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The Contribution of Multimodal AI Tools to Multilingual Teachers' GenAI Literacy: An Interventional Latent Growth Curve Modeling (LGCM) Analysis

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Abstract

The contributions of artificial intelligence (AI) technologies to different aspects of teachers' instruction and behaviors have been widely examined in prior research. However, a shortage of research exists regarding the intersection of multimodal AI tools and multilingual teachers' generative AI (GenAI) literacy development. To fill the gap, this interventional study aimed to discover possible developmental changes in multilingual teachers' GenAI literacy over a semester. The study adopted a longitudinal design involving a 10-week online course. A GenAI literacy questionnaire was completed by 184 teachers three times to measure the changes from the outset to the end of the intervention course. The latent growth curve modeling (LGCM) results indicated significant overall growth in teachers' GenAI literacy across the three measurement points, with individual differences in initial literacy levels and growth rates. Implications for teachers and teacher education in multilingual contexts are provided to theoretically and pedagogically empower them for AI-mediated education that is spreading across the world.

***Keywords*:** Artificial intelligence (AI), GenAI literacy, interventional study, latent growth curve modeling analysis, multimodal AI tools

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1. Introduction

Artificial intelligence (AI) has been recognized as a key driver of technological innovation across educational domains (Derakhshan & Solhi, 2026; Li & Kesen Mutlu, 2025; Liu & Fan, 2024; Solhi et al., 2026; Teng & Shen, 2026; Wang & Smith, 2025; Wolpert et al., 2026; Wu & Wang, 2025; Yang & Zhao, 2024; Yolum & Atay, 2026). One such domain pertains to multilingual education, which has witnessed a surge of attention in adopting AI technologies (Jiang & Gu, 2025; Ulla & Teng, 2024; Wu et al., 2025; Yu et al., 2025). Research evidence suggests that AI technologies can be beneficial for multilingual learners in that such tools provide learners with instantaneous feedback, customized learning practices, and skill enhancement (Liu & Wang, 2024; Yang, 2026; Yoon et al., 2025; Yu et al., 2025; Zhao & Yang, 2026). AI-mediated multilingual education can foster students' comprehension, vocabulary retention, and fluency. Chatbots can support multilingual education by broadening learners' understanding of languages and cultures, aligning with its emphasis on intercultural competence and awareness (Lo, 2023).

Advances in AI systems such as Gemini and ChatGPT have also contributed to the growing use of multimodal AI tools in educational settings (Alrabai & Derakhshan, 2026; Heilala et al., 2025; Kohnke et al., 2025; Wang & Wang, 2026; Wang et al., 2026; Zou, 2025). These tools can process and generate content across visual, auditory, and textual modalities (Mai et al., 2024), supporting teaching and learning through materials tailored to learners' needs and preferences (Jiang, 2023; Jiang & Lai, 2025). By integrating multiple forms of input, multimodal AI tools can create engaging learning experiences (Heilala et al., 2025) and support the development of learners' creativity and critical thinking skills (Aure & Cuenca, 2024; Jung & Suh, 2024).

Despite the affordances of multimodal AI tools, limited research has examined their role in developing teachers' professional competencies, including GenAI literacy. This construct has recently attracted growing scholarly attention (e.g., Ding et al., 2024; Ng et al., 2021; Sperling et al., 2024; Wang et al., 2025; Wu & Derakhshan, 2025). As GenAI tools become increasingly common in education,

teachers need the knowledge and skills to understand, use, and critically evaluate them (Kong et al., 2021). Building on broader conceptualizations of AI literacy as the competencies required to engage with AI technologies thoughtfully, skillfully, and responsibly (Long & Magerko, 2020), GenAI literacy in language education encompasses teachers' ability to use generative tools to support language teaching and learning (Huang et al., 2025). Recent research has further sought to identify and operationalize its underlying dimensions in language education (e.g., Huang et al., 2025; Wang et al., 2025).

Despite growing interest in teachers' GenAI literacy, its development in multilingual educational contexts remains underexplored. In particular, limited longitudinal research has examined how engagement with multimodal AI tools may contribute to this development. Consequently, little is known about how multilingual teachers' GenAI literacy changes over time or how patterns of change vary across individuals. An innovative technique to trace the developmental changes in teachers' GenAI literacy is Latent growth curve modeling (LGCM), which draws on structural equation modeling (SEM) to model change in individual units over time.

Addressing these gaps, the present study uses LGCM to examine changes in multilingual Turkish teachers' GenAI literacy during an intervention incorporating multimodal AI tools, including ChatGPT, Gemini, and Copilot. By examining overall growth and individual differences in developmental trajectories, the study offers insights to inform teacher education aimed at supporting GenAI literacy in multilingual contexts.

2. Literature Review

2.1. Multimodal AI Technologies and Multilingual Education

The inclusion of AI technologies in multilingual education has garnered noticeable attention in recent years (Cizrelioğlu & Aydin, 2025; Derakhshan & Park, 2026; Fu et al., 2026; Saini, 2025; Yu et al., 2025; Zou et al., 2025). AI incorporation in multilingual education has culminated in the enhancement and instruction of various languages since AI technologies can offer speech recognition, machine

translation, and diverse language learning tools (Wang & Wang, 2026). AI-enhanced multilingual education has the potential to provide learners with customized learning experiences and personalized support (Yu et al., 2025). It is noteworthy that diverse chatbots like ChatGPT are reported to foster learners' understanding of languages, cultures, and traditions around the globe, showcasing the role of AI in multilingual education and putting emphasis on cross-cultural understanding among different languages (Lo, 2023). Moreover, AI-enhanced multilingual education can aid learners in correcting their errors and enhancing adaptive learning practices, resulting in the enhancement of motivation and engagement in multilingual educational domains (Alharbi, 2023).

Prior research accentuates the positive role of AI in enhancing different skills of multilingual learners (Cizrelioğlu & Aydin, 2025). For instance, AI-mediated reading support systems that encompass qualities like text-to-speech transformation and context-based translation are deemed fruitful in fostering multilingual learners' reading fluency, comprehension, and vocabulary acquisition. Likewise, AI inclusion can assist multilingual learners by providing automated writing evaluations and instantaneous feedback (Uddin, 2022). Only recently have Yu et al. (2025) examined ChatGPT's utility and efficiency in multilingual teaching applications. In their study, they adopted a quasi-experimental research methodology, exploring the experiences of 100 international students in China. The findings indicated that ChatGPT was effective in multilingual instruction since it promoted personalized learning support and cultural understanding among learners.

More importantly, advances in AI models such as Gemini and ChatGPT have led to the increasing integration of multimodal AI tools into educational settings to enhance teaching, learning, and assessment practices (Heilala et al., 2025). Multimodal AI tools have the capability to process and integrate a variety of input and output modalities, namely visual, textual, auditory, and the like (Derakhshan et al., 2026; Mai et al., 2024). Multimodal AI tools can transform text-to-video, video-to-text, and text-to-music (Chen et al., 2024). Such a transformation provides diverse affordances for educational settings since each modality can offer a specific entry point for learning (Chen & Wu, 2024; Mohamed & Lucke-Wold, 2024). Multimodal AI technologies can contribute to educational purposes since they can

adjust the learning contents and practices in accordance with learners' personalized needs and preferences. It is also noteworthy that the incorporation of multimodal AI tools enables access to both visual and auditory learning materials, enriching the learning process with dynamic and immersive learning opportunities (Heilala et al., 2025). Similarly, as Al-Dokhny et al. (2024) maintained, multimodal AI systems respond to students' unique needs, ultimately augmenting their academic achievements. As for language education, multimodal AI tools can enhance creativity (Vartiainen et al., 2023), interactive learning practices (Aure & Cuenca, 2024), and critical thinking (Jung & Suh, 2024).

2.2. GenAI Literacy: Concept and Related Research

Due to the ubiquity of AI technologies, many instructors nowadays feel a strong obligation to embed such technologies in their teaching approaches (Alzubi, 2024). In this regard, diverse teachers' professional tasks, including feedback provision, lesson planning, content creation, and activity design, have been reshaped by the inclusion of AI tools (Ng et al., 2021). With AI now embedded in many aspects of teaching and learning, teachers are required to develop literacy to understand, apply, and critically analyze different types of emerging technologies in their instructional practices (Kong et al., 2021). Consequently, instructors are expected to cultivate AI literacy to effectively deal with the evolving demands of AI-based contemporary education. Within the emergence of GenAI tools like ChatGPT, Gemini, Copilot, and so forth, the concept of GenAI literacy has gained prominence in educational settings (Ding et al., 2024; Ng et al., 2021; Sperling et al., 2024). GenAI literacy literacy is described as an individual's competencies in learning or applying GenAI tools (Steinbauer et al., 2021), indicating how effectively instructors can employ GenAI technologies (Wang et al., 2025). Huang et al. (2025) define GenAI literacy as teachers' ability to use GenAI tools to support language teaching and learning by critically evaluating the accuracy of generated outputs, crafting effective prompts, and adhering to ethical principles.

GenAI literacy is not only an individual competency but also a multidimensional notion that is conceptualized within a social practice (Liu, 2023;

Liu & Darvin, 2024). GenAI literacy is context-specific and can be shaped by the distinctive characteristics of each discipline (Liu et al., 2025). However, A review of the literature indicates that GenAI literacy has primarily been examined in general education, K–12 education, and higher education (Long & Magerko, 2020; Ng et al., 2021; Velander et al., 2024). For example, Ding et al. (2024) probed the effects of GenAI literacy on the professional development of teachers in general education. In the context of higher education, Ayyoub et al. (2025) examined the factors affecting faculty members' GenAI literacy. The qualitative data were collected from 33 participants, and the quantitative data were collected from 538 faculty members from diverse disciplines in Palestine. The findings uncovered that influencing factors included AI competencies, perceived usefulness of AI, ease of use, community support, and professional development.

In language education, Wang et al. (2025) took measures to develop the scale of GenAI literacy to explore the underlying factors of English as a foreign language (EFL) teachers' GenAI literacy. 603 EFL teachers partook in the study, and the results uncovered five factors of GenAI literacy, including GenAI knowledge, GenAI use, GenAI evaluation, GenAI design, and GenAI ethics. Adopting a mixed-method interventional design, Huang et al. (2025) examined the effect of GenAI tools on pre-service language teachers' GenAI literacy. 90 pre-service English language teachers from China participated in a 12-week training course. The participants were divided into an experimental and a control group, with the former receiving the AI intervention. The results illustrated improvements in the experimental group's overall GenAI literacy across five dimensions of GenAI literacy, including technical proficiency, creative application, critical evaluation, ethical competence, and communication proficiency after the 12-week intervention.

Notwithstanding the prominence of GenAI literacy in language education, there is a dearth of studies exploring GenAI literacy among multilingual teachers. Moreover, the role of multimodal AI tools in teachers' GenAI literacy is underexplored to date. Specifically, examining the longitudinal effects of multimodal AI tools on multilingual teachers' GenAI literacy is an underexplored area of research. In response to these gaps, the present study adopts an intervention-based design to examine the contributions of multimodal AI tools to multilingual

Turkish teachers' GenAI literacy. In so doing, this study adopts LGCM as a suitable statistical technique to capture variable fluctuations over time. The study delves into the dynamism of teachers' GenAI literacy across three periods of intervention, seeking to answer the following research question:

1. Does the use of multimodal AI tools contribute to multilingual teachers' GenAI literacy growth?

3. Method

3.1. Participants and Context

The initial pool included 205 multilingual Turkish teachers. After cleaning the data, 184 participants were retained for analysis (Table 1). They voluntarily took part in the study. The age of the participants ranged from 22 to 55, with a mean value of 29.61 and a standard deviation of 5.36. The number of male teachers was 50 (27.2%), while females were 134 (72.8%). The teachers had high, medium, and low AI familiarity levels. Their teaching experience ranged from less than 5 years to 20 years or more. Academically, the participants held BA, MA, and Ph.D. degrees. All participants were multilingual teachers who spoke Turkish, English, and at least one additional language. These additional languages included French, Italian, and Arabic.

Table 1
Demographic Features of the Participants

		Frequency	Percent
Gender	Male	50	27.2
	Female	134	72.8
Academic Degree	Bachelor	132	71.7
	Master	43	23.4
	Ph.D.	9	4.9
Teaching Experience	Below 5	17	9.2
	5 to 9	96	52.2
	10 to 14	35	19.0
	15 to 19	27	14.7
	20 and above	9	4.9
AI Familiarity Level	Low	40	21.7
	Medium	93	50.5
	High	51	27.7
Total		184	100.0

3.2. Instruments

3.2.1. GenAI Literacy Scale

The construct of teacher GenAI literacy was evaluated through a questionnaire recently developed and validated by Wang et al. (2025). It comprises 32 items and five sub-components of AI Knowledge (8 items), AI Use (9 items), AI Evaluation (5 items), AI Design (6 items), and AI Ethics (4 items). Each item was responded to on a 5-point Likert scale ranging from 1 (strongly agree) to 5 (strongly disagree). The overall reliability of the instrument was acceptable as estimated by Cronbach's alpha (.92). "*I use GenAI tools to search for teaching and learning materials*" is a sample item from the questionnaire.

3.2.2. Intervention Course

The participants took part in a 10-week online intervention course during the second semester of the 2025–2026 academic year. The course focused on using multimodal AI tools, including ChatGPT, Gemini, and Copilot, to develop and adapt instructional materials for multilingual learners. Each session lasted 90 minutes and included explicit instruction, demonstrations, class discussions, and practical activities. Participants completed in-class and out-of-class assignments with AI assistance and were encouraged to explore applications relevant to their teaching contexts.

In Week 1, teachers were introduced to the textual, visual, and auditory capabilities available across the selected AI tools through demonstrations and guided exploration. They examined how these capabilities could support language teaching and create opportunities for learners to draw on their full linguistic repertoires.

In Week 2, teachers were introduced to five materials adaptation techniques: adding, deleting or omitting, modifying, simplifying, and reordering (McDonough et al., 2013). Drawing on Solhi (2026), explicit instruction and demonstrations illustrated how these techniques could guide AI-assisted materials adaptation. Teachers examined existing materials, selected appropriate techniques, and

formulated prompts specifying the intended changes. They then evaluated the outputs for linguistic accuracy, pedagogical suitability, and cultural relevance. For example, for adding, teachers explored extension through additional activities of the same type such as comprehension questions, and expansion through new activity types such as role-plays extending vocabulary or grammar practice into speaking. Modifying was addressed through rewriting and restructuring. Teachers practiced rewriting passages to incorporate locally relevant cultural references and redesigning questions to encourage critical thinking. Restructuring involved adjusting interaction patterns such as converting individual activities into pair work or adapting role-plays for larger classes.

In Week 3, teachers were introduced to the principles of translanguaging pedagogy, with particular attention to how learners' first languages and broader linguistic repertoires could support L2 learning. They explored prompts for activities that encouraged purposeful use of these resources such as brainstorming in familiar languages before producing an English text. Through successive revisions, teachers refined their prompts and evaluated whether the resulting materials supported both multilingual participation and the intended language learning objectives.

In Week 4, the focus shifted to integrating multimodal resources into different language learning skills such as vocabulary, listening, and speaking instruction. Teachers developed vocabulary materials around noticing, retrieval, and elaboration (see Solhi, 2026). They generated contextualized stories and accompanying images, highlighted target words, and designed follow-up activities requiring learners to recall and reuse vocabulary. They also explored word families and extended meanings across contexts. To incorporate translanguaging, teachers drew on their multilingual knowledge to evaluate cross-language associations and design activities connecting English vocabulary with familiar expressions and mnemonic cues in learners' other languages. For listening, teachers practiced adapting materials across pre-, while-, and post-listening stages (see Solhi, 2026). They generated introductory texts and images to activate background knowledge, developed listen-and-fill, listen-and-restore, and sequencing tasks, and prepared reflective or diagnostic follow-up activities. For speaking, teachers expanded

existing materials into role-plays, retelling tasks, and structured for-and-against discussions. They prepared supporting arguments, visual prompts, and sentence starters to encourage meaningful reuse of target vocabulary. Teachers used their multilingual and cultural knowledge to evaluate and adapt the scenarios for their learners.

During Weeks 5–10, teachers extended these practices by designing writing tasks, evaluating AI-generated feedback, and comparing outputs across languages and tools. They developed lesson plans integrating textual, visual, and auditory materials with opportunities for translanguaging. Teachers presented their materials, explained their adaptation decisions, and revised their work in response to peer feedback. Throughout these sessions, discussions and reflections addressed the pedagogical suitability of the materials and effective GenAI use for language teaching purposes.

3.3. Data Collection Procedure

Data were collected electronically using an online version of the GenAI literacy questionnaire administered through Google Forms. Participants were recruited across Turkish universities through social media and personal contacts. Before the intervention, all participating teachers were informed of the purpose and procedures of the study and assured that their privacy and the confidentiality of their responses would be protected. The questionnaire was administered at three time points: before, at the midpoint, and the end of the intervention. A direct link to the questionnaire was shared via email, accompanied by a brief note defining technical terms related to AI. The questionnaire was administered in English because the participants were proficient users of the language. Data collection across the three time points took approximately three months. Once data collection was complete, the researchers screened the responses in Excel to identify and remove incomplete or erroneous entries. The data were then imported into SPSS and AMOS for statistical analyses addressing the study's research question.

3.4. Data Analysis

To answer the research question of the study, a statistical model was created through LGCM. This model used SEM to estimate the change over time. The mean, covariance, and variance obtained from this analysis were reported to capture the nature and direction of the change.

4. Results

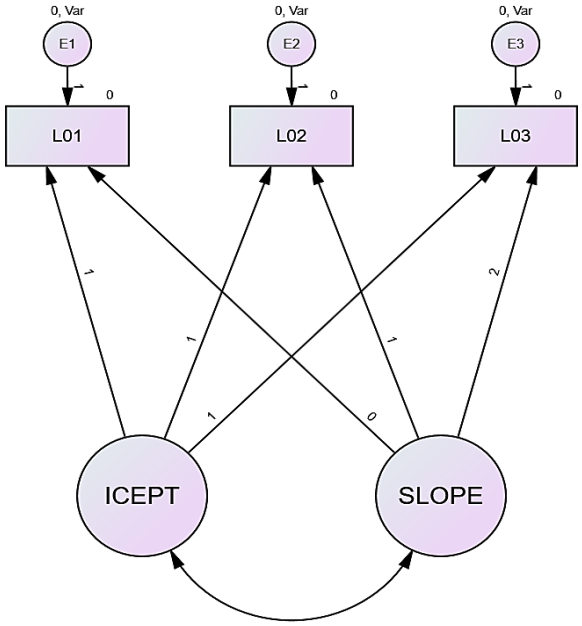
The study aimed to investigate the going-togetherness of GenAI literacy in the given context. The variable was captured three times over the course of time. Table 2 presents the descriptive statistics of the obtained results.

Table 2
Descriptive Statistics of Scores

						Skewness	
	N	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**Statistic**	**Std. Error**
L01	184	32	144	83.09	28.561	-.145	.179
L02	184	34	149	87.50	29.904	-.120	.179
L03	184	34	160	95.09	33.330	-.214	.179

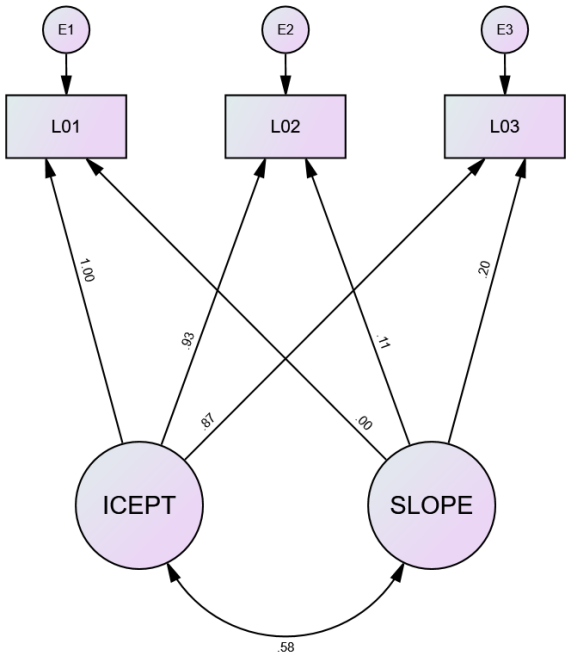
As shown in Table 2, GenAI literacy showed growing patterns throughout time. The inspection of the skewness ratios also suggested that the data was normally distributed in all three administrations. In order to see if this growth is significant, a latent growth curve model was created. The proposed model is depicted in Figure 1.

Figure 1
Proposed LGCM Model for the Change in GenAI Literacy



The measurement model shown in Figure 1 was used in analyzing the growth (change) in the scores of the participants. In the model, L01, L02, and L03 represent the three scores obtained from the administration of GenAI literacy. The ICEPT presents the initial score (which is set to a constant value of 1 for all three administrations) and SLOPE (which is set from 0 to 2) aims to capture the change. Finally, the covariance between the ICEPT and SLOPE shows the correlation between the initial state and the growth pattern. The measurement model with standardized values is presented in Figure 2.

Figure 2
LGCM Model with Standardized Estimates



With regard to the goodness of fit, the model had CFI of .962, TLI of .960, and RMSEA of .061. We also examined covariances, and means in the model. The report of the standardized and unstandardized estimates is presented in Table 3.

Table 3
Variance, Covariances, and Mean Values for the LGCM Model

			Unstandardized				Standardized Estimates
			Estimate	S.E.	C.R.	P	
Covariance							
	ICEPT <-->	SLOPE	54.142	8.571	6.317	<.001	.583
Variances	ICEPT		811.234	84.810	9.565	<.001	
	SLOPE		10.637	1.376	7.729	<.001	
Means	ICEPT		83.091	2.105	39.464	<.001	
	SLOPE		5.682	.266	21.352	<.001	

As reported in Table 3, the inspection of the covariances showed that there was a significant correlation ($r = .58$, $p < .001$) between ICEPT and SLOPE, indicating that the changes were also highly correlated with the participants' initial state of literacy. The inspection of the variances showed a significant value for the ICEPT, indicating heterogeneity of individuals' levels of literacy ($\sigma^2 = 811.23$, $SE = 84.81$, $p < .001$) at the outset of the study. Besides, the significant value of variance in the SLOPE ($\sigma^2 = 10.64$, $SE = 1.38$, $p < .001$) indicated the existence of individual differences in the growth pattern. In other words, while some participants were going through a high rate of change, others were going through a low rate. Finally, with regard to the direction and extent of change, significant results were found for the SLOPE (Mean Difference = 5.682, $SE = .266$, $C.R. = 21.35$, $p < .001$), indicating that GenAI literacy significantly increased through time.

5. Discussion

This intervention study used LGCM to examine changes in multilingual Turkish teachers' GenAI literacy during a course incorporating multimodal AI technologies. The results indicated significant growth across the three measurement points, alongside individual differences in initial literacy levels and rates of change. These findings are broadly consistent with previous research highlighting the potential contributions of AI technologies to multilingual education (e.g., Yu et al., 2025). They also complement Huang et al.'s (2025) findings concerning improvements in GenAI literacy following structured training and Ayyoub et al.'s (2025) identification of professional development and AI-related competencies as factors relevant to educators' GenAI literacy.

One possible explanation for the observed growth is the combination of explicit instruction and repeated opportunities to apply AI tools to pedagogical tasks. Throughout the intervention, teachers practiced designing prompts, adapting materials, comparing outputs, and evaluating their linguistic accuracy, cultural relevance, and pedagogical suitability. These activities addressed the knowledge and use dimensions of GenAI literacy identified by Wang et al. (2025), while also providing opportunities to develop evaluation, design, and ethical competencies.

Sustained practice and peer feedback may have supported increasingly purposeful and critical engagement with the tools. However, because the analysis examined overall GenAI literacy, it does not establish which dimensions changed most or which activities contributed most to the observed growth.

The multilingual orientation of the course offers another possible explanation. Teachers were encouraged to draw on their linguistic repertoires when comparing AI outputs and preparing materials that supported translanguaging. These tasks may have connected AI use with familiar pedagogical concerns, including cross-language differences, cultural representation, and learners' varied linguistic resources. Such connections could have made the training more relevant to teachers' instructional needs and encouraged closer scrutiny of AI-generated content.

The findings also indicated that teachers differed in their initial GenAI literacy levels and rates of growth, indicating that the overall increase was accompanied by individual variation in development. Individual differences and educational backgrounds may explain initial differences in GenAI literacy of the participants. Previous work with EFL learners has also linked personality traits and perceived teacher support to their motives for using AI (e.g., Mozaffarzadeh & Jahanbakhsh, 2025), suggesting that dispositional and social factors may similarly contribute to individual differences in engagement with AI tools. The present study provides similar evidence for claiming that teaching programs and professional courses may foster GenAI literacy development and changes over time, a finding reported in prior studies as well (e.g., Ayyoub et al., 2025; Ding et al., 2024).

This study extends the literature by examining GenAI literacy development in multilingual education through a single-group longitudinal intervention design. The study also highlights the role of contextuality in teachers' GenAI literacy, which is consistent with the conceptualization of the term as a social practice (Liu, 2023; Liu & Darvin, 2024). The dynamism of teachers' GenAI literacy might be due to teachers' openness to change and to grow professionally in the age of AI. It can be asserted that, like other teacher literacies, GenAI literacy is socio-technical, transformative, and evolving. Another justification can be the impact of language

education disciplinary idiosyncrasies that demand instructors to constantly work on their literacies to keep up with the emerging trends including AI-mediated education. It is also assertable that the participants showed improvements in GenAI literacy in phases two and three due to their perceived usefulness and affordability of multimodal AI technologies that they had been employing in the classes. This idea is in tune with the technology acceptance model (Davis, 1989), which underscores the role of one's perceptions and beliefs about technology in its adoption. The inherent features of multimodal AI tools are also possible triggers of GenAI dynamism among the teachers. Possibly, visual and interactive elements of such tools have made them more engaging and accessible over time. Furthermore, the teachers' multilingual and multicultural repertoires may have shaped and reshaped their AI adoption during the intervention course.

6. Conclusion and Implications

This longitudinal intervention study sought to examine the fluctuations of GenAI literacy among multilingual Turkish teachers in light of using and teaching through multimodal AI technologies. The results indicated gradual increases in GenAI literacy from the start to the end of the course. In view of the obtained results, it can be concluded that GenAI literacy is a dynamic construct, which may go through developmental changes as time passes by. It is also asserted that teachers' instructional practice and professional courses have the potential to develop GenAI literacy. From the results, it can also be concluded that AI incorporation and practice contribute to multilingual teachers and multilingual education.

The results provide insightful ideas concerning the intersection of AI and multilingual education and teacher education. Theories and models related to multilingual teachers and technology adoption may benefit from this study to update their conceptualizations and components. An AI element can be added to such theoretical foundations in multilingual contexts. Theories about AI literacy, AI readiness, and technology acceptance can draw on the results to renovate their propositions in the future. On the practical level, the study may help multilingual teachers understand the dynamism of GenAI literacy and the contributing role of

multimodal AI tools adoption in their literacy. Teachers may also get encouraged to use multimodal AI tools more than before when they realize how such tools can develop their literacy in the age of AI. They also become familiar with the sub-components of GenAI literacy and look for effective strategies to tap into and cultivate each of them in their classroom practices. Policymakers in multilingual education settings may find the study significant in that they can change, revisit, and update their educational policies and plans regarding technology integration and multilingual education. Teacher educators can use this study to design and develop workshops and training courses related to GenAI literacy, AI readiness, and AI acceptance in order to train literate teachers for the age of AI. In teacher training programs, explicit GenAI literacy modules can be incorporated. For example, scaffolded, reflective, and multimodal training sessions can be designed and delivered to novice teachers. Collaborative discussions can be held focusing on critical AI literacy, AI biases, and ethical issues in using AI tools in multilingual settings. Courses with multiple sessions can be offered to multilingual teachers with different experiences and AI literacy levels by expert teacher educators. Both theoretical and pedagogical aspects of GenAI literacy can be cultivated in such programs. At the macro level, within Turkey's educational system, the results can pave the way for more AI integration into multilingual education. Ample support and motivation by higher stakeholders and authorities should be given to teachers to work on their GenAI literacy.

7. Limitations and Suggestions for Future Research

Despite its contributions, this study has several limitations. First, the single-group design limits the extent to which the observed growth in GenAI literacy can be attributed to the intervention. Future studies could include a comparison group to strengthen causal inference. Second, the unequal gender distribution may limit the representativeness of the sample. Recruiting participants from a wider range of institutions and achieving a more balanced gender distribution would strengthen the generalizability of the findings. Third, the study relied exclusively on self-report questionnaire data collected at three time points. Mixed-methods designs

incorporating additional measurement points, reflective diaries, interviews, and analyses of teachers' AI-assisted materials could provide a more detailed understanding of how GenAI literacy develops and is enacted in practice. Future research could also examine teachers' demographic characteristics, teaching experience, and academic qualifications as predictors of initial GenAI literacy and subsequent growth. Investigating teachers' intentions and reasons for adopting or avoiding multimodal AI tools, together with factors such as personality traits and perceived support (Mozaffarzadeh & Jahanbakhsh, 2025), could further clarify their engagement with these technologies. Comparative studies of multimodal AI tools could help clarify the role of modality in GenAI literacy development. Incorporating multilingual learners' perspectives alongside those of teachers could also reveal areas of agreement and divergence concerning the classroom use of these tools. Finally, cross-cultural research could examine how developmental patterns vary across educational and sociolinguistic contexts, helping establish the transferability and contextual boundaries of the findings.

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