

Smart Classrooms as Linguistic Ecosystems: A New Paradigm for Interactive Language Pedagogy

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ABSTRACT

***This study explores** the implementation of a smart classroom model conceptualized as a linguistic ecosystem to enhance student engagement in Indonesian language learning within a higher education context*

***Materials and methods.** Employing a Design Based Research approach, the study was conducted in three iterative phases involving model design, classroom implementation, and systematic evaluation. A total of 65 undergraduate students aged 18 to 22, along with two Indonesian language lecturers, participated in the study conducted at a major public university in Indonesia. Data collection utilized two validated instruments. The Student Engagement Questionnaire, administered before and after the intervention, measured cognitive, behavioral, emotional, and social engagement through 24 items on a Likert scale. The Interaction Observation Sheet documented observable student behaviors, including the use of multiple modes of communication and collaborative participation, during 14 instructional sessions. Quantitative data were analyzed using paired sample t-tests and Cohen's d to assess changes in engagement levels, while qualitative data from classroom observations were analyzed thematically to identify patterns of interaction.*

***Results.** Findings indicated statistically significant increases across all domains of engagement, with the most notable improvement observed in cognitive engagement. Qualitative analysis revealed a rise in spontaneous language use, peer collaboration, and multimodal communication. These results suggest that a smart classroom designed as a linguistic ecosystem fosters a more interactive and engaging learning environment, supporting deeper student involvement and more dynamic language learning experiences.*

***Keywords:** smart classroom, linguistic ecosystem, student engagement, design-based research*

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PENDAHULUAN

The rapid advancement of smart technologies has significantly reshaped the landscape of education, leading to the widespread adoption of smart classrooms across various disciplines. In language education, studies have documented the use of smart boards, AI-based tutoring systems, IoT devices, and adaptive learning platforms to facilitate personalized instruction and enhance learning outcomes (Leshchenko et al., 2023; Weng & Chiu 2023; Zhang & Zou, 2020; Malik, A.R 2023). Despite these developments, most research remains predominantly focused on the functional deployment of discrete technologies rather than on how the overall learning environment can be systematically designed to foster collaborative and socially meaningful language use. A critical review by Cebrian et al (2020) emphasizes that current smart classroom models are largely driven by technological affordances without integrating holistic, interaction-centered pedagogical frameworks,

leaving a substantial gap in understanding how intelligent environments can evolve into ecosystems that sustain linguistic development.

The urgency to reconceptualize smart classrooms stems from emerging paradigms in second language acquisition (SLA) and educational psychology that view language learning as a socially co-constructed, multimodal, and dynamic process (Wong et al., 2024; Dixon, 2012). Research indicates that authentic language acquisition thrives in contexts where learners actively negotiate meaning, engage in dialogic exchanges, and interact with multimodal inputs (Jiang, 2016). However, many technologically enhanced classrooms still replicate traditional didactic models that prioritize content delivery over interactional engagement. Integrating the physical, digital, and social affordances of smart environments to create interconnected spaces for spontaneous linguistic collaboration is therefore becoming a pressing educational necessity, particularly in an era where intercultural communication and critical thinking are essential competencies (Zwitserslood, 2015).

Designing smart classrooms as linguistic ecosystems offers a transformative response to this necessity. Conceptualizing the classroom as an ecosystem highlights the interplay between learners, technologies, spatial configurations, and communicative practices, thus positioning interaction, collaboration, and adaptability at the core of language pedagogy (Aguayo et al., 2021). Recent studies underscore that ecological learning environments support deeper cognitive engagement, foster a sense of co-presence, and enable more authentic participation in language tasks (Chik & Ho, 2022; Chen & Hsu, 2020). In contrast to conventional smart classrooms that prioritize technological intervention, an ecological approach advocates for designing intelligent learning spaces that are sensitive to the emergent, negotiated, and contextual nature of language learning experiences.

The increasing normalization of hybrid, blended, and post-digital education models further accentuates the relevance of this ecological perspective. Learners today operate within complex communicative ecologies where physical presence intertwines with virtual interaction, necessitating classroom environments that can support multimodal discourse, collaborative knowledge construction, and culturally responsive communication practices (Liantada, 2023; O'Dowd, 2021). Smart classrooms, when designed as living linguistic ecosystems, have the potential to offer fluid, participatory, and learner-centered environments that mirror the distributed nature of contemporary communication and align with critical frameworks of digital pedagogy and inclusive education.

This study seeks to explore how smart classrooms can be designed and implemented as linguistic ecosystems to support collaborative and interactive language learning. It aims to propose a conceptual model that integrates technological, spatial, and social elements in a coherent ecological framework and to empirically investigate its effects on learner engagement, interaction quality, and language acquisition outcomes. To achieve these objectives, the study addresses the following research questions:

RQ1: How can smart classrooms be designed as linguistic ecosystems to foster collaborative and interactive language learning?

RQ2: What are the impacts of ecosystem-based smart classroom design on learners' engagement, interaction quality, and language acquisition processes?

LITERATURE REVIEW

Smart Classrooms in Language Education: Developments and Gaps

Smart classrooms have rapidly evolved as a cornerstone of educational innovation, integrating IoT devices, AI-driven feedback systems, and adaptive learning technologies to personalize instruction (Chen et al., 2023; Wang et al., 2021). In the field of language education, smart environments have been used to facilitate automated pronunciation correction, real-time grammar support, and individualized reading or speaking exercises (Zhao et al., 2022). These developments have significantly enhanced the capacity of teachers to address diverse learner needs and have provided students with flexible, immediate access to language resources.

However, despite the technological sophistication, recent evaluations suggest that smart classrooms in language education often remain centered on individual learning rather than promoting collective linguistic engagement (Li & Han, 2023). Existing smart learning designs tend to prioritize efficiency and assessment over social interaction and negotiation of meaning, which are critical elements in second language acquisition (SLA) (Kington, 2022). Automated systems frequently lack the sensitivity to contextual nuances and cultural variation inherent in authentic language use, thus limiting learners' opportunities for situated language practice.

Critics argue that the current model of smart classrooms replicates traditional teacher-centered paradigms under a new technological guise rather than fundamentally transforming the nature of language learning (Pérez-Llantada, 2023). Without intentional design strategies that integrate collaboration, dialogue, and real-world communication scenarios, the potential of smart environments to serve as dynamic linguistic ecosystems remains unrealized. This gap underscores the necessity of shifting the design focus from technology deployment toward ecosystemic orchestration of social, spatial, and technological elements.

Conceptualizing Linguistic Ecosystems in Education

The notion of learning environments as ecosystems has gained momentum in educational theory, emphasizing the interconnectedness of learners, tools, spaces, and cultural practices (Aguayo et al., 2021; Bond et al., 2022). In a linguistic ecosystem, language learning is viewed not merely as cognitive acquisition but as an emergent, socially negotiated process shaped by multimodal interactions within a dynamic environment. Ecosystemic perspectives align closely with sociocultural

theories of learning, highlighting the centrality of dialogue, mediation, and contextual meaning-making (Lantolf et al., 2020).

Applying an ecological lens to language education suggests that smart classrooms should be designed to foster fluidity between formal and informal interactions, support spontaneous peer collaboration, and encourage engagement with diverse communicative modes (Chik & Ho, 2022). Studies have shown that learners thrive when they can move freely between spaces of exploration, reflection, and social interaction, using technology not as a directive force but as an enabler of agency and shared meaning-making (Wang & Lin, 2021). Flexible spatial configurations, sensor-augmented feedback, and ambient digital scaffolding are key features in constructing such ecosystems.

Recent empirical research confirms that ecological learning spaces improve learner autonomy, deepen intercultural competence, and enhance the quality of peer interactions (Byram & Wagner, 2023; O'Dowd, 2021). For language classrooms, this means designing smart environments that simulate real-world communicative ecologies, where learners engage in authentic discourse across multiple modes and platforms. Emphasizing relationality, adaptability, and co-construction of meaning, the linguistic ecosystem framework offers a robust alternative to prevailing technology-centric approaches.

Toward a Model of Smart Classrooms as Linguistic Ecosystems

Emerging models of smart learning environments advocate for reimagining the classroom as a living system, where learners, technologies, physical spaces, and pedagogical strategies interact symbiotically (Chen et al., 2023; Bond et al., 2022). In language education, this requires designing smart classrooms that enable seamless transitions between individual reflection, small group collaboration, and whole-class interaction, supported by ambient technologies that adapt to learners' evolving needs and contexts (Kim & Lim, 2021). Spatial flexibility, multimodal inputs, and sensor-based analytics become critical enablers of interactional richness and linguistic development.

One promising approach is the integration of AI-mediated conversation agents, virtual reality scenarios, and real-time collaboration dashboards within flexible classroom architectures (Zhang & Hung, 2023). Such affordances can facilitate spontaneous communication, authentic negotiation of meaning, and cross-cultural exchanges, thus aligning smart classroom design with the interactive demands of modern language pedagogy. Multimodal learning analytics, which track gesture, voice, text, and collaborative behaviors, can further inform adaptive instructional strategies and promote deeper engagement.

Designing smart classrooms as linguistic ecosystems challenges educators and designers to move beyond a technology-centered logic toward a pedagogy of relationality, co-presence, and multimodal exploration (Pérez-Llantada, 2023; O'Dowd, 2021). It calls for orchestrating technologies,

spaces, and human interactions in ways that support the organic emergence of language practices within authentic communicative ecologies. Developing such models will be crucial for advancing equitable, responsive, and future-ready language education in an increasingly interconnected world.

METODE PENELITIAN

Research Design

This study employed a Design-Based Research (DBR) approach to develop, implement, and evaluate a smart classroom model conceptualized as a linguistic ecosystem for Bahasa Indonesia learning. DBR was selected because of its ability to bridge theoretical frameworks and practical innovations through iterative cycles of design, enactment, analysis, and redesign (Wang & Hannafin, 2021). The research was conducted over three main phases: initial exploration and collaborative model design with lecturers, iterative implementation within the smart classroom environment, and retrospective analysis to refine both theoretical insights and instructional practices. The study was situated at a major public university in Indonesia where smart classroom technology had been adopted for general Bahasa Indonesia courses.

Participant

Participants consisted of undergraduate students enrolled in Bahasa Indonesia general education classes. A total of 65 students aged between 18 and 22 years voluntarily participated after giving informed consent. In addition, two lecturers of Bahasa Indonesia were involved to assist with the design and classroom observation processes. Participants were selected using purposive sampling to ensure that the sample represented typical language learners in a higher education context.

Table 1. Participant Demographics

Category	Number of Participants	Percentage (%)
Total students	65	100%
Gender		
- Male	24	36.9%
- Female	41	63.1%
Age Range		
- 18–19 years	20	30.8%
- 20–21 years	32	49.2%
- 22 years	13	20.0%

Instrument

Data collection relied on two primary instruments developed and adapted for this study. The first instrument was an Interaction Observation Sheet (IOS), which was used during classroom activities to capture the frequency and quality of student interactions. The IOS focused on observable indicators such as the initiation of dialogue, turn-taking in group discussions, use of multimodal resources (e.g., oral speech, visual aids, and writing), and evidence of spontaneous language production

in Bahasa Indonesia. The observation framework was adapted from Chik and Ho's (2022) model of interactional analysis in technology-supported environments but modified to suit the linguistic and cultural context of Indonesian Language learning.

The second instrument was a Student Engagement Questionnaire (SEQ), administered before and after the intervention. The SEQ contained 24 items measured on a five-point Likert scale, assessing four domains of engagement: cognitive engagement (attention, strategy use), behavioral engagement (participation, task completion), emotional engagement (enjoyment, interest), and social engagement (collaboration and group interaction). The questionnaire was adapted from Fredricks et al. (2021) to fit the characteristics of Indonesian language learning activities within a smart classroom context. Both instruments were validated through expert review and piloting to ensure clarity, relevance, and reliability.

Data Collecting

Data collection was conducted over a full academic semester spanning 14 instructional sessions. During the initial phase, students completed the baseline SEQ to assess their initial engagement profiles. Throughout the implementation phase, students participated in structured collaborative tasks designed for the smart classroom environment, which included interactive polls, shared digital writing tasks, and group discussions using smart boards and personal devices. Observations using the IOS were conducted systematically during each session, supported by selective video recordings for further interactional analysis. After the intervention period concluded, students completed the final SEQ to evaluate any changes in engagement levels. Participation in the study was voluntary, and all ethical guidelines related to informed consent, anonymity, and the right to withdraw were strictly adhered to throughout the research.

Data Analysis

To examine the impact of the smart classroom intervention on student engagement, paired sample t-tests were employed to compare pre-test and post-test scores across the four domains of the Student Engagement Questionnaire (SEQ), namely cognitive, behavioral, emotional, and social engagement. The analysis aimed to determine whether significant changes occurred following the intervention. In addition to statistical significance, the magnitude of the effect was assessed using Cohen's d, providing insight into the practical relevance of the observed differences. The internal consistency of the SEQ was evaluated through Cronbach's alpha calculations for each engagement domain, with a threshold of 0.75 adopted to ensure the reliability of measurement. Interactional data recorded through the Interaction Observation Sheet (IOS) were analyzed qualitatively using a thematic coding approach. Observable behaviors, including collaborative interaction, multimodal communication (oral, written,

visual), and instances of spontaneous language use, were systematically coded to uncover emerging patterns of interaction within the smart classroom environment. Findings from both statistical and thematic analyses were integrated during the interpretation phase to construct a holistic understanding of how the ecological smart classroom model influenced students' engagement and collaborative language practices.

HASIL DAN PEMBAHASAN

This section presents the findings of the study, including descriptive statistics, assumption tests, paired sample t-test results, effect size estimations, and analysis of classroom interactions based on observations.

Descriptive Statistics of Student Engagement

Descriptive statistics for each domain of student engagement before and after the smart classroom intervention are presented in table 2.

Table 2. Descriptive Statistics for Student Engagement Pre-test and Post-test

Engagement Domain	N	Pre-test (M)	Mean	Pre-test SD	Post-test (M)	Mean	Post-test SD
Cognitive Engagement	65	3.21		0.45	3.87		0.40
Behavioral Engagement	65	3.05		0.48	3.76		0.44
Emotional Engagement	65	3.10		0.50	3.81		0.42
Social Engagement	65	3.00		0.55	3.79		0.47

The mean scores for all domains increased following the intervention, suggesting an overall enhancement in student engagement. Before conducting the paired sample t-tests, assumption checks for normality and homogeneity were performed.

Table 3. Shapiro-Wilk Test of Normality for Engagement Scores

Engagement Domain	Pre-test (p-value)	Post-test (p-value)
Cognitive Engagement	0.181	0.212
Behavioral Engagement	0.125	0.168
Emotional Engagement	0.137	0.198
Social Engagement	0.110	0.192

The Shapiro-Wilk test indicated that all p-values were greater than 0.05, confirming that the engagement scores were normally distributed.

Table 4. Levene’s Test for Equality of Variances

Engagement Domain	F-value	p-value
Cognitive Engagement	1.54	0.218
Behavioral Engagement	0.97	0.327
Emotional Engagement	1.20	0.276
Social Engagement	1.03	0.314

Homogeneity of variances was also satisfied across all engagement domains, as indicated by p-values greater than 0.05.

Paired Sample t-Test Results

Paired sample t-tests were conducted to determine whether the observed improvements in engagement were statistically significant. All four domains showed statistically significant improvements at the 0.001 level.

Table 5. Paired Sample t-Test Results

Engagement Domain	t-value	df	p-value	Mean Difference	Significance
Cognitive Engagement	8.76	64	<0.001	0.66	Significant
Behavioral Engagement	9.02	64	<0.001	0.71	Significant
Emotional Engagement	7.88	64	<0.001	0.71	Significant
Social Engagement	8.11	64	<0.001	0.79	Significant

Effect Size Estimation

Cohen’s d was calculated to assess the practical significance of the differences. The results indicate large effect sizes across all domains according to Cohen’s (1988) criteria, suggesting that the intervention had a strong practical impact.

Table 6. Cohen’s d Effect Size Estimates

Engagement Domain	Cohen’s d	Interpretation
Cognitive Engagement	1.09	Large
Behavioral Engagement	1.14	Large
Emotional Engagement	0.98	Large
Social Engagement	1.01	Large

Interactional Patterns Observed in the Smart Classroom

Interaction Observation Sheet (IOS) analysis captured the frequency and nature of student interactions during the intervention. A notable increase in all types of interactional behaviors was observed, particularly during the mid-phase of the implementation.

Table 7. Frequency of Observed Interactional Behaviors

Interactional Behavior		Early Phase (Sessions 1–3)	Mid Phase (Sessions 4–10)	Late Phase (Sessions 11–14)
Peer Collaboration Instances		58	132	94
Multimodal Utilization	Resource	41	115	87
Spontaneous Production	Language	36	98	74

Emergent Themes from Observations

Thematic analysis of classroom observations revealed recurrent patterns that characterize the nature of student engagement in the smart classroom. These findings suggest that the smart classroom environment fostered a more flexible, interactive, and multimodal approach to language learning.

Table 8. Emergent Themes Identified

Theme		Description
Flexible Collaboration		Students dynamically switched between individual and group tasks.
Multimodal Communication		Students utilized a variety of modalities (oral, written, visual).
Increased Initiative		Students more frequently initiated discussions and problem-solving activities.
Real-Time Meaning	Negotiation of	Students engaged in immediate clarification of ideas through dialogue.

Discussion

The results of this study show a significant increase in all domains of student engagement following the implementation of the smart classroom intervention. This increase is clearly evident in the average pre-test and post-test scores, which rose across all dimensions of engagement: cognitive, behavioral, emotional, and social. These score improvements indicate that a smart technology-based learning environment can create a more engaging, interactive, and inclusive atmosphere for students. This intervention changed the classroom dynamics not only technically but also had a positive psychological impact on students in approaching the learning process. Technology acts as a medium that strengthens the connectivity between students, instructors, and learning content simultaneously. A previous study reported that smart classrooms can enhance learning engagement by providing real-

time interaction, flexible access to materials, and more varied instructional media (Yu et al., 2022; Lu et al., 2022).

The cognitive engagement dimension showed a particularly notable improvement, as evidenced by the t-test results and a Cohen's d estimate of 1.09 which falls into the category of a large effect. This increase suggests that students were more active in engaging in higher-order thinking processes such as analyzing, evaluating, and synthesizing information during the learning sessions. This reflects the success of the intervention in promoting deep learning, involving deep understanding, reflective thinking, and conceptual integration. Cognitive engagement is considered the core of academic engagement because it shows how deeply students process the information they receive (Navarro et al., 2024; Schnitzler et al. 2020). Within the smart classroom, the use of digital tools such as interactive simulations, online discussion forums, and multimedia learning resources provides adequate stimulation to encourage students' cognitive activity. As a result, students are no longer passive recipients of knowledge but actively construct understanding through critical thinking and self-reflection.

A significant increase was also observed in the behavioral engagement dimension, with the largest effect size of 1.14. This dimension encompasses student participation in classroom activities, task completion, attendance, and contributions to discussion. The considerable increase indicates that students became more disciplined and proactive in following the learning sessions. This can be attributed to the dynamically designed learning environment where students felt more motivated due to the variation in instructional delivery, enhanced visuals, and ease of access to learning instructions. Behavioral engagement is strongly influenced by autonomous and positively challenging learning experiences (Malik, A.R, 2019). In this study, students displayed active behavior through teamwork, data gathering, and problem-solving presented during the sessions.

The emotional engagement aspect also experienced a significant increase, as shown by a mean difference of 0.71 and a Cohen's d value of 0.98. This suggests that students felt happier, safer, and more enthusiastic during the learning process. The smart classroom environment had a positive impact on students' emotional comfort and satisfaction. A classroom atmosphere that supports self-expression, freedom to explore ideas, and opportunities to learn from mistakes was a key factor that promoted this engagement. Digital technology, when used reflectively in learning, can enhance affective engagement and learning satisfaction because students feel connected to the content and their peers (Burhan et al., 2024). Under such conditions, learning is no longer perceived as a burden but as a meaningful and enjoyable experience.

The social engagement dimension showed the highest increase in mean score at 0.79, with a large effect size of 1.01. This finding confirms that the integration of technology in the classroom does not reduce the quality of social interaction but enriches and expands its forms. Students more

frequently engaged in teamwork, group discussions, and the exchange of ideas. These interactions became more dynamic with the help of digital media that enable communication across time and space. Learning happens optimally through meaningful social interaction (Darwis et al, 2020). The smart classroom provides a space for collaboration that includes not only verbal conversation but also digital text, forum comments, and collaborative editing of online documents. These interactions strengthen mutual trust and help build a solid learning community.

Observational data showed that students' interaction patterns changed dynamically throughout the intervention phases. In the initial phase, the number of interactions was relatively low as students were still adapting to the technology and new learning approach. During the middle phase, there was a significant surge in interaction frequency, particularly in peer collaboration, the use of multimodal learning resources, and spontaneous language production. This indicates that students began to feel comfortable and capable of optimizing the digital learning environment. A multimodal approach increases learner participation because it provides multiple access points to meaning (Sankey, 2010). Learning through various channels such as visuals, text, audio, and images allows learners with different styles to find approaches that suit their needs.

The themes “Flexible Collaboration” and “Increased Initiative” reinforce the idea that students were not merely receiving information but actively engaged in the learning process. Students were able to shift between individual and group work depending on the task demands and group dynamics. They also increasingly took the initiative to ask questions, contribute ideas, and resolve differences of opinion. This finding suggests the formation of a learning culture that is autonomous and participatory. Learning designed in authentic and open-ended contexts encourages learners to take responsibility for their own learning process (Land, 2000). In a smart classroom, this flexibility is supported by the availability of digital tools and platforms that help students determine the most effective learning approach.

The theme “Real-Time Negotiation of Meaning” indicates that students were actively involved in meaning-making during the learning process. This occurred through peer dialogue, group discussion, and interactions with the instructor in both synchronous and asynchronous formats. Students engaged in concept clarification, feedback exchange, and elaboration of arguments. These interactions support the development of deeper and more stable understanding. Meaning is constructed through the exchange of perspectives in social contexts (Kim, 2024). Therefore, the smart classroom becomes not only a space for information transfer but also a space for constructing meaning that enriches academic perspectives. Overall, this study provides strong evidence that implementing smart classrooms has a significant impact on improving the quality of student engagement. The pedagogical implications are broad, ranging from the need to design instruction that integrates technology and collaboration, to preparing educators to use digital tools effectively, and

creating flexible and adaptive learning environments. The integration of technology must align with a comprehensive pedagogical strategy. Educational institutions should develop policies and infrastructure that support systemic digital transformation while upholding humanistic values in education. Recommended steps include consistent integration of digital platforms into courses, enhancement of assessment models that emphasize interaction and engagement, and the cultivation of a learning culture that fosters interdisciplinary collaboration. Opportunities for future research include examining the long-term effects of smart classrooms on learning outcomes and the development of twenty-first-century competencies.

KESIMPULAN

This study demonstrates that the implementation of smart classrooms significantly enhances student engagement across cognitive, behavioral, emotional, and social domains. The improvements in pre-test and post-test scores indicate that a technology-integrated learning environment fosters greater interactivity, inclusivity, and learner participation. Notably, cognitive engagement showed a large effect size, reflecting an increase in students' critical thinking, analytical reasoning, and reflective learning. Behavioral engagement also improved markedly, as students became more disciplined, proactive, and collaborative due to the dynamic and visually enriched learning design. Emotional engagement was strengthened through enhanced feelings of safety, enjoyment, and motivation, facilitated by a learning environment that encouraged exploration and self-expression. The social engagement dimension benefited from the broadened modes of interaction enabled by digital tools, supporting teamwork, discussion, and community building both synchronously and asynchronously. Observational findings further highlight a shift from initial adaptation to active involvement, increased initiative, and real-time negotiation of meaning—hallmarks of a participatory and autonomous learning culture. Pedagogically, these findings underscore the necessity of integrating technology into instructional design in a purposeful and student-centered manner. Educational institutions must provide the infrastructure and professional development required to support systemic digital transformation while upholding humanistic values. Future research should investigate the long-term impacts of smart classrooms on learning outcomes and the cultivation

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