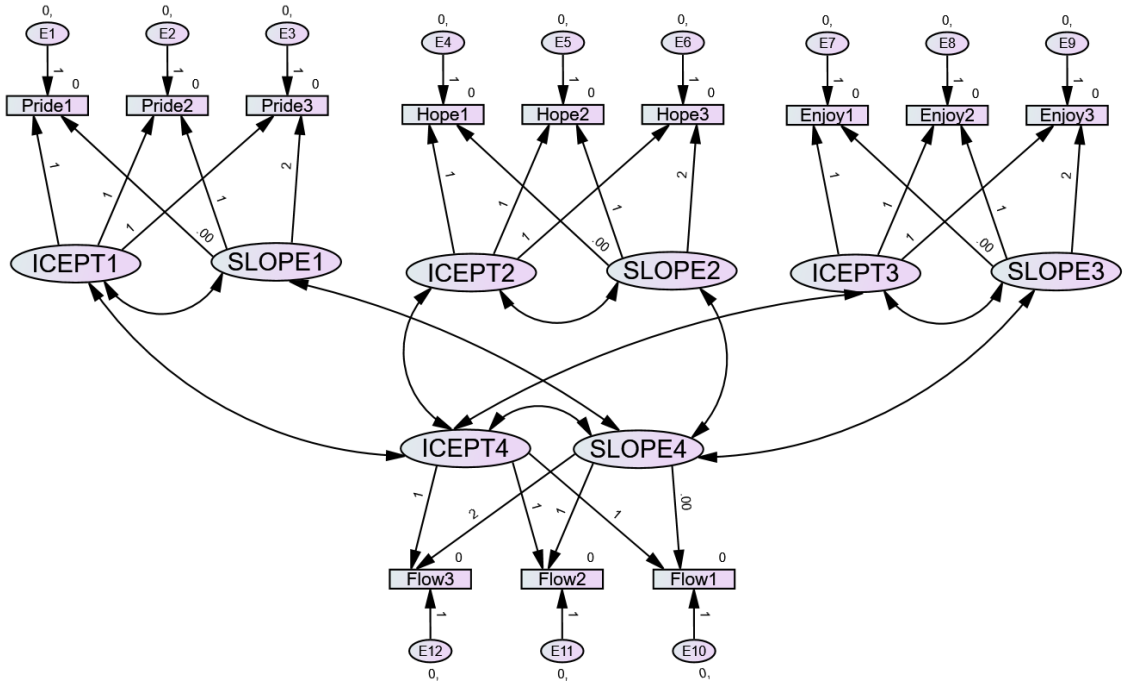
As shown in Table 3, after accounting for the possible effects of the treatment, significant differences emerged between the post-test scores of the experimental and control groups for both flow and achievement emotions. For flow, the ANCOVA results indicated a significant effect ($F = 29.68$, $p < 0.01$, $\eta^2 = 0.122$), suggesting a moderate effect size. Similarly, for achievement emotions, the results were also statistically significant ($F = 48.45$, $p < 0.01$, $\eta^2 = 0.185$), indicating a stronger effect size compared to flow. These results indicated that the AI-assisted teaching exerted a statistically significant impact on both the flow experience and positive achievement emotions of participants.

Intensity and Direction of Changes in Positive Achievement Emotions and Flow State

To capture the direction and intensity of changes in achievement emotions (pride, hope, and enjoyment) and the flow state of the experimental group, an LGCM was constructed. The proposed LGCM is represented in Figure 2, illustrating the hypothesized developmental patterns of the variables over the course of the intervention.

Figure 2

Proposed LGCM Model



The LGCM model depicted in Figure 2 was designed to measure both the initial state (intercepts) and the changes over time (slopes) in the four main variables of the study: pride, hope, enjoyment, and flow. The model comprises four blocks, each representing one variable, with measurements taken at three key intervals. In the model, the intercepts (ICEPTs) were fixed to estimate the baseline levels of each variable at the start of the intervention. The slopes (SLOPEs) captured the rate and direction of change for each variable from the first administration to the third. To model the growth trajectory effectively, fixed values of 0, 1, and 2 were assigned to the three-time points, corresponding to the pre-test, mid-test, and post-test, respectively. The results are summarized in Table 4. The LGCM with standardized estimates is also presented in Figure 3, illustrating the relationships and growth trajectories in a clear and interpretable manner.

Table 4

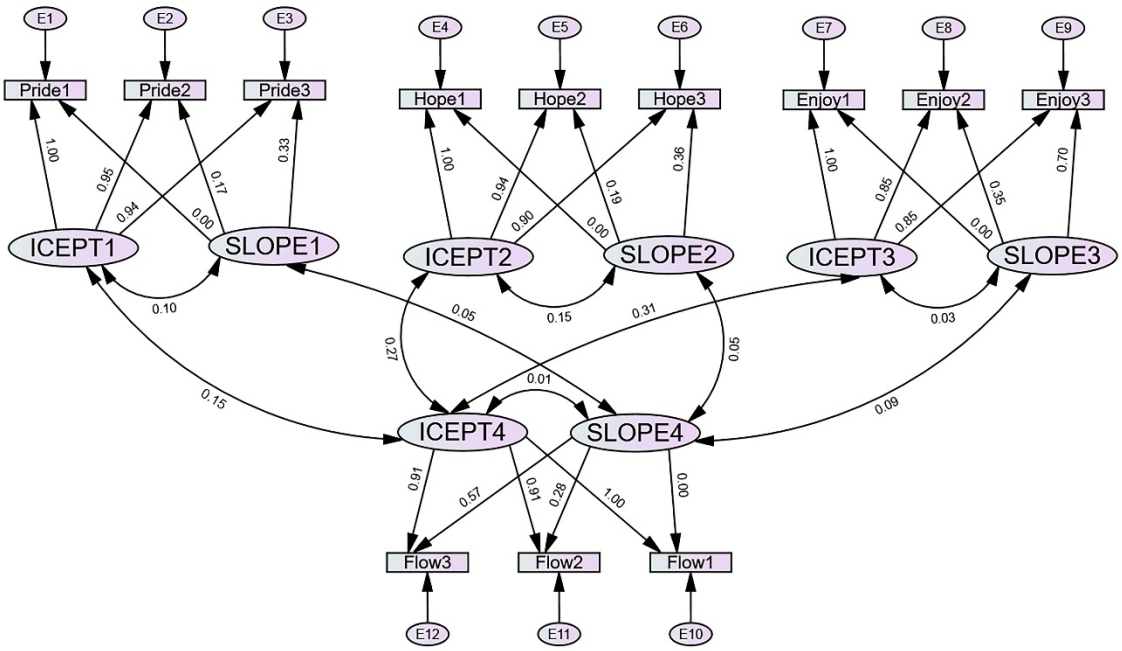
LGCM Results

				Unstandardized				Standardized Estimates
				Estimate	S.E.	C.R.	P	
Covariances	ICEPT1	<-->	SLOPE1	.805	.393	2.048	.041	.097
	ICEPT2	<-->	SLOPE2	1.020	.342	2.982	.003	.155
	ICEPT3	<-->	SLOPE3	.295	.237	1.244	.213	.026
	ICEPT4	<-->	SLOPE4	.178	.361	.494	.621	.008
	ICEPT1	<-->	ICEPT4	10.943	4.707	2.324	.022	.152
	ICEPT2	<-->	ICEPT4	13.031	4.240	3.074	.002	.273
	ICEPT3	<-->	ICEPT4	13.415	4.020	3.337	.000	.311
	SLOPE1	<-->	SLOPE4	.149	.036	4.206	.000	.047
	SLOPE2	<-->	SLOPE4	.150	.036	4.137	.000	.051
	SLOPE3	<-->	SLOPE4	.494	.074	6.653	.000	.089
Variances	ICEPT1			46.757	6.152	7.601	.000	
	SLOPE1			1.485	.201	7.391	.000	
	ICEPT2			32.942	4.305	7.653	.000	
	SLOPE2			1.314	.172	7.652	.000	
	ICEPT3			26.867	3.528	7.614	.000	
	SLOPE3			4.636	.568	8.157	.000	
	SLOPE4			6.686	.825	8.103	.000	
	ICEPT4			69.100	8.995	7.682	.000	
Means	ICEPT1			24.137	.636	37.978	.000	
	SLOPE1			.598	.062	9.630	.000	
	ICEPT2			24.956	.533	46.816	.000	
	SLOPE2			.634	.065	9.795	.000	
	ICEPT3			24.782	.481	51.475	.000	
	SLOPE3			.770	.075	10.329	.000	
	ICEPT4			61.089	.772	79.139	.000	
	SLOPE4			.823	.079	10.457	.000	

As indicated in Table 4 and visually represented in Figure 3, significant correlations were observed during the initial administration between flow and the three positive achievement emotions—pride, hope, and enjoyment. Specifically, flow demonstrated a positive and statistically significant correlation with pride ($r = .152$, $p = .022$), hope ($r = .273$, $p = .002$), and enjoyment ($r = .311$, $p = .000$). Regarding the changes over time, the analysis revealed significant covariances between the ICEPTs and SLOPEs of pride and hope, indicating that the extent of changes in these variables was significantly related to their initial levels. Conversely, non-significant covariances were found for enjoyment and flow, suggesting that the changes in these variables were more heterogeneous among participants, with individual growth patterns varying independently of their starting points. Furthermore, the covariances between SLOPE4 (flow) and the SLOPEs of the three emotions (pride, hope, and enjoyment) indicated significant correlations in the rate of changes across all constructs. The strongest correlation was observed between the slopes of flow and enjoyment ($r = .089$, $p = .000$), followed by flow and hope ($r = .051$, $p = .000$). The weakest but still significant correlation was found between flow and pride ($r = .047$, $p = .000$).

Figure 3

LGCM Model with Standardized Estimates



In terms of the direction and extent of change, the examination of the mean differences in the SLOPEs revealed significant and positive changes across all four variables. Among these, flow demonstrated the most substantial increase, with the highest mean difference (*MD* = 0.823, *SE* = 0.079, *p* = .000). This indicated that participants experienced the greatest growth in their flow states during the intervention period. On the other hand, pride exhibited the smallest mean change (*MD* = 0.598, SE = 0.062, *p* = .000), though this increase was still statistically significant. The two other variables, hope (*MD* = 0.643, *SE* = 0.065, *p* = .000) and enjoyment (*MD* = 0.77, *SE* = 0.075, *p* = .000), also showed meaningful and statistically significant growth over time.

Discussion

By adopting a longitudinal approach, this intervention study sought to evaluate the sustained impact of AI-mediated language instruction on L2 students' positive achievement emotions and flow states over the course of a twelve-week semester. Specifically, the study aimed to examine whether the integration of AI tools, such as Speeko and QuillBot, could influence the students' hope, pride, and enjoyment, as well as their experiences of flow during L2 tasks or activities. The ANCOVA results revealed notable and statistically significant differences in the post-test scores of achievement emotions and flow states between the control and experimental groups. Compared to the control group that followed traditional, teacher-led instruction, the experimental group, which was exposed to AI-mediated teaching, exhibited higher improvements in both achievement emotions (pride, hope, and enjoyment) and flow states. These results emphasize the potential of AI-assisted instruction in fostering students' emotional and psychological states within L2 classrooms.

The observed differences between the experimental and control groups concerning the experience of hope, enjoyment, pride, and flow can be well explained through the lens of CVT (Pekrun, 2006). This theory posits that students' achievement emotions are influenced by their perceptions of control over the

learning process and the value they attribute to the learning tasks at hand (Pekrun et al., 2011). These emotions, in turn, significantly affect their focus, perseverance, and attention levels (Pekrun & Linnenbrink-Garcia, 2012). According to CVT, students who feel more in control of the learning process and attribute more value to the learning tasks are more likely to experience positive achievement emotions like enjoyment, hope, and pride (Pekrun & Perry, 2014; Pekrun & Stephens, 2010), which encourage them to deeply engage in classroom activities (Pekrun et al., 2017). In this study, AI-powered tools (i.e., Speeko and QuillBot) offered tailored and adaptive learning experiences for the experimental group, which likely enhanced their sense of control over the learning process. By providing engaging, interactive, and personalized content, these tools made L2 learning more meaningful and relevant to students' individual needs and preferences, which likely increased the value they placed on learning tasks. These augmented senses of control and value, according to CVT, cultivate positive achievement emotions among students, which in turn lead to their intense attention and focus (i.e., flow state) (Shao et al., 2020). This finding also aligns with the results of Çelik and Aşık (2023) and Yuan and Liu (2025), who found that technology-mediated instruction can strengthen learners' positive feelings and drive them to deeply engage in the L2 acquisition process.

Furthermore, using a repeated measures design, this research attempted to capture the intensity and direction of changes in L2 students' positive achievement emotions—pride, hope, and enjoyment—as well as their flow state over the semester. By administering multiple assessments at different time points, the study tried to find out how these psycho-emotional variables evolved in response to the AI-assisted teaching. The results obtained from LGCM revealed notable, positive changes in all four variables—pride, hope, enjoyment, and flow—across the semester. The ongoing developments observed in the participants' pride, hope, enjoyment, and flow experiences throughout the intervention suggest that AI-powered tools have the potential to go beyond transient, momentary effects and exert a sustained impact on the students' emotional and psychological states. This result also supports the notion that AI applications can lead students to sustained emotional and cognitive investment in the learning process (Guo & Wang, 2025; Xu et al., 2023).

The LGCM outcomes further identified significant covariances between the intercepts and slopes of flow and those of pride, hope, and enjoyment. These outcomes demonstrated a strong connection between students' flow experiences and their positive achievement emotions, suggesting that progress in one domain is closely associated with improvements in the others. The observed interplay between L2 students' positive achievement emotions and flow experience can be rationally justified through the CVT, which posits that students' classroom engagement is shaped by their emotional responses to the learning tasks or outcomes (Pekrun & Perry, 2014). According to this theory, while negative emotional responses like shame, anxiety, hopelessness, and boredom decrease students' engagement levels (Derakhshan, 2026; Pekrun et al., 2010; Zhao & Wang, 2024), positive emotional reactions such as pride, enjoyment, and hope enhance students' academic engagement, driving them to immerse themselves in learning tasks and activities (Pekrun et al., 2017). This result seems to be consistent with the findings of Bakır-Yalçın and Usluel (2024) and Shakki (2023), who found a reciprocal relationship between language learners' positive achievement emotions and their sustained engagement.

Limitations and Future Research

While this longitudinal study offered important insights into the developmental trajectory of L2 students' positive achievement emotions and flow experiences in AI-supported classrooms, it suffers from three serious limitations that need to be acknowledged. Acknowledging these limitations not only contextualizes the findings but also highlights promising avenues for future research. The first limitation of this study lies in its relatively homogeneous sample. The participants were drawn exclusively from undergraduate students at a single public university. This limits the transferability of the outcomes to a wider range of students, particularly those from diverse cultural or academic backgrounds. Future research should consider replicating this study across different educational settings and cultural contexts

to evaluate the cross-cultural applicability of the findings. Second, while this research employed a robust longitudinal design, the data collection spanned only one academic semester. Although this timeframe was sufficient to capture meaningful changes in students' achievement emotions and flow states, it may not fully encapsulate the longer-term developmental patterns. Future studies should adopt extended timelines to explore how these constructs evolve over multiple semesters or academic years, providing a more comprehensive picture of their trajectories. Third, this study exclusively focused on pride, hope, and enjoyment as three key instances of positive achievement emotions. While these emotions are critical to understanding students' flow state, other positive emotions, such as gratitude or interest, may also play significant roles in shaping this psychological state. Future research should explore a broader spectrum of positive emotions to deepen our understanding of their influence on students' engagement levels.

Conclusion

This intervention study was primarily aimed at assessing the influence of AI-assisted teaching on L2 students' pride, hope, enjoyment, and flow state. Furthermore, the study sought to track the developmental trajectory of these psycho-emotional constructs across a whole semester. The outcomes revealed that AI-mediated teaching could lead to notable improvements in students' positive achievement emotions and their flow experiences within L2 learning environments. This suggests that AI-powered tools, if used effectively, can develop an emotionally supportive learning environment where language learners tend to deeply engage in the learning process. The outcomes also indicated a continuous development in the students' achievement emotions and flow experiences throughout the intervention period. This highlights the sustained impact that AI-mediated instruction can exert on students' psychological and emotional experiences over time.

Together, these findings contribute to the existing body of research grounded in Pekrun's CVT, which emphasizes the role of students' perceived control and value in shaping their achievement emotions and engagement levels. The upward trajectory observed in students' pride, hope, enjoyment, and flow states in response to AI-mediated instruction underscores the relevance of CVT in understanding the potential of advanced technologies to improve students' emotional and psychological experiences. The study further extends CVT by showing that AI technologies can strengthen students' perceptions of control and value, which collectively lead to positive emotions and intense engagement. From a practical standpoint, the study underscores the potential of AI technologies to foster deep and sustained engagement in language learning environments. By increasing a sense of control and value, AI technologies can foster positive emotions in classroom contexts that encourage learners to remain engaged in the learning process. Accordingly, language programs and institutions should consider using AI technologies as part of their curriculum to enhance students' overall engagement and success.

Acknowledgements

This publication is supported by the following sources: National Philosophy and Social Science Fund General Project (Research on the Multi-Dimensional Collaborative Multidimensional Coordinating Mechanism of Second Language Learner Agency in the Context of Digital and Intelligent Technologies (24BYY112); Guangdong Provincial Philosophy and Social Science Project: Research on the Foreign Language Learner Agency under the Integrated Digital Resource Educational Model (GD24CWY08); Guangdong Provincial Education Department Higher Education Teaching Quality Engineering Project: Reform and Practice Based on the Intelligent Teaching Model—Taking "Academic English Writing" as an Example (No Project Number).

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Appendix A. Flow Scale

Instruction: The items of this scale measure your flow experience in learning activities in your AI-enhanced classroom. All items are scored on an 8-point frequency rating scale, ranging from 1 (do not agree at all) to 8 (completely agree).

1. I get involved.
2. I get anxious.
3. I clearly know what I am supposed to do.
4. I get direct clues as to how well I am doing.
5. I feel I can handle the demands of the situation.
6. I feel self-conscious.
7. I get bored.
8. I have to make an effort to keep my mind on what is happening.
9. I would do it even if I didn't have to.
10. I get distracted.
11. Time passes more slowly or more quickly.
12. I enjoy the experience and the use of my skills.

Appendix B. AEQ

Instruction: Please respond to the following statements on a five-point Likert scale.
(1 = Strongly disagree; 2 = Disagree; 3 = Neutral; 4 = Agree; 5 = Strongly agree)

1. I am proud of myself.
2. I take pride in being able to keep up with the material.
3. I am proud that I do better than the others in this course.
4. I think that I can be proud of what I know about this subject.
5. I am proud of the contributions I have made in class.
6. When I make good contributions in class, I get even more motivated.
7. Because I take pride in my accomplishments in this course, I am motivated to continue.
8. I would like to tell my friends about how well I did in this course.
9. When I do well in class, my heart throbs with pride.
10. I am confident when I go to class.
11. I am full of hope.
12. I am optimistic that I will be able to keep up with the material.
13. I am hopeful that I will make good contributions in class.
14. I am confident because I understand the material.
15. Being confident that I will understand the material motivates me.
16. My confidence motivates me to prepare for class.

17. My hopes that I will be successful motivate me to invest a lot of effort.
18. I get excited about going to class.
19. I enjoy being in class.
20. After class I start looking forward to the next class.
21. I am looking forward to learning a lot in this class.
22. I am happy that I understood the material.
23. I am glad that it paid off to go to class.
24. I am motivated to go to this class because it's exciting.
25. My enjoyment of this class makes me want to participate.
26. It's so exciting that I could sit in class for hours listening to the professor.
27. I enjoy participating so much that I get energized.

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