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The Effect of Digital Literacy on Perceived Interactivity in Learner–Artificial Intelligence Interaction: The Moderating Role of Digital Stress

Mohamad. Porfarzollah[1], Samira. Pali[2*]

[1] Department of Educational Management, To.C., Islamic Azad University, Tonekabon, Iran
[2] Department of Educational Sciences, To.C., Islamic Azad University, Tonekabon, Iran

*** Corresponding author email address**: samirapali624@gmail.com

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A B S T R A C T

Objective: This study aimed to investigate the effect of digital literacy on perceived interactivity in learner–artificial intelligence interaction and to examine the moderating role of digital stress among elementary school teachers.

Methods and Materials: This applied study employed a descriptive-survey design. The statistical population consisted of all elementary school teachers employed by the Department of Education in Rudsar during the 2025–2026 academic year. Based on the Krejcie and Morgan sample size table, 234 teachers were selected using stratified random sampling. Data were collected using the standardized questionnaire developed by Ren et al. (2025), comprising perceived interactivity in learner–AI interaction, digital literacy, and digital stress constructs. The instrument was scored on a five-point Likert scale. Content validity was confirmed by experts, while Cronbach's alpha, composite reliability, and average variance extracted supported the reliability and convergent validity of the measurement model. Data were analyzed using SPSS and SmartPLS. The Kolmogorov–Smirnov test was used to assess normality, and partial least squares structural equation modeling was applied to test the research hypotheses and moderation effect.

Findings: Digital literacy had a positive and statistically significant effect on perceived interactivity in learner–AI interaction ($\beta = 0.319$, $t = 5.135$, $p < .05$). In addition, the interaction effect of digital stress and digital literacy on perceived interactivity was negative and statistically significant ($\beta = -0.131$, $t = 2.660$, $p < .05$), confirming the moderating role of digital stress. The model explained 38.8% of the variance in perceived interactivity ($R^2 = 0.388$), and the Q^2 value of 0.237 indicated satisfactory predictive relevance.

Conclusion: Higher digital literacy enhances teachers' perceived interactivity with AI by improving their ability to experience AI-supported learning as more responsive, controllable, engaging, and personalized; however, elevated digital stress weakens this positive effect.

Keywords: *digital literacy, perceived interactivity in learner–artificial intelligence interaction, digital stress*

1 Introduction

The rapid expansion of artificial intelligence (AI) in education has transformed the nature of teaching, learning, and technology-mediated interaction. AI-supported learning environments increasingly incorporate adaptive learning systems, intelligent tutoring tools, conversational agents, generative AI platforms, automated feedback mechanisms, and personalized recommendation systems. These technologies can potentially provide learners with immediate responses, individualized guidance, flexible learning pathways, and continuous access to educational support. At the same time, their effectiveness depends not only on the technical capabilities of AI systems but also on the extent to which users perceive the interaction as responsive, controllable, engaging, and personalized. The educational value of AI therefore emerges from the interaction between technological affordances and users' ability to understand, manage, and productively engage with these systems. Recent literature on large language models and generative AI has emphasized that educational benefits such as individualized assistance, rapid feedback, content generation, and learner support coexist with concerns related to overreliance, misinformation, ethical use, and unequal digital competencies (Kasneci et al., 2023). Similarly, reviews of ChatGPT in higher education indicate that successful integration requires moving beyond mere access to AI tools toward the development of appropriate digital capabilities, pedagogical strategies, and interaction patterns that allow learners and educators to use these technologies critically and effectively (Bhullar et al., 2024). Consequently, understanding the factors that shape perceived interactivity in learner–AI interaction has become an important issue in contemporary educational management and digital learning research.

Perceived interactivity refers to the degree to which individuals experience a technology-mediated environment as enabling reciprocal communication, responsiveness, control, involvement, and meaningful exchange. Although interactivity has traditionally been examined in online communities, digital platforms, and technology-mediated communication, its conceptual foundations are highly relevant to AI-supported learning contexts. Research in digital communication has shown that perceived interactivity can strengthen users' psychological involvement and relational responses by increasing the sense that the system or platform is responsive to their inputs and supports meaningful reciprocal exchange (Wang et al., 2020). In educational settings, perceived interactivity is similarly important because learners are more likely to engage with digital systems when they believe that their actions elicit relevant responses and that they can influence the direction of the learning experience. Evidence from massive open online courses has demonstrated that interactivity contributes to engagement and continuance intention, suggesting that learners' willingness to remain involved in digital learning environments depends partly on the interactive quality they perceive (Shao & Chen, 2021). In AI-supported learning, this issue becomes even more significant because AI systems are designed to simulate adaptive and responsive interaction. Thus, the perceived quality of learner–AI interaction can be understood through dimensions such as responsiveness, learner control, learning engagement, and personalization.

Responsiveness reflects the extent to which an AI system provides timely, relevant, and context-sensitive reactions to learner inputs. Learner control concerns the degree to which users perceive themselves as capable of directing, regulating, and modifying the interaction according to their needs. Learning engagement reflects the extent to which interaction with AI captures attention and sustains meaningful cognitive and behavioral involvement, whereas personalization refers to the perception that AI responses and learning experiences are tailored to individual needs, abilities, and preferences. These dimensions are particularly important in adaptive learning environments. Research on adaptive learning has indicated that learner–content interaction can influence student performance by facilitating more individualized and responsive learning processes (Ipinnaiye & Risquez, 2024). Likewise, interactive AI tools, adaptive learning technologies, and personalized feedback have been associated with greater student engagement, especially when users possess sufficient digital literacy to make effective use of these features (Yaseen et al., 2025). Such findings suggest that the objective presence of interactive features is not sufficient by itself; learners and educators must also have the competence required to recognize, interpret, and effectively use the opportunities provided by AI-supported systems.

Digital literacy is therefore a central construct in understanding the quality of learner–AI interaction. Digital literacy extends beyond basic access to digital devices or the ability to operate software. It encompasses the knowledge, skills, competencies, and critical judgment required to use digital technologies effectively, safely, and purposefully. In educational environments, digital literacy includes technical

literacy, digital skills, information evaluation, problem-solving, digital communication, and the capacity to select and employ technological tools in ways that are consistent with pedagogical goals. As AI becomes embedded in educational systems, digital literacy increasingly functions as a prerequisite for meaningful interaction with intelligent technologies. Teachers and learners who possess stronger digital competencies are more likely to understand system functionalities, formulate effective prompts, interpret AI-generated information, manage digital resources, and adjust their interaction strategies when system outputs are incomplete or inappropriate. This competence can enhance the perceived quality of the interaction by increasing users' sense of control, reducing operational barriers, and enabling them to make better use of personalization and feedback capabilities.

Research has increasingly demonstrated the importance of digital literacy and related competencies in AI-supported education. Hajizadeh et al. found that AI and digital literacy are meaningfully related to educational and academic outcomes and that personal and social resources can shape how these competencies are translated into productive activity (Hajizadeh et al., 2025). Similarly, Khadivi et al. showed that digital skills play a mediating role in the relationship between AI literacy and the quality of educational services, highlighting that knowledge of AI must be accompanied by practical digital competence if technological capabilities are to improve educational processes (Khadivi et al., 2025). These findings are particularly important for teachers because educators are not simply technology users; they are also responsible for selecting, interpreting, and integrating digital systems into teaching practices. Teachers with stronger digital literacy may be more capable of evaluating AI-generated content, adapting AI-supported resources to students' needs, managing interactive educational applications, and establishing effective human–AI collaboration in classroom settings.

The importance of such competencies is further supported by studies examining AI literacy in teacher education. Hosseini reported that AI literacy can contribute to the development of higher-order thinking skills among student teachers, with behavioral engagement and peer interaction playing important explanatory roles (Hosseini, 2025). This suggests that AI-related competence may influence learning outcomes partly by changing the way individuals interact with digital tools and with their broader learning environment. From this perspective, digital literacy may contribute to perceived learner–AI interactivity because digitally competent users are more likely to engage actively rather than passively with AI systems. They can explore alternative functions, critically evaluate system responses, request refinements, adapt prompts, and use feedback recursively. In contrast, users with limited digital literacy may experience AI technologies as opaque, difficult to control, or insufficiently responsive, even when the same systems are technically capable of providing high levels of personalization and interaction.

Teacher preparedness is particularly important because the educational use of AI is shaped by professional beliefs, technological confidence, and the perceived role of AI in instructional practice. Haroud and Saqri demonstrated that teachers and students hold complex views regarding the supportive and potentially substitutive functions of generative AI, and they emphasized digital literacy as a key condition for meaningful and responsible adoption (Haroud & Saqri, 2025). This distinction between AI as a supportive tool and AI as a potential replacement mechanism has important implications for perceived interactivity. When users understand the capabilities and limitations of AI, they may be more likely to treat interaction with the system as a collaborative and controllable process. By contrast, insufficient digital competence may increase uncertainty, unrealistic expectations, or mistrust. Thus, digital literacy can be expected to enhance perceived interactivity by enabling users to interact with AI more strategically, to interpret outputs more accurately, and to maintain greater control over the learning process.

Related evidence from teachers' broader digital behavior also indicates that self-efficacy and competent media use are important in determining whether technology contributes positively to professional functioning. Rahmanzadeh et al. showed that the effect of media use on teachers' health literacy is partly transmitted through self-efficacy (Rahmanzadeh et al., 2024). Although this work was not specifically focused on artificial intelligence, it demonstrates that teachers' outcomes from digital technology depend on more than exposure alone. Users require confidence and effective capabilities to transform access into beneficial outcomes. In AI-supported learning, a similar mechanism is likely to apply: digital literacy can increase users' confidence in navigating AI tools, reduce uncertainty regarding system operation, and improve their ability to sustain productive interaction. This perspective is consistent with the view that technology acceptance and interaction

quality are partly psychological and competency-based phenomena rather than purely technical properties.

However, greater digital engagement does not necessarily produce uniformly positive outcomes. The increasing integration of technology into work, education, and social life can generate digital stress, which refers to stress reactions associated with persistent connectivity, information demands, social expectations, communication overload, fear of missing out, and the requirement to remain continuously attentive to digital environments. Digital stress is particularly relevant in AI-supported educational settings because AI technologies often intensify the amount, speed, and continuity of digital interaction. Teachers may face pressure to learn new systems, monitor multiple digital platforms, respond to messages, evaluate rapidly changing technological tools, and remain available across online channels. In this context, even digitally literate users may experience reduced benefits from technology when psychological demands become excessive.

Digital stress is a multidimensional phenomenon. Availability stress refers to pressure associated with the expectation of constant accessibility through digital technologies. Communication overload occurs when users are exposed to excessive messages, information, notifications, or interaction demands. Online vigilance describes persistent attentional orientation toward digital environments and the tendency to continuously monitor online activity. Social approval anxiety concerns worry about how one is evaluated or accepted in digital spaces, while fear of missing out involves concern that important information, opportunities, or interactions may occur in one's absence. These dimensions can consume cognitive and emotional resources, reduce concentration, and negatively influence the quality of technology-mediated interaction. Zhan et al. demonstrated that digital stress is associated with problematic patterns of social media use through emotional pathways, illustrating that digital environments may generate psychological strain that changes the way individuals engage with technology (Zhan et al., 2025). Although AI-supported learning differs from social media use, the underlying mechanisms of overload, vigilance, and constant connectivity can similarly influence educational technology experiences.

Digital stress may therefore alter the relationship between digital literacy and perceived learner–AI interactivity. In principle, digitally literate users should be better able to understand AI systems, exercise control, and benefit from personalization and responsiveness. Yet, under conditions of high digital stress, some of these advantages may be weakened. A teacher experiencing communication overload or persistent online vigilance may have sufficient technical competence but insufficient cognitive resources to engage deeply with AI-generated feedback. Likewise, fear of missing out or pressure to remain constantly available may turn digital interaction into a source of demand rather than support. Under such conditions, the same digital literacy skills that ordinarily facilitate productive interaction may yield smaller improvements in perceived interactivity because attention and emotional resources are already taxed.

This moderating perspective is supported directly by recent research examining AI-supported learning. Ren et al. developed and tested a framework linking digital competence, self-efficacy, digital stress, and perceived interactivity in AI-supported learning contexts (Ren et al., 2025). Their work highlights that digital competence is positively associated with users' perceptions of interactive AI environments, while digital stress represents an important psychological condition that can influence the quality of this relationship. Such evidence provides a strong theoretical basis for considering digital stress not merely as an independent negative factor, but as a contextual variable that can modify how effectively digital competencies are translated into positive learner–AI interaction. This distinction is important because two users with similar levels of digital literacy may experience the same AI system differently depending on the amount of digital pressure, overload, and psychological strain they are experiencing.

The psychological consequences of AI adoption provide further support for this reasoning. Kim and Lee found that the adoption of AI can have implications for mental health and that self-efficacy plays a crucial role in shaping these effects (Kim & Lee, 2024). Their findings suggest that the consequences of AI use are influenced by users' internal psychological resources. In an educational context, this implies that technological competence and confidence may buffer certain challenges, but the presence of stress can still alter how AI interaction is perceived. Thus, digital literacy and digital stress should not be examined independently when seeking to explain the quality of learner–AI interaction. Rather, they represent interconnected dimensions of technology use: one reflects the user's capacity to operate effectively within digital environments, while the other reflects the psychological burden that these environments may impose.

The relationship between digital literacy and AI-supported interaction may be particularly consequential for

elementary school teachers. Elementary teachers increasingly encounter digital systems for instructional planning, content generation, assessment, differentiated instruction, communication, and professional development. Because they work with younger learners, they also have substantial responsibility for mediating children's exposure to and use of emerging technologies. Teachers' ability to interact effectively with AI can therefore influence not only their own professional efficiency but also the quality of AI-supported learning opportunities provided to students. If teachers perceive AI tools as responsive, controllable, engaging, and personalized, they may be more willing to incorporate them into instruction. Conversely, if interaction with AI is experienced as stressful, cognitively demanding, or difficult to manage, adoption may remain superficial or inconsistent despite adequate technical infrastructure.

Existing studies have generated substantial evidence concerning digital literacy, AI literacy, adaptive learning, student engagement, interactive technologies, and digital stress, but several gaps remain. First, much of the literature has focused on higher education, university students, or general users rather than elementary school teachers. Second, studies frequently examine digital literacy as a direct predictor of technology-related outcomes without simultaneously considering whether digital stress changes the strength of this relationship. Third, although perceived interactivity has been examined in online platforms, MOOCs, and digital communication, its application to learner–AI interaction remains comparatively new. Finally, research on educational AI often emphasizes adoption, intention to use, performance, or attitudes, whereas perceived interactivity captures the experiential quality of the actual human–AI exchange and may therefore provide a more nuanced understanding of effective AI-supported learning.

The emerging evidence concerning adaptive and interactive AI systems also reinforces the need for such investigation. Yaseen et al. demonstrated that the effects of adaptive learning technologies, personalized feedback, and interactive AI tools on engagement are conditioned by digital literacy, indicating that technology-rich learning environments do not affect all users equally (Yaseen et al., 2025). Ipinnaiye and Risquez likewise emphasized the importance of adaptive learning and learner interaction in shaping educational performance (Ipinnaiye & Risquez, 2024). These findings align with the broader literature showing that interactivity supports continued involvement in digital learning (Shao & Chen, 2021) and that perceived interactivity influences users' relational and behavioral responses in digital environments (Wang et al., 2020). Taken together, this body of research suggests that digital literacy can strengthen learner–AI interaction, but psychological pressures associated with digital technology may constrain the extent to which such competence is translated into positive interactive experiences.

From an educational management perspective, examining these relationships can provide practical evidence for designing teacher development initiatives and AI implementation policies. Investment in digital infrastructure alone is unlikely to ensure effective AI integration if teachers lack the literacy needed to interact with intelligent systems or if excessive digital demands undermine their capacity to use these systems productively. Professional development should therefore address both competence enhancement and the management of digital stress. Such an approach is consistent with current scholarship emphasizing that AI integration should be accompanied by educational support, critical digital literacy, self-efficacy development, and careful attention to the psychological consequences of technology use (Bhullar et al., 2024; Haroud & Saqri, 2025; Kim & Lee, 2024). By examining digital literacy and digital stress within a unified model of perceived learner–AI interactivity, research can offer a more comprehensive account of why some teachers experience AI as an enabling and responsive educational partner while others experience the same technological environment as demanding or difficult to manage.

Accordingly, the aim of the present study was to investigate the effect of digital literacy on perceived interactivity in learner–artificial intelligence interaction among elementary school teachers, with particular emphasis on the moderating role of digital stress.

2 Methods and Materials

The present study employed a descriptive-survey research design and was applied in terms of purpose. The statistical population consisted of all elementary school teachers employed by the Department of Education in Rudsar during the 2025–2026 academic year. Based on the Krejcie and Morgan sample size table, the sample size was determined to be 234 participants, who were selected using stratified random sampling.

The following questionnaire was used to measure the study variables.

To assess the research variables, the standardized questionnaire developed by Ren et al. (2025) for measuring perceived interactivity in learner–artificial intelligence interaction, digital literacy, and digital stress was used. The questionnaire comprises three main constructs. Perceived interactivity in learner–AI interaction consists of 17 items across four dimensions: responsiveness, learner control, learning engagement, and personalization. Digital literacy consists of 10 items across two dimensions: technical literacy and digital skills. Digital stress consists of 22 items across five dimensions: availability stress, online vigilance, communication overload, social approval anxiety, and fear of missing out. Responses were scored on a five-point Likert scale ranging from strongly agree (5) to strongly disagree (1).

The content validity of the research instruments was evaluated and confirmed through expert review by university faculty members and specialists in the field of management. Prior to the main administration of the study, the reliability of the questionnaires was assessed using a pilot sample of 15 participants. The results indicated that Cronbach's alpha coefficients for all three constructs—perceived interactivity in learner–AI interaction, digital literacy, and digital stress—were above .70, indicating satisfactory reliability. Composite reliability (CR) and convergent validity were also assessed using the average variance extracted (AVE). The results confirmed the satisfactory reliability and convergent validity of the study constructs.

Data were collected using both library-based and field methods. In the library-based phase, the required information was obtained through a review of books, scientific articles, and relevant online sources. In the field phase, after obtaining informed consent from the participants, the questionnaires were distributed among the selected sample, and the required data were collected.

The data were analyzed using descriptive and inferential statistics. In the descriptive analysis, indices such as the mean and standard deviation were used to summarize the data. In the inferential analysis, after examining the required statistical assumptions, structural equation modeling was employed to test the relationships among the study variables and to examine the moderating role of digital stress. Data analyses were conducted using SPSS and SmartPLS software.

3 Findings and Results

A total of 234 elementary school teachers participated in the data analysis. Of these, 130 (55.56%) were women and 104 (44.44%) were men. In terms of age, 55 participants (23.50%) were younger than 40 years, 107 (45.73%) were between 40 and 50 years of age, and 72 (30.77%) were older than 50 years. Regarding educational attainment, 143 participants (61.11%) held a bachelor's degree and 91 (38.89%) held a master's degree. With respect to work experience, 61 participants (26.07%) had less than 10 years of experience, 94 (40.17%) had between 10 and 20 years of experience, and 79 (33.76%) had more than 20 years of work experience. Overall, the highest frequencies were observed among women, participants aged 40–50 years, those holding a bachelor's degree, and those with 10–20 years of work experience.

According to the study objectives, three main variables were measured using standardized questionnaires. The descriptive findings for these variables are presented in Table 1.

Table 1

Mean and Standard Deviation of the Main Study Variables

Variable	Mean	Standard Deviation
Perceived interactivity in learner–AI interaction	3.31	0.600
Digital literacy	3.37	0.776
Digital stress	2.51	0.797

Based on the descriptive findings, perceived interactivity in learner–AI interaction had a mean of 3.31 and a standard deviation of 0.600. Digital literacy had a mean of 3.37 and a standard deviation of 0.776, whereas digital stress had a mean of 2.51 and a standard deviation of 0.797.

The Kolmogorov–Smirnov test was used to examine the distribution of the data.

Table 2

Results of the Kolmogorov–Smirnov Test

Variable	Test Statistic	Significance Level	Test Result
Perceived interactivity in learner–AI interaction	0.076	.002	Non-normal
Digital literacy	0.109	.001	Non-normal
Digital stress	0.084	.001	Non-normal

As shown in Table 2, the significance level of the Kolmogorov–Smirnov test was below .05 for all study constructs. Therefore, the distributions of the study variables were non-normal. Given the non-normal distribution of the data, partial least squares structural equation modeling (PLS-SEM) was employed to test the research hypotheses and assess the significance of the path coefficients.

Before examining the relationships among the study variables, the measurement model was assessed to evaluate the reliability and validity of the constructs and their corresponding items. For this purpose, confirmatory factor analysis based on the partial least squares structural equation modeling approach was conducted. The results for Cronbach's alpha, composite reliability (CR), and average variance extracted (AVE) are presented in Table 3.

Table 3

Cronbach's Alpha, Composite Reliability, and Average Variance Extracted for the Study Constructs

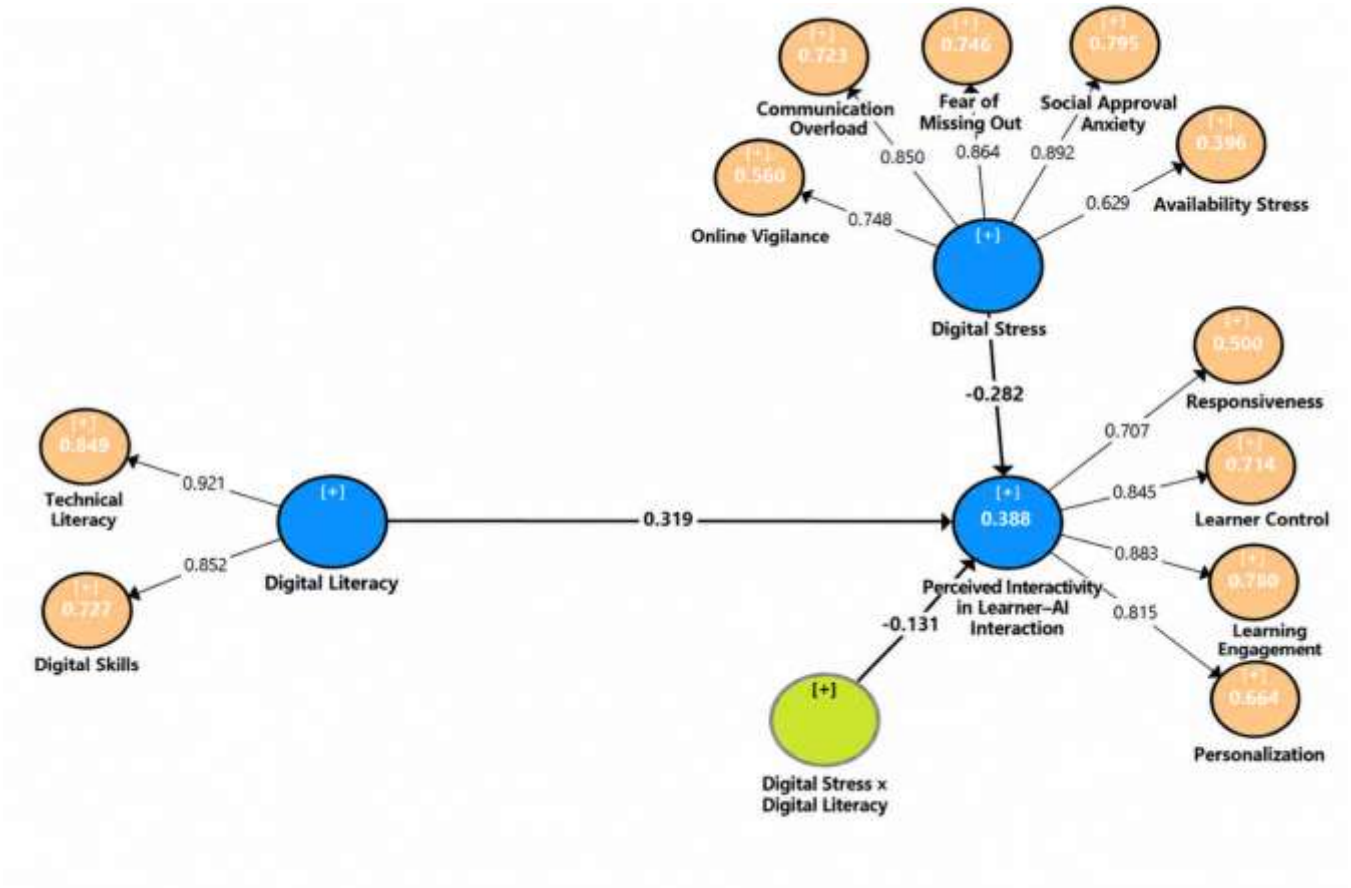
Variable	Construct	AVE	Composite Reliability	Cronbach's Alpha
Digital literacy	Technical literacy	0.721	0.911	0.870
Digital literacy	Digital skills	0.685	0.927	0.903
Digital stress	Availability stress	0.762	0.906	0.845
Digital stress	Social approval anxiety	0.601	0.882	0.832
Digital stress	Fear of missing out	0.800	0.941	0.917
Digital stress	Communication overload	0.697	0.932	0.913
Digital stress	Online vigilance	0.768	0.930	0.899
Perceived interactivity	Responsiveness	0.610	0.886	0.839
Perceived interactivity	Learner control	0.647	0.843	0.716
Perceived interactivity	Learning engagement	0.527	0.869	0.820
Perceived interactivity	Personalization	0.599	0.817	0.765

As shown in Table 3, Cronbach's alpha coefficients for all constructs exceeded .70, indicating satisfactory internal consistency reliability. Similarly, composite reliability (CR) values for all constructs were above .70, confirming adequate construct reliability. In addition, the AVE values for all constructs exceeded .50. Therefore, based on the CR and AVE values, the convergent validity of the study constructs was also confirmed.

After establishing the convergent validity of the measurement model, the structural model was tested. Figure 1 presents the conceptual model of the study together with the factor loadings, path coefficients, and coefficients of determination.

Figure 1

Testing of the Overall Research Model



The results indicated that all path coefficients were statistically significant at the .05 level, as the calculated *t* values for all paths exceeded 1.96. This finding demonstrates that the relationships among the constructs were statistically significant and, consequently, that the research hypotheses were supported at the 95% confidence level.

Subsequently, the fit and predictive performance of the structural model were evaluated using the key indices of R^2 (coefficient of determination) and Q^2 (predictive relevance). The results are summarized in Table 4.

Table 4

R^2 and Q^2 Values for the Endogenous Study Variable

Variable	R^2	Q^2
Perceived interactivity in learner–AI interaction	0.388	0.237

As shown in Table 4, the coefficient of determination (R^2) for perceived interactivity in learner–AI interaction was 0.388, indicating that 38.8% of the variance in this variable was explained by the predictor variables included in the model. In addition, the Q^2 value was 0.237. Because this value was positive, it indicated that the model possessed predictive relevance for the endogenous variable.

Based on the results presented in Table 5, the structural model was evaluated to test the research hypotheses.

Table 5

Results of the Structural Model Evaluation for Testing the Research Hypotheses

No.	Path	Path Coefficient (β)	*t* Statistic	Result
1	Digital literacy → Perceived interactivity in learner–AI interaction	0.319	5.135	Supported
2	Digital stress × Digital literacy → Perceived interactivity in learner–AI interaction	−0.131	2.660	Supported

The results of hypothesis testing indicated that digital literacy had a positive and statistically significant effect on perceived interactivity in learner–AI interaction ($\beta = 0.319$, $t = 5.135$). Therefore, the first research hypothesis was supported. Furthermore, the interaction effect of digital stress and digital literacy on perceived interactivity was statistically significant ($\beta = -0.131$, $t = 2.660$). Accordingly, the moderating role of digital stress in the relationship between digital literacy and perceived interactivity was confirmed.

4 Discussion

The present study examined the effect of digital literacy on perceived interactivity in learner–artificial intelligence interaction and investigated the moderating role of digital stress among elementary school teachers. The findings showed that digital literacy had a positive and statistically significant effect on perceived interactivity in learner–AI interaction ($\beta = 0.319$, $t = 5.135$). In addition, the interaction between digital stress and digital literacy had a significant negative effect on perceived interactivity ($\beta = -0.131$, $t = 2.660$), confirming the moderating role of digital stress. The structural model explained 38.8% of the variance in perceived interactivity ($R^2 = 0.388$), while the positive Q^2 value of 0.237 indicated acceptable predictive relevance. Taken together, these findings suggest that teachers with higher levels of digital literacy are more likely to perceive interaction with AI systems as responsive, controllable, engaging, and personalized, whereas digital stress weakens the extent to which digital literacy is translated into a positive interactive experience.

The first major finding indicated that digital literacy positively predicted perceived interactivity in learner–AI interaction. This result is theoretically plausible because digital literacy provides users with the technical knowledge and digital skills required to navigate, understand, evaluate, and effectively use AI-supported learning environments. Teachers who possess stronger digital literacy are likely to have a clearer understanding of system functions, to formulate more precise prompts, to interpret AI-generated outputs more accurately, and to adjust their interaction strategies based on the responses generated by AI. These capabilities can strengthen the perception that an AI system is responsive and controllable because users are better able to elicit relevant outputs and manage the direction of interaction. The finding is consistent with Ren et al., who demonstrated that digital competence is closely associated with perceived interactivity in AI-supported learning contexts (Ren et al., 2025). Their results support the proposition that users' technological competence contributes directly to the quality of their subjective interaction with intelligent learning systems.

This finding is also aligned with the results reported by Yaseen et al., who showed that digital literacy plays an important role in determining the extent to which adaptive learning technologies, personalized feedback, and interactive AI tools contribute to student engagement (Yaseen et al., 2025). Their study indicates that technologically sophisticated learning environments do not automatically produce high levels of engagement; rather, users require adequate digital literacy to benefit from interactive and personalized technological features. The present finding extends this reasoning to teachers by suggesting that digital literacy affects not only engagement outcomes but also the perceived quality of the interaction itself. When teachers possess adequate digital competencies, they may experience AI-supported learning technologies as more transparent, manageable, and adaptive to their needs.

The positive association between digital literacy and perceived interactivity is further supported by research on adaptive learning and learner–content interaction. Ipinnaiye and Risquez found that adaptive learning environments can improve learner–content interaction and student performance by enabling more tailored and responsive educational experiences (Ipinnaiye & Risquez, 2024). In the context of AI-supported learning, digital literacy may allow teachers to make more effective use of adaptive features and personalized feedback. For example, a digitally literate teacher may recognize how to refine input, adjust parameters, evaluate alternative responses, and integrate AI-generated suggestions into instructional decisions. Such active and iterative engagement is likely to increase perceived responsiveness and personalization, two central dimensions of perceived interactivity.

The finding can also be interpreted in light of previous research on interactivity in digital learning environments. Shao and Chen showed that interactivity contributes to users' engagement and continuance intention in massive

open online courses (Shao & Chen, 2021). Similarly, Wang et al. demonstrated that perceived interactivity plays an important role in shaping users' responses and relationships in digital communication environments (Wang et al., 2020). Although these studies were conducted in different technological settings, they collectively support the idea that perceived interactivity is not simply a technical characteristic of a digital system but a psychological perception that emerges through users' effective engagement with the system. Digital literacy can strengthen this perception by allowing users to interact more confidently and strategically with AI, thereby enhancing the sense of responsiveness, control, and meaningful exchange.

The present finding is also consistent with studies focusing specifically on educators and AI-related competencies. Hajizadeh et al. highlighted the importance of AI literacy and digital literacy in explaining productive academic and educational outcomes (Hajizadeh et al., 2025). Their findings imply that digital competence creates the conditions necessary for meaningful participation in technologically enriched academic environments. Similarly, Khadivi et al. found that digital skills mediate the relationship between AI literacy and the quality of educational services (Khadivi et al., 2025). This evidence supports the interpretation that knowledge of AI alone is insufficient unless it is accompanied by practical digital skills that enable individuals to translate technological knowledge into effective behavior. In the present study, digital literacy may have improved teachers' perceived interactivity because it helped them transform AI capabilities into usable and personally meaningful interactive experiences.

A related explanation can be derived from Hosseini's findings on AI literacy, behavioral engagement, and higher-order thinking among student teachers (Hosseini, 2025). That study showed that AI literacy was associated with educational outcomes through mechanisms involving engagement and interaction. This supports the present result by suggesting that digitally competent users are more likely to become behaviorally and cognitively involved in AI-supported learning. Such involvement may enhance perceived interactivity because users who actively explore AI tools, ask follow-up questions, compare outputs, and integrate responses into decision-making are more likely to experience the interaction as dynamic rather than passive.

The findings are also consistent with Haroud and Saqri, who emphasized digital literacy as a critical condition for meaningful engagement with generative AI in higher education (Haroud & Saqri, 2025). Their work showed that perceptions of AI as a supportive educational tool depend partly on users' ability to understand its functions and limitations. This is relevant to the present findings because digitally literate teachers are likely to have more realistic expectations regarding AI capabilities. They may understand that high-quality interaction depends on iterative communication, clear instructions, verification, and appropriate task selection. Consequently, they may perceive AI systems as more interactive because they know how to engage with them in ways that produce relevant and useful responses.

The second major finding of the present study was that digital stress significantly moderated the relationship between digital literacy and perceived interactivity, with the negative interaction coefficient indicating that higher digital stress weakened the positive effect of digital literacy on perceived interactivity. This result suggests that digital competence does not operate in isolation. Even teachers who possess adequate technical literacy and digital skills may experience reduced benefits from these competencies when they are simultaneously exposed to high levels of availability pressure, communication overload, online vigilance, social approval anxiety, or fear of missing out. In other words, digital literacy may provide users with the capacity to interact effectively with AI, but digital stress can reduce the cognitive and emotional resources available for taking advantage of that capacity.

This finding closely aligns with Ren et al., who specifically linked digital competence, self-efficacy, digital stress, and perceived interactivity in AI-supported learning contexts (Ren et al., 2025). Their framework emphasizes that digital stress can shape how users experience and respond to interactive educational technologies. The present study strengthens this line of evidence by demonstrating a moderating effect: the positive contribution of digital literacy to perceived interactivity becomes weaker as digital stress increases. This means that interventions focused exclusively on improving digital skills may produce limited results if the psychological burden of constant digital engagement is not simultaneously addressed.

The moderating effect can also be explained through the cognitive consequences of digital stress. Zhan et al. demonstrated that digital stress is associated with problematic patterns of technology use through emotional pathways (Zhan et al., 2025). High digital stress can consume attentional resources, increase psychological fatigue, and heighten emotional reactivity. In educational

contexts, teachers experiencing digital overload may find it more difficult to focus on AI-generated feedback, evaluate multiple alternatives, or engage in sustained iterative communication with AI systems. Thus, although they may possess the technical competence to interact effectively, the subjective quality of interaction may decline because their cognitive resources are strained.

The negative moderating effect is particularly understandable when considering the multidimensional nature of digital stress. Communication overload can reduce teachers' capacity to process additional information generated by AI systems. Online vigilance may create a persistent state of divided attention, making sustained interaction more difficult. Availability stress may cause AI-supported digital environments to be experienced as an extension of continuous professional demands rather than as supportive learning tools. Fear of missing out may encourage excessive or fragmented engagement with digital platforms, while social approval anxiety may increase concern about performance or evaluation in technology-mediated contexts. Together, these pressures may reduce users' perceptions of control, engagement, and personalization, thereby weakening the positive influence of digital literacy.

The role of psychological resources in AI adoption has also been emphasized by Kim and Lee, who showed that self-efficacy is crucial in understanding the mental health implications of AI adoption (Kim & Lee, 2024). Their findings suggest that the effects of AI technologies depend not only on exposure or competence but also on users' psychological capacity to manage technological demands. From this perspective, digital literacy may operate most effectively when accompanied by sufficient confidence, emotional regulation, and manageable levels of digital stress. When stress is high, users may have adequate skills but still perceive the interaction as demanding, intrusive, or cognitively exhausting.

The results can also be linked to findings concerning self-efficacy in teachers' use of digital media. Rahmanzadeh et al. showed that self-efficacy plays a mediating role in the relationship between media use and teachers' health literacy (Rahmanzadeh et al., 2024). Although the context differs from AI-supported learning, the underlying implication is similar: positive outcomes from digital technology depend on psychological as well as technical resources. Teachers who feel overwhelmed by constant technological demands may be less able to transform their digital competence into effective interaction, even if their actual technical skills remain high.

The findings are also consistent with the broader literature on generative AI integration. Kasneci et al. emphasized that large language models offer substantial educational opportunities but also introduce challenges related to misuse, overreliance, cognitive load, and uncertainty (Kasneci et al., 2023). Bhullar et al. similarly noted that successful integration of ChatGPT into education requires adequate digital capability, pedagogical preparedness, and strategies for managing emerging risks and challenges (Bhullar et al., 2024). These observations support the present finding that digital literacy alone does not guarantee optimal learner–AI interaction. As AI becomes more integrated into teaching and learning, the psychological demands associated with persistent digital engagement must also be considered.

The R^2 value of 0.388 is also noteworthy. It indicates that the model explained 38.8% of the variance in perceived interactivity, suggesting that digital literacy and the modeled effects of digital stress account for a meaningful proportion of differences in how teachers experience learner–AI interaction. At the same time, a substantial proportion of the variance remains unexplained, implying that perceived interactivity is also shaped by additional factors such as AI self-efficacy, prior experience with AI tools, perceived usefulness, trust in AI, task characteristics, institutional support, interface quality, and attitudes toward technological change. The positive Q^2 value of 0.237 further indicates that the model possesses predictive relevance and is not limited to explaining only the observed sample data.

5 Conclusion

Overall, the findings contribute to the literature by showing that digital literacy should be understood as an important enabling resource for effective learner–AI interaction, while digital stress should be treated as a boundary condition that can weaken this positive relationship. The results integrate two perspectives that are often studied separately: the competence perspective, which emphasizes what users are capable of doing with digital technologies, and the psychological-demand perspective, which emphasizes the strain generated by intensive technology use. In practical terms, the findings imply that educational organizations cannot assume that increasing digital competence will automatically produce more positive AI-supported experiences. The effectiveness of digital

literacy depends partly on the psychological context within which digital interaction occurs.

The present study has several limitations that should be considered when interpreting the findings. First, the cross-sectional and descriptive-survey design does not permit definitive causal conclusions regarding the relationships among digital literacy, digital stress, and perceived interactivity. Second, the study relied on self-report questionnaire data, which may be affected by social desirability, common method variance, recall bias, or differences in participants' interpretations of questionnaire items. Third, the participants were elementary school teachers from a single geographical area, which may limit the generalizability of the results to teachers working at other educational levels, in other regions, or in different cultural and institutional contexts. Fourth, the study focused on perceived rather than objectively observed interactivity, and therefore the findings represent teachers' subjective evaluations of AI-supported interaction rather than behavioral records of actual human–AI exchanges. Finally, although the model explained a meaningful proportion of the variance in perceived interactivity, other potentially important variables such as AI self-efficacy, trust, perceived usefulness, organizational support, technological infrastructure, prior AI experience, and attitudes toward AI were not incorporated into the model.

Future studies should employ longitudinal and experimental designs to clarify the temporal and causal relationships among digital literacy, digital stress, and perceived interactivity. Researchers could examine whether targeted digital literacy training produces lasting improvements in perceived learner–AI interaction and whether reductions in digital stress strengthen these effects over time. Future research should also replicate the model among secondary school teachers, university instructors, students, educational administrators, and other professional groups to determine whether the relationships observed in this study are stable across populations and contexts. Multigroup analyses could examine whether the structural relationships differ according to age, gender, teaching experience, educational level, or prior experience with AI technologies. Further studies may also extend the model by incorporating AI self-efficacy, trust in AI, perceived usefulness, technology anxiety, organizational support, digital well-being, or cognitive load as mediators or moderators. Combining questionnaire data with behavioral indicators, usage logs, experimental interaction tasks, and qualitative interviews could also provide a more comprehensive understanding of how users actually experience and manage interaction with AI systems.

Educational institutions should develop professional development programs that address both digital competence and digital well-being rather than focusing exclusively on technical skill acquisition. Training programs for teachers should include practical instruction on effective AI use, prompt formulation, evaluation of AI-generated content, management of personalized learning tools, and strategies for maintaining learner control during human–AI interaction. At the same time, schools and educational authorities should reduce unnecessary digital demands by establishing clear expectations regarding online availability, communication load, and the use of multiple digital platforms. Teachers should be provided with structured opportunities to practice AI-supported teaching in low-pressure environments, receive technical assistance, and develop confidence before AI tools are fully integrated into routine instructional work. Institutional policies should also encourage balanced technology use, minimize redundant notifications and communication channels, and provide guidance for managing digital overload. By simultaneously strengthening digital literacy and reducing digital stress, educational organizations can create conditions in which teachers are better able to experience AI-supported interaction as responsive, controllable, engaging, and personalized.

Authors' Contributions

All authors have contributed significantly to the research process and the development of the manuscript.

Declaration

In order to correct and improve the academic writing of our paper, we have used the language model ChatGPT.

Transparency Statement

Data are available for research purposes upon reasonable request to the corresponding author.

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The authors report no conflict of interest.

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