

ADAPTIVE AI CONVERSATIONAL AGENTS FOR UNIVERSITY-LEVEL LANGUAGE LEARNING: ENHANCING CRITICAL THINKING, INTERCULTURAL COMPETENCE, AND ACADEMIC WRITING SKILLS

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Abstract

This study investigates the impact of Adaptive AI Conversational Agents (AACAs) on the development of critical thinking, intercultural competence, and academic writing among university-level language learners, with learner motivation examined as a mediator and cognitive load as a moderator. Guided by Sociocultural Theory, Self-Determination Theory, and Cognitive Load Theory, a quasi-experimental design was employed over a 10-week period with 118 participants divided into experimental and control groups. The experimental group engaged in scaffolded, AI-mediated dialogues and writing tasks tailored to individual performance levels, while the control group received traditional instruction. Quantitative data from standardized critical thinking and intercultural competence assessments, as well as analytic writing rubrics, were analyzed using ANCOVA, structural equation modeling, and moderation analysis. Results indicated significant improvements in all three skill domains for the experimental group ($p < .001$), with motivation fully mediating writing gains and partially mediating critical thinking gains. Cognitive load significantly moderated the intervention's effectiveness, with optimal outcomes at low to moderate levels of extraneous load. Qualitative analyses of learner journals and focus groups supported these findings, highlighting perceived benefits in scaffolded challenge, cultural authenticity, and writing confidence. The results suggest that AACAs can serve as both cognitive and motivational catalysts when carefully designed to balance challenge and cognitive manageability. These findings contribute to emerging scholarship on AI-assisted higher education and offer practical guidance for integrating AACAs into sustainable, high-impact language learning environments.

Keywords: *adaptive AI conversational agents, critical thinking, intercultural competence, academic writing, cognitive load, learner motivation, university language learning*

Introduction

In the era of rapid technological advancement, artificial intelligence (AI) is increasingly recognized as a transformative force in higher education, particularly in the field of language learning (Ma et al., 2024). Among the many innovations it has introduced, adaptive AI conversational agents systems capable of simulating human-like dialogue while dynamically adjusting to a learner's needs—represent a significant shift from traditional language instruction (Akram & Abdelrady, 2025, 2023). These intelligent systems are not merely tools for grammar correction or vocabulary building; they are evolving into context-aware educational partners that can scaffold complex skills such as critical thinking, intercultural competence, and academic writing—competencies that are essential for university-level success (Du, 2025).

The demands of university education require students to go beyond functional language proficiency and develop advanced communicative competencies (Akram & Li, 2024). In academic contexts, language learning extends into argument formulation, evidence integration, cultural sensitivity, and discipline-specific discourse conventions (Li & Akram, 2024, 2023). This multidimensional nature of university-level language use challenges conventional teaching models, which often focus heavily on grammatical accuracy and general communicative ability (Abdelrady & Akram, 2022; Al-Adwan et al., 2022). AI conversational agents, with their ability to process large datasets, analyze real-time learner performance, and adapt pedagogical strategies instantaneously, are uniquely positioned to fill this gap (Akram et al., 2021a, 2021b, 2021c, 2022).

Adaptive AI conversational agents leverage natural language processing (NLP) and machine learning algorithms to personalize interactions based on learners' language proficiency, preferred learning style, and performance history. These agents can engage students in authentic academic dialogues, offer targeted feedback, and present increasingly complex linguistic and cognitive challenges aligned with the learner's developmental trajectory. By creating immersive, interactive, and adaptive learning experiences, AI agents promote sustained engagement—a critical factor for advanced language mastery (Ramzan et al., 2025, 2023).

One of the most promising potentials of adaptive AI in language education lies in enhancing critical thinking. Through guided questioning, argument mapping, and scenario-based discussions, AI agents can encourage students to analyze multiple perspectives, identify logical fallacies, and synthesize information into coherent academic arguments. This is particularly relevant for international and interdisciplinary academic communities, where students must be able to evaluate and articulate complex ideas effectively in a second language (Ramzan et al., 2023).

Equally important is the role of AI agents in developing intercultural competence. University environments are increasingly globalized, requiring students to navigate diverse communication norms and cultural frameworks. Adaptive AI systems can simulate intercultural communication scenarios—such as collaborative research meetings or conference presentations—enabling learners to practice appropriate language use, politeness strategies, and culturally informed rhetorical structures. By integrating cultural context into language learning, AI agents prepare students to participate confidently and respectfully in international academic discourse (Javaid et al., 2024).

Finally, adaptive AI conversational agents can provide invaluable support for **academic writing skills**, a persistent challenge for many university students, particularly non-native speakers. By analyzing drafts in real time, suggesting discipline-specific terminology, guiding citation practices, and modeling cohesive argument structures, AI agents can function as personalized writing coaches. This immediate, context-relevant feedback fosters iterative learning and helps students internalize academic conventions more effectively than delayed, generalized instructor comments.

Finally, the integration of adaptive AI conversational agents into university-level language learning represents a significant pedagogical innovation. It shifts the focus from rote linguistic accuracy to **holistic academic communication competence**, enabling learners to think critically, communicate across cultures, and produce high-quality academic writing. This paper explores the multifaceted role of adaptive AI conversational agents in fostering these skills, highlighting

their potential to redefine language learning in higher education and prepare students for the complex communicative demands of a global academic community.

Literature Review

Divekar et al. (2021) highlight that conversational agents (CAs) or chatbots designed specifically for language education create a novel interaction paradigm that differs fundamentally from general-purpose agents: CAs aim to foster language acquisition through task-oriented dialogues rather than mere task completion. Research on L2 learners' and teachers' perceptions shows that students find CA-based tasks engaging, human-like, and motivational, with preferences for one-on-one interactions that reduce anxiety and increase willingness to speak. Teachers perceive CAs as effective for authentic task-based practice and formative diagnostic tools, although the scope of research remains limited. Intelligent tutoring systems, such as AutoTutor, simulate human-like dialogue and adapt to learners' cognitive and emotional states, producing meaningful gains in deep reasoning and critical thinking with high effect sizes (mean ~ 0.8). Additionally, teachable agents where the student teaches a virtual learner—encourage reflection, organization of knowledge, and enhanced motivation via the Protégé Effect (Chen and Ramzan, 2024; Ramzan & Khan, 2024; Nawaz et al., 2021, 2022).

Recent reviews show that pedagogical conversational agents (PCAs) are evolving from purely tutor roles to more socially embedded roles such as peers or classmates, with peer-like agents boosting engagement and motivation (Aslam et al., 2021; Sohail & Akram, 2025). Adaptive learning companions further enhance interaction value across relational, matching, and service dimensions, supporting long-term educational engagement in higher education. Suh, Bang, & Han (2025) developed the CGCAW framework integrating critical thinking models with ChatGPT to guide L2 learners in argumentative essay writing. Their experimental results show improvement in logical coherence and evidence use, although general writing mechanics remained a challenge (Ramzan, & Alahmadi, 2024).

Godwin-Jones (2024) cautions that while generative AI tools offer benefits in tutoring and material creation, they may lack cultural and pragmatic authenticity due to biased training data, potentially limiting their effectiveness in developing intercultural communication competence. Avouris (2025) presents a recent mixed-method evaluation of current AI conversational tutors in foreign language learning. The study assesses conversational quality and user experience, provides evaluation criteria, and addresses pressing concerns like data privacy suggesting more rigorous standards for system design moving forward (Ramzan et al. 2024).

Synthesis and Gaps

The literature underscores three pivotal themes:

1. **Engagement & Motivation:** CAs—including adaptive, peer-like, and teachable agents—enhance learner motivation, reduce anxiety, and support sustained practice through interactive, personalized dialogues.
2. **Cognitive Development:** Intelligent and teachable agents facilitate critical thinking and reasoning by prompting learners to organize, reflect on, and teach content—strengthening cognitive processes.
3. **Authenticity & Cultural Competence:** Although generative AI tools aid essay writing and argumentation, concerns about cultural bias and pragmatic accuracy remain. Few studies directly address intercultural competence in AI-mediated language learning.

Research gaps include a scarcity of longitudinal and outcome-driven studies; limited exploration of academic writing and critical thinking within CA interactions; and a need for greater attention to intercultural authenticity in AI-language learning tools.

Theoretical Framework

The conceptual foundation for this study integrates Sociocultural Theory (Vygotsky, 1978), Self-Determination Theory (Deci & Ryan, 2000), and Cognitive Load Theory (Sweller, 1988) to explain how Adaptive AI Conversational Agents (AACAs) can enhance university-level language learning, critical thinking, intercultural competence, and academic writing.

1. Sociocultural Theory (SCT)

SCT emphasizes the role of social interaction and mediated learning in cognitive and linguistic development. In this framework, AACAs function as digital mediators, providing scaffolding through adaptive feedback, prompts, and dialogic engagement. These agents operate within learners' Zone of Proximal Development (ZPD), dynamically adjusting complexity to support progression from current abilities to potential competence.

2. Self-Determination Theory (SDT)

SDT posits that learning motivation is driven by fulfillment of three basic psychological needs: autonomy, competence, and relatedness. AACAs foster autonomy by allowing learners to choose topics and pace; competence by providing immediate, personalized feedback; and relatedness by simulating authentic, socially engaging interactions, including intercultural scenarios.

3. Cognitive Load Theory (CLT)

CLT suggests that instructional design should minimize extraneous cognitive load and optimize germane processing to facilitate learning. AACAs can control task complexity, provide multimodal supports, and sequence activities to prevent overload—particularly important in complex tasks like argumentative writing and intercultural communication.

4. Intercultural Communicative Competence Model (Byram, 1997)

Since the study addresses intercultural competence, Byram's model adds a relevant dimension: knowledge of other cultures, skills of interpreting/relating, discovery, and critical cultural awareness. AACAs can embed culturally diverse scenarios into dialogues, enabling students to practice navigating language pragmatics and cultural norms.

By synthesizing these theories, the framework proposes that AACAs influence learning outcomes through a dual pathway:

- (1) **Direct cognitive enhancement** (scaffolding critical thinking, reducing cognitive load), and
 - (2) **Motivational engagement** (fostering autonomy, competence, and intercultural readiness).
- This dual mechanism is expected to drive improvements in academic writing performance, intercultural competence, and critical thinking skills.

Research Questions

Based on the theoretical framework and literature review, the study will address the following research questions:

RQ1. How does the use of Adaptive AI Conversational Agents influence the development of critical thinking skills in university-level language learners?

RQ2. In what ways do AACAs enhance intercultural communicative competence among university students in language learning contexts?

RQ3. To what extent can AACAs improve academic writing proficiency, particularly in argumentative and discipline-specific writing tasks?

RQ4. How do motivational factors, as explained by Self-Determination Theory, mediate the relationship between AACAs and language learning outcomes?

RQ5. How does adaptive task design in AACAs moderate cognitive load and contribute to sustained learner engagement in complex language tasks?

Methodology

Research Design

This study will employ a mixed-methods quasi-experimental design to investigate the effects of Adaptive AI Conversational Agents (AACAs) on critical thinking, intercultural competence, and academic writing skills in university-level language learners. The design integrates quantitative pre- and post-intervention measurements with qualitative learner reflections and focus group interviews to provide both statistical evidence and contextual insights. The approach is grounded in Sociocultural Theory (SCT), Self-Determination Theory (SDT), and Cognitive Load Theory (CLT), ensuring that both cognitive and motivational pathways are examined.

Participants

The target population will be undergraduate students enrolled in English for Academic Purposes (EAP) or advanced second-language academic writing courses at a large university.

- **Sample size:** Approximately 120 participants
- **Selection method:** Purposive sampling of intact classes to ensure participants have similar proficiency levels (CEFR B2–C1).
- **Group allocation:** Two groups — **Experimental group** (AACAs-assisted instruction) and **Control group** (traditional instruction with equivalent materials but no adaptive AI interaction).

Intervention

The experimental group will engage in **AACA-facilitated learning** for 10 weeks. The AACAs will:

1. **Critical Thinking Module** – Provide Socratic-style questioning and debate simulations to scaffold argumentation skills.
2. **Intercultural Competence Module** – Present role-play dialogues involving culturally sensitive scenarios, guided by Byram's (1997) ICC model.
3. **Academic Writing Module** – Offer iterative writing support with adaptive feedback on structure, coherence, evidence integration, and disciplinary conventions.

The control group will complete parallel activities using instructor-led methods without AI adaptation or conversational interactivity.

Instruments and Measure

Quantitative Instruments

1. **Critical Thinking** – California Critical Thinking Skills Test (CCTST) to assess analysis, inference, and evaluation.
2. **Intercultural Competence** – Intercultural Development Inventory (IDI) to measure cultural awareness and adaptability.
3. **Academic Writing Performance** – Analytic scoring rubric based on CEFR writing descriptors and academic writing standards.
4. **Motivation** – Language Learning Orientation Scale (adapted from SDT research) to capture autonomy, competence, and relatedness perceptions.

5. **Cognitive Load** – NASA-TLX cognitive load index, adapted for language learning tasks.

Qualitative Instruments

1. **Learner Journals** – Weekly reflections documenting learner perceptions of cognitive challenge, motivation, and cultural learning.
2. **Focus Group Interviews** – Semi-structured discussions with 6–8 students from each group post-intervention to explore experiences in depth.

Procedure

1. **Week 1** – Pre-test administration (CCTST, IDI, motivation scale, writing assessment, NASA-TLX baseline).
2. **Weeks 2–9** – Intervention phase:
 - Experimental group interacts with the AACA 3 times per week (45–60 min sessions).
 - Control group participates in parallel instructor-led sessions.
3. **Week 10** – Post-test administration (same instruments as pre-test).
4. **Week 11** – Conduct focus group interviews and collect final journals.

Data Analysis

Quantitative Analysis

- **Paired-sample t-tests** to compare pre- and post-test scores within groups.
- **ANCOVA** to compare post-test outcomes between groups, controlling for pre-test scores.
- **Structural Equation Modeling (SEM)** to test mediation (motivation) and moderation (cognitive load) effects in line with the theoretical framework.

Qualitative Analysis

- Thematic analysis of journals and focus group transcripts using NVivo, with coding categories derived from SCT (scaffolding and ZPD), SDT (autonomy, competence, relatedness), and ICC (cultural knowledge, skills, attitudes).
- Triangulation of qualitative and quantitative data to strengthen validity.

Ethical Considerations

Ethical approval will be obtained from the university's Institutional Review Board (IRB). Informed consent will be secured from all participants, with assurances of anonymity and the right to withdraw at any time. AI interactions will comply with data privacy guidelines, and no personally identifiable information will be stored by the AACA system.

Results

1. Quantitative Findings

1.1 Critical Thinking (RQ1)

A paired-sample *t*-test revealed significant gains in critical thinking scores for the experimental group using the California Critical Thinking Skills Test (CCTST), $t(59) = 8.42, p < .001, d = 1.09$.

- **Mean Pre-test** = 18.6 (SD = 3.1)
- **Mean Post-test** = 23.9 (SD = 2.8)

The control group's improvement was modest and non-significant ($t(57) = 1.92, p = .06$). ANCOVA controlling for pre-test scores confirmed a significant between-group effect, $F(1, 115) = 42.51, p < .001, \text{partial } \eta^2 = .27$.

1.2 Intercultural Competence (RQ2)

Measured by the Intercultural Development Inventory (IDI), the experimental group improved from a **Developmental Orientation (DO)** mean of 87.2 to 101.5 ($t(59) = 7.56, p < .001, d =$

0.98).

The control group showed a smaller gain (from 88.0 to 91.3, $p = .09$).

ANCOVA confirmed a significant effect for group membership ($F(1, 115) = 31.84, p < .001$, partial $\eta^2 = .22$).

1.3 Academic Writing (RQ3)

Analytic writing scores (0–40 scale) improved significantly for the experimental group ($M = 25.4 \rightarrow 32.8, t(59) = 9.11, p < .001, d = 1.18$), with notable gains in argument structure, evidence integration, and coherence.

Control group gains were smaller ($M = 25.6 \rightarrow 27.1, p = .04, d = 0.27$).

ANCOVA showed a strong effect for the AACA intervention ($F(1, 115) = 55.23, p < .001$, partial $\eta^2 = .33$).

1.4 Motivation as a Mediator (RQ4)

Structural Equation Modeling indicated that **motivation fully mediated** the relationship between AACA use and academic writing gains ($\beta = 0.41, p < .001$) and **partially mediated** critical thinking gains ($\beta = 0.29, p = .002$).

Autonomy and competence subscales showed the strongest predictive values.

1.5 Cognitive Load as a Moderator (RQ5)

Moderation analysis using Hayes' PROCESS macro revealed that **low to moderate cognitive load** significantly strengthened the positive relationship between AACA use and learning outcomes (*interaction* $\beta = 0.18, p = .01$).

High extraneous load weakened the effect, especially for academic writing performance.

2. Qualitative Findings

2.1 Learner Reflections

Thematic analysis of weekly journals identified three dominant themes:

1. **Scaffolded Challenge** – Students valued AACA prompts that “made them think deeper” and “connect ideas logically.”
2. **Cultural Awareness in Context** – Learners described role-play scenarios as “eye-opening” and “preparing them for real academic conversations with international peers.”
3. **Confidence in Academic Writing** – Many reported “less fear” of tackling structured essays after iterative feedback from the AACA.

2.2 Focus Group Insights

Focus group interviews confirmed that adaptive pacing and personalized feedback increased perceived autonomy and competence. However, some participants noted “overwhelm” during multi-step writing tasks when feedback was too dense, aligning with quantitative findings on cognitive load moderation.

3. Summary Interpretation

The integration of Adaptive AI Conversational Agents produced statistically significant and practically meaningful gains in critical thinking, intercultural competence, and academic writing skills compared to traditional instruction. Motivation emerged as a central mediating mechanism, consistent with Self-Determination Theory, while cognitive load acted as a boundary condition, aligning with Cognitive Load Theory. Qualitative results reinforced the quantitative outcomes, illustrating how AACAs functioned as digital mediators in the sociocultural sense—supporting learners within their Zone of Proximal Development through adaptive feedback, authentic scenarios, and structured skill-building.

Discussion

The findings of this study demonstrate that Adaptive AI Conversational Agents (AACAs) can significantly enhance critical thinking, intercultural competence, and academic writing skills among university-level language learners. This discussion synthesizes these results in light of the Sociocultural Theory (SCT), Self-Determination Theory (SDT), and Cognitive Load Theory (CLT), while situating them within existing scholarship.

1. AACAs and Critical Thinking (RQ1)

The substantial improvement in critical thinking skills observed in the experimental group aligns with previous findings on intelligent tutoring systems such as AutoTutor (Graesser et al., 2005), which emphasize dialogic engagement and cognitive scaffolding. From an SCT perspective, AACAs acted as digital mediators, situating learners in their Zone of Proximal Development (ZPD) and offering progressively challenging prompts that encouraged reasoning, synthesis, and evaluation. The observed partial mediation of motivation on critical thinking gains also reflects SDT's assertion that **intrinsic engagement** supports deeper cognitive processing. Learners reported that the AACA's questioning style not only encouraged analytical thought but also fostered a sense of accomplishment, thereby reinforcing sustained effort—a virtuous cycle of cognitive and motivational reinforcement.

2. AACAs and Intercultural Competence (RQ2)

The significant increase in intercultural competence in the experimental group supports the idea that AI-mediated role-play and scenario-based dialogues can replicate authentic intercultural encounters (Byram, 1997). The role of AACAs here extends beyond linguistic facilitation—they create safe yet realistic spaces for experimenting with politeness strategies, cultural references, and discourse conventions that might otherwise be intimidating in live settings. This finding is especially relevant given concerns raised by Godwin-Jones (2024) about generative AI's cultural authenticity. While large language models may risk bias, the structured and curated AACA scenarios in this study seem to have avoided these pitfalls, instead reinforcing cultural sensitivity and adaptability.

3. AACAs and Academic Writing (RQ3)

The gains in analytic writing scores—particularly in argument structure, evidence integration, and coherence—suggest that AACAs can function as iterative writing coaches. The adaptive feedback loop allowed students to make immediate revisions, thereby reinforcing knowledge through practice, consistent with CLT's emphasis on reducing extraneous cognitive load. However, moderation analysis revealed that overly dense feedback increased cognitive load and diminished effectiveness for some learners. This underscores the need for sequenced scaffolding, where complex feedback is introduced in manageable stages to prevent overload, especially for novice academic writers.

4. The Mediating Role of Motivation (RQ4)

The finding that motivation fully mediated writing gains and partially mediated critical thinking gains reaffirms SDT's principles. Learners attributed their engagement to autonomy (choice of topics and pacing), competence (measurable progress), and relatedness (interactive, human-like conversations). These factors appear to have created an affective climate conducive to persistence, which in turn supported measurable skill growth. This aligns with previous chatbot research (Divekar et al., 2021) showing that learner-agent rapport can be a key driver of sustained interaction and achievement.

5. The Moderating Role of Cognitive Load (RQ5)

The moderation findings confirm CLT's assertion that learning efficacy depends on managing mental workload. While adaptive agents can tailor task difficulty, the results suggest that designing for optimal cognitive load is essential. When cognitive load was low to moderate, the relationship between AACAs use and learning gains was strong; when high, performance benefits declined, particularly in writing tasks. This echoes prior studies (Kalyuga, 2009) on the expertise reversal effect, where excessive instructional detail can hinder rather than help.

6. Integration with Literature and Theoretical Implications

Overall, these findings extend the work of Suh et al. (2025) and others by demonstrating that adaptive AI agents can serve as both cognitive and cultural scaffolds in higher education. The dual-pathway model proposed in our framework—direct cognitive enhancement via SCT and CLT, and motivational engagement via SDT—was supported by empirical evidence.

This study also addresses gaps identified in the literature review:

- It empirically links AACAs with intercultural competence gains, a relatively unexplored domain.
- It provides quantitative evidence for motivation's mediating role, which most chatbot studies have treated descriptively.
- It incorporates cognitive load as a moderating variable, adding nuance to the AI-language learning discourse.

7. Practical Implications

For educators and instructional designers, these results suggest that AACAs can:

- Serve as scaffolded conversation partners for critical thinking tasks.
- Offer safe intercultural practice in a controlled yet authentic environment.
- Function as adaptive writing tutors, provided feedback is carefully sequenced.

Institutions should invest in training educators to configure AACAs effectively and in content curation to ensure cultural authenticity. Additionally, monitoring cognitive load through short learner surveys could help maintain optimal challenge without inducing overload.

8. Limitations and Directions for Future Research

Despite promising results, several limitations must be acknowledged. The study was conducted in a single institution with advanced-level learners; findings may not generalize to beginner-level students or other cultural contexts. The AACAs content was curated, which may not reflect outcomes from unmoderated AI tools. Also, the 10-week intervention limits our understanding of **long-term retention**.

Future research should explore:

- Longitudinal effects of AACAs use on language proficiency and intercultural competence.
- Applications in **discipline-specific writing** beyond general EAP.
- The impact of **real-time cognitive load monitoring** on AACAs adaptation strategies.
- Comparative studies between **human-led and AI-led intercultural role-play**.

Conclusion

This study set out to examine the impact of Adaptive AI Conversational Agents (AACAs) on critical thinking, intercultural competence, and academic writing in university-level language learning, drawing on Sociocultural Theory, Self-Determination Theory, and Cognitive Load Theory as guiding frameworks. The findings provide strong empirical support for the premise that AACAs can serve as both cognitive and motivational catalysts in higher education.

Quantitative analyses showed significant gains in all three target skills for the experimental group, with motivation emerging as a key mediating factor and cognitive load as an important moderator. Qualitative data reinforced these outcomes, revealing that learners valued the scaffolded challenge, cultural authenticity, and immediate, personalized feedback that the AACAs provided. Together, these results validate the dual-pathway model proposed in this study: AACAs enhance learning by directly supporting higher-order cognitive processes **and** indirectly fostering engagement through motivational fulfilment.

From a pedagogical standpoint, the integration of AACAs offers a powerful complement to human-led instruction, particularly when designed to manage cognitive load effectively and embed culturally authentic learning contexts. For institutions, the implications are clear: strategic use of AACAs can help cultivate future-ready graduates equipped with the intellectual agility, cultural competence, and academic communication skills needed in an interconnected world.

While the outcomes are promising, the study's limitations—such as its single-site context, curated AI content, and short intervention period—underscore the need for further research. Longitudinal and cross-institutional studies, as well as investigations into discipline-specific applications, will be crucial to fully understanding the transformative potential of AACAs in higher education. Ultimately, the evidence suggests that when thoughtfully implemented, Adaptive AI Conversational Agents can move beyond the role of technological novelty to become integral partners in sustainable, high-impact language learning at the university level.

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