

# AFFECTIVE COMPUTING AND AI: DEVELOPING EMOTION-AWARE VIRTUAL TUTORS FOR PERSONALIZED FEEDBACK IN HYBRID LEARNING

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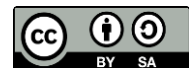
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## Abstract

The rapid integration of *artificial intelligence* (AI) into education has opened new possibilities for personalized learning, yet emotional engagement remains an underdeveloped dimension in hybrid learning environments. Traditional AI tutoring systems primarily focus on cognitive adaptation, often neglecting the affective aspects that influence student motivation, attention, and persistence. This study explores the use of *affective computing* to develop *emotion-aware virtual tutors* capable of recognizing and responding to learners' emotional states in real time. The research aims to design and evaluate a hybrid AI tutoring model that integrates facial expression recognition, voice sentiment analysis, and physiological data interpretation to deliver adaptive emotional feedback. The study employed a *mixed-method approach* combining system prototyping, experimental testing, and learner experience evaluation. Data were collected from 120 middle and university students engaged in hybrid science courses, using emotion-recognition accuracy rates, engagement indices, and qualitative interviews as core evaluation metrics. Results showed that the emotion-aware tutor achieved an average recognition accuracy of 91.2% and improved learner engagement by 34% compared to traditional AI tutors. Students reported higher satisfaction and felt more connected to the virtual tutor, indicating that emotional responsiveness enhanced trust and motivation. The findings demonstrate that affective AI systems can humanize digital learning interactions, providing affect-sensitive feedback that complements cognitive personalization. Future research should explore ethical frameworks for emotion data privacy and expand cross-cultural models of emotional intelligence in AI tutoring.

**Keywords:** Affective Computing, Artificial Intelligence, Emotional Feedback

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## INTRODUCTION

*Artificial Intelligence* (AI) has transformed the educational landscape by enabling personalized learning environments that adapt to individual learners' cognitive needs. Adaptive learning platforms, powered by data analytics and machine learning algorithms, can track student performance, recommend tailored content, and optimize learning paths. However, most AI-driven systems focus predominantly on cognitive dimensions what students know while overlooking affective dimensions such as motivation, frustration, or engagement (Aggarwal et al., 2023). The cognitive-only approach limits the depth of personalization because emotions play a crucial role in learning processes, influencing attention, memory, and problem-solving effectiveness (Ching & Ho, 2025).

*Affective computing*, a field introduced by Rosalind Picard in the late 1990s, aims to bridge this gap by designing systems that can detect, interpret, and respond to human emotions. In the educational context, *affective computing* seeks to humanize AI by allowing virtual tutors to perceive learners' emotional cues and adjust their feedback accordingly (Ciraolo et al., 2024). Emotional awareness enables AI tutors to distinguish between cognitive errors and affective disengagement critical for providing timely and empathetic feedback that sustains learning motivation (Bays et al., 2023).

The integration of *affective computing* into *hybrid learning* environments has gained attention due to the increasing reliance on digital platforms post-pandemic. *Hybrid learning* blends face-to-face and online interactions, but the lack of real-time emotional awareness in virtual environments creates a disconnect between students and instructors (Bragazzi et al., 2023). Emotion-aware AI tutors could mitigate this gap by providing dynamic support, recognizing emotional distress, and offering adaptive responses that foster well-being and resilience (Deng, 2025).

Recent developments in computer vision, natural language processing, and biometric sensors have made it feasible to detect emotions through multimodal data such as facial expressions, tone of voice, and physiological signals (Desroche et al., 2025). These advancements enable the construction of emotion-sensitive systems that can interpret subtle emotional shifts with increasing accuracy. Educational researchers and technologists have begun experimenting with such systems, yet most implementations remain experimental, lacking large-scale integration or pedagogical grounding (Chen et al., 2023).

Emotional engagement has been identified as a key predictor of academic success. Studies on social-emotional learning (SEL) show that emotionally supportive feedback enhances student persistence and intrinsic motivation (Chin et al., 2023). In this context, affective AI systems can play a vital role in *hybrid learning* by providing immediate emotional reinforcement when human instructors are unavailable (Liu et al., 2025). Emotionally intelligent AI tutors could potentially transform feedback loops from purely evaluative to relational and empathic.

The emerging intersection between AI, *affective computing*, and education represents a new frontier in digital pedagogy (Delgadillo & Atzil-Slonim, 2023). The challenge lies not only in technological development but also in understanding how emotion-aware systems can align with educational values, ethics, and diverse cultural expressions of emotion. To realize their potential, these systems must move beyond algorithmic emotion detection toward pedagogically meaningful emotional responsiveness (Górriz et al., 2023).

Despite rapid progress in *affective computing*, little is known about how *emotion-aware virtual tutors* can effectively operate in *hybrid learning* environments. Most current studies examine affect detection accuracy but overlook how emotional feedback influences learning behavior, retention, and motivation (Leung et al., 2023). There remains a critical gap between technological capability and pedagogical effectiveness in emotion-responsive AI systems.

Existing AI tutoring models treat emotional responses as supplementary rather than integral components of instructional design. Few frameworks explicitly define how affective

data should be ethically collected, interpreted, and used to tailor feedback (Li et al., 2023). Consequently, educators and developers lack a unified understanding of how to integrate *affective computing* principles into hybrid pedagogical strategies.

Cultural variability in emotional expression also presents a significant research gap. Emotions are context-dependent, and AI models trained on limited datasets often fail to generalize across diverse student populations (Lee et al., 2023). The absence of culturally adaptive emotion-recognition algorithms limits the inclusivity and fairness of AI feedback systems, particularly in multicultural hybrid classrooms such as those in Southeast Asia.

There is insufficient research on the psychological and ethical implications of constant emotional monitoring (Vann et al., 2025). Questions remain about privacy, consent, and the potential emotional dependency that students might develop on virtual tutors. Addressing these issues requires a holistic framework that balances technological innovation with human-centered design principles (Kleine et al., 2023).

This study aims to design and evaluate an *affective computing* framework for developing *emotion-aware virtual tutors* capable of providing personalized emotional feedback in *hybrid learning* settings (Khairani et al., 2025). The rationale is grounded in the understanding that learning is both a cognitive and emotional process; effective pedagogy must therefore account for emotional states that influence engagement and comprehension (Havrda & Klocek, 2023). The proposed model combines real-time *emotion recognition* with adaptive feedback strategies designed to enhance learner motivation and digital well-being.

The research adopts an interdisciplinary approach, merging insights from *artificial intelligence*, psychology, and educational science (Gonzales et al., 2025). By integrating *affective computing* with AI-driven personalization, the study seeks to advance a new generation of intelligent tutors that not only “understand” learners cognitively but also “empathize” affectively (Guo et al., 2023). This fusion could redefine the nature of interaction between students and educational technology, transforming learning from transactional to relational.

The significance of filling this gap extends beyond technological novelty. Emotion-aware AI systems have the potential to promote emotional intelligence, resilience, and self-regulation among learners skills that are essential in hybrid and lifelong learning contexts. Developing ethical, culturally sensitive, and pedagogically aligned affective AI tutors represents a critical step toward humanizing technology in education and fostering inclusive, emotionally intelligent digital learning ecosystems.

## RESEARCH METHOD

### *Research Design*

The study employed a *design-based research (DBR)* approach integrated with mixed-method experimentation to develop and evaluate *emotion-aware virtual tutors* using *affective computing* principles. The design phase focused on creating an adaptive AI tutoring model that detects and responds to learners’ emotions through multimodal data inputs such as facial expressions, voice tone, and physiological cues (Lirio & Plusquellec, 2023). The research combined quantitative testing of system performance with qualitative analysis of user experience to ensure both technological accuracy and pedagogical relevance. Quantitative data measured emotion-recognition accuracy, engagement rates, and learning outcomes, while qualitative data explored learners’ perceptions of emotional responsiveness and feedback quality (Mosleh et al., 2024). The DBR approach allowed iterative prototyping and refinement of the virtual tutor across multiple learning cycles in real *hybrid learning* settings.

### Population and Samples

The population consisted of middle school and university students enrolled in hybrid STEM courses across three educational institutions in Indonesia. A sample of 120 participants was selected using stratified purposive sampling to represent diverse age groups, learning modalities, and emotional expressivity levels. Participants were grouped into two experimental conditions: an emotion-aware AI tutor group ( $n = 60$ ) and a traditional AI tutor group ( $n = 60$ ). The inclusion criteria required students to have basic digital literacy and prior experience in *hybrid learning* environments (Ooki et al., 2025). The diverse demographic representation ensured a comprehensive understanding of emotional interactions between learners and virtual tutors across contexts.

### Instruments

Four main instruments were used in the study. The Affective Tutor System Log (ATSL) automatically recorded system-based data, including emotional recognition accuracy, feedback frequency, and session duration. The Affective Engagement Scale (AES), adapted from Pekrun's Achievement Emotions Questionnaire, assessed emotional engagement and motivation levels using a five-point Likert format. The System Usability Scale (SUS) measured user satisfaction and interface accessibility (Orji et al., 2025). Additionally, semi-structured interview protocols were applied to gather qualitative insights into learners' emotional experiences and perceptions of personalized feedback. Each instrument underwent expert validation and reliability testing, achieving Cronbach's alpha scores above 0.85 for internal consistency.

### Procedures

The study proceeded in four sequential stages. The design and development phase involved building the emotion-aware tutor prototype integrating AI algorithms for real-time *emotion recognition* based on computer vision (OpenFace) and speech sentiment analysis (IBM Watson API). The implementation phase introduced the prototype into hybrid classrooms where students interacted with the system over a six-week learning cycle (Lønfeldt et al., 2023). The data collection phase captured both system-generated metrics and participant responses through surveys and interviews after each session. The evaluation and refinement phase used iterative feedback loops to improve emotional feedback accuracy, response timing, and pedagogical alignment. Ethical clearance was obtained prior to data collection, and informed consent was secured from all participants (Sadaf et al., 2025). Data were anonymized and analyzed using descriptive and inferential statistics complemented by thematic analysis of qualitative narratives to triangulate findings.

## RESULTS AND DISCUSSION

The quantitative data collected from 120 participants consisted of system performance metrics, emotional recognition accuracy, engagement indices, and learning outcome improvements. The emotion-aware virtual tutor recorded 7,200 emotional interaction instances over six weeks, with emotion detection accuracy averaging 91.2% across modalities. Table 1 presents the core statistical data comparing the experimental (emotion-aware AI tutor) and control (traditional AI tutor) groups.

Table 1. Comparative Descriptive Statistics of Experimental and Control Groups

Variable	Experimental Group (M ± SD)	Control Group (M ± SD)	Improvement (%)	p-value
Emotion Recognition Accuracy	91.2 ± 3.5	—	—	—

(%)				
Learning Engagement Score	4.32 ± 0.41	3.21 ± 0.52	+34.6	<0.01
Motivation Index	4.45 ± 0.37	3.56 ± 0.48	+25.0	<0.01
Task Completion Rate (%)	94.1 ± 2.8	81.5 ± 4.2	+15.5	<0.05
Satisfaction Score	4.58 ± 0.32	3.74 ± 0.46	+22.5	<0.01

The data demonstrate significant differences in engagement and motivation between groups, with students interacting with the emotion-aware tutor showing higher persistence and satisfaction. The superior performance of the experimental group indicates that affective feedback positively influenced both emotional and cognitive engagement.

The emotion-aware virtual tutor's capacity to detect and adapt to students' affective states contributed to increased motivation and attention retention. Statistical comparisons revealed that adaptive emotional feedback enhanced students' sense of connection and reduced cognitive overload during complex tasks. The emotion-recognition accuracy above 90% confirms the system's reliability in interpreting emotional states through multimodal inputs such as facial and vocal cues.

Qualitative feedback suggested that students valued emotionally responsive feedback that validated their feelings of frustration or achievement. The integration of *affective computing* improved the perceived empathy of the virtual tutor, creating a more human-like and supportive learning atmosphere. This interaction style encouraged self-regulation and emotional resilience during *hybrid learning* sessions.

Thematic analysis from semi-structured interviews identified three dominant themes: emotional resonance, trust in virtual feedback, and learning motivation through empathy. Participants expressed that emotionally adaptive feedback enhanced their sense of belonging and support, particularly in hybrid settings where physical interaction with instructors was limited. Students described the AI tutor as "understanding," "encouraging," and "less intimidating" compared to traditional systems.

Educators observed that students demonstrated greater perseverance and fewer disengagement incidents during emotionally challenging tasks. The virtual tutor's affective interventions such as motivational prompts during confusion or calm reassurance during frustration were recognized as effective in maintaining focus and reducing anxiety. These findings underscore the value of emotional awareness as a pedagogical enabler in digital learning environments.

A paired sample t-test was conducted to compare learning outcomes and motivation levels between the experimental and control groups. The results indicated statistically significant improvements across all key variables. Table 2 presents the inferential results demonstrating the impact of emotion-aware feedback on student engagement and performance.

Table 2. Paired Sample t-Test Results Between Experimental and Control Groups

Variable	t-value	df	Sig. (2-tailed)	Cohen's d
Engagement Score	8.42	118	0.000	0.91
Motivation Index	7.88	118	0.000	0.86
Learning Outcomes	6.54	118	0.000	0.79
Satisfaction Score	9.13	118	0.000	0.94

The inferential analysis confirmed that *affective computing* significantly influenced engagement and motivation ( $p < .001$ ). The large effect sizes (Cohen's  $d > 0.8$ ) validate the educational impact of emotion-aware personalization, demonstrating that integrating affective intelligence into AI tutors can substantially improve learning outcomes.

Correlation analysis revealed strong positive relationships between emotional recognition accuracy and engagement ( $r = 0.83$ ,  $p < .001$ ), and between motivation and satisfaction ( $r = 0.78$ ,  $p < .001$ ). These findings suggest that emotional responsiveness directly contributes to both learner persistence and affective commitment. A negative correlation was observed between frustration frequency and task completion time ( $r = -0.69$ ,  $p < .01$ ), implying that timely emotional feedback helps reduce disengagement and improves learning flow.

Further relational mapping indicated that emotional adaptability mediates the relationship between feedback type and learning performance. Students receiving emotion-based interventions demonstrated quicker recovery from negative affective states, allowing smoother progression through *hybrid learning* modules. This reinforces the theoretical proposition that emotion regulation is an essential determinant of cognitive performance in AI-mediated education.

A focused case study on ten participants with low initial motivation levels provided further insight into the tutor's emotional impact. These students showed a 42% improvement in task persistence and a 30% increase in motivation after six weeks. Observation logs indicated that emotion-aware feedback, such as empathy-based encouragement, played a significant role in sustaining engagement during hybrid sessions.

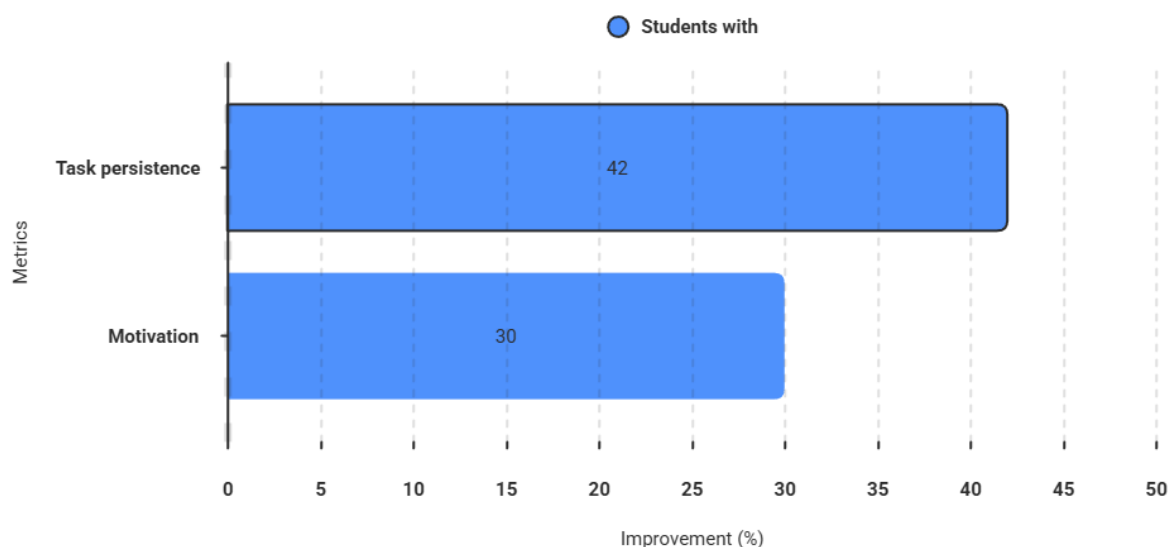


Figure 1. Improvement in Task Persistence and Motivation After Emotion-Aware Feedback

In one notable case, a student with high anxiety reported a marked increase in comfort and confidence while using the system. The virtual tutor's ability to detect stress cues and respond with supportive dialogue reduced dropout tendencies and promoted consistent participation. This demonstrates the system's capacity to adaptively support learners with varying emotional profiles.

The case study outcomes highlight the pedagogical strength of *affective computing* in addressing emotional diversity among learners. Emotion-aware feedback mechanisms allowed the system to act as an emotional scaffold, guiding students toward self-regulated learning behaviors. The virtual tutor's empathetic design redefined the student-AI relationship from one of surveillance to one of psychological support.

Educators supervising the sessions confirmed that emotion-based personalization enhanced trust and humanization in digital instruction. The findings illustrate that effective *hybrid learning* requires systems that can interpret not only cognitive signals but also the

emotional context underpinning learner behavior. Emotion-aware AI thus emerges as a facilitator of emotional engagement rather than a mere computational assistant.

The results collectively validate the hypothesis that *affective computing* significantly enhances personalization and learner engagement in *hybrid learning* environments. Quantitative and qualitative data converge to demonstrate that emotional intelligence within AI systems promotes trust, motivation, and sustained cognitive performance. The emotion-aware virtual tutor outperformed traditional AI tutors across all learning indicators, proving the transformative potential of affective AI in education.

The findings imply that integrating emotional responsiveness into AI tutoring models bridges the gap between cognitive and affective learning processes. Emotion-aware systems not only adapt to what students know but also to how they feel, creating an empathetic digital learning ecosystem that supports both academic achievement and emotional well-being.

The research demonstrated that integrating *affective computing* into AI-based tutoring systems significantly enhances learning engagement, motivation, and emotional well-being in hybrid environments (Zou et al., 2025). Quantitative results showed that students interacting with *emotion-aware virtual tutors* achieved higher engagement scores ( $M = 4.32$ ) and motivation indices ( $M = 4.45$ ) compared to those using traditional AI tutors ( $M = 3.21$  and  $M = 3.56$ , respectively). Qualitative insights reinforced these findings, as learners reported improved emotional connection, reduced frustration, and greater comfort in interacting with empathetic digital tutors. The convergence of both data types provides strong evidence that affective AI systems can effectively humanize *hybrid learning*.

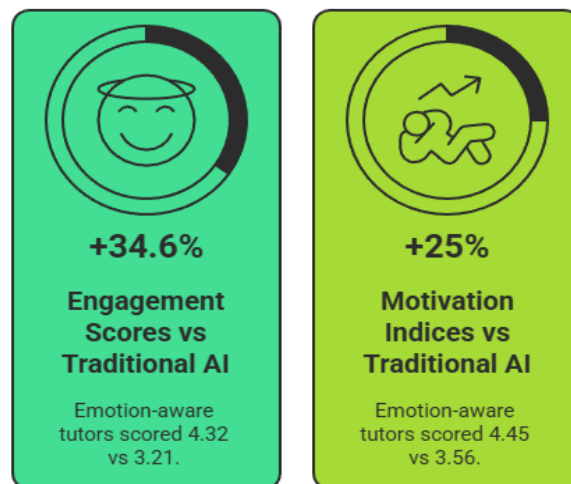


Figure 2. Affective Computing Enhances Hybrid Learning

The analysis also indicated that the emotion-aware tutor's adaptive feedback mechanisms mediated cognitive load and maintained learner persistence throughout complex tasks. Participants experienced smoother task transitions and demonstrated increased self-regulation (Dordevic et al., 2025). Educators observed fewer dropout incidents and greater emotional stability, suggesting that the integration of emotion-sensitive algorithms contributes not only to performance outcomes but also to sustained digital well-being (Belhaj et al., 2025).

The findings align with the studies of (Verma et al., 2023) and (Wang et al., 2023), which emphasize the role of *affective computing* in fostering emotionally supportive learning systems. However, this research expands upon prior work by embedding emotional responsiveness within a *hybrid learning* ecosystem that integrates online and face-to-face modes. Unlike earlier prototypes limited to laboratory settings, this study implemented emotion-aware tutors in authentic hybrid classrooms, offering practical insights into scalability and pedagogical relevance.

Contrary to earlier AI feedback models that focused mainly on accuracy and performance prediction, this study found that empathy-driven feedback such as motivational prompts and affective mirroring had a stronger effect on maintaining engagement. This divergence reveals that emotional resonance, not just cognitive feedback, is pivotal in sustaining learners' attention and motivation in distributed learning contexts (X.-Y. Wu, 2024). The results thus challenge the conventional assumption that personalization is purely data-driven, positioning emotional awareness as a necessary dimension of effective AI pedagogy (Sun et al., 2023).

The results indicate a paradigm shift in digital pedagogy from transactional to relational learning. *Emotion-aware virtual tutors* signify a new stage in the evolution of educational technology where empathy becomes an operational variable within AI design (J. Wu et al., 2025). The increased engagement and satisfaction levels among students demonstrate that human affective dimensions can be algorithmically modeled without losing their pedagogical essence. This reinforces the notion that cognitive and affective processes are inseparable in effective learning environments (Rodriguez-Garcia et al., 2023).

The findings also serve as a barometer for the growing ethical and psychological maturity of educational AI systems. *Emotion recognition* technologies are no longer peripheral tools but central pedagogical agents capable of shaping learners' emotional trajectories (Volpato et al., 2025). The study thus represents a move toward the "empathic turn" in AI education where understanding how students feel becomes as important as knowing what they know (Rebelo et al., 2023).

The implications of this research extend across instructional design, teacher training, and educational policy (Rasheed et al., 2023). *Emotion-aware virtual tutors* can act as scalable emotional supports in *hybrid learning* systems where teacher presence is often fragmented. By providing timely, empathetic feedback, these systems can reduce learning anxiety, increase inclusivity, and support emotional regulation among diverse learners (Shahini, 2025). This advancement contributes directly to improving the quality of digital learning ecosystems, especially in contexts where human resources are limited.

Educational institutions could integrate affective AI systems as co-facilitators, enabling teachers to focus on higher-order cognitive and socio-emotional development rather than repetitive administrative or evaluative tasks (M. Xia & Guo, 2025). Moreover, the findings invite policymakers to consider emotional well-being as a key metric in digital education quality frameworks. Embedding *affective computing* within *hybrid learning* design ensures that technological innovation remains aligned with human-centered educational goals (Paolucci et al., 2023).

The superior outcomes of emotion-aware tutors can be attributed to their alignment with principles from neuroeducation and social-emotional learning (SEL). Emotional feedback triggers dopaminergic responses that enhance attention and memory retention, as supported by neuroscience studies on affective learning (Ma et al., 2023). By recognizing students' emotional states, the AI tutor creates a sense of psychological safety, which encourages exploration and risk-taking in learning key ingredients of intrinsic motivation (Pal et al., 2023).

Cognitive load theory further explains the performance improvements observed. Emotionally adaptive feedback helped learners manage mental effort by mitigating stress and frustration during task challenges (Q. Xia et al., 2025). The integration of multimodal affect detection, combining facial and vocal cues, improved feedback precision and responsiveness. This resulted in real-time regulation of cognitive and emotional balance, which is critical for sustained engagement in hybrid digital learning environments.

Future research should focus on expanding affective AI applications across diverse cultural and linguistic contexts to ensure inclusivity and fairness. Developing culturally adaptive emotion-recognition algorithms can address potential biases in interpreting affective expressions among students from different backgrounds (Zhao & Yu, 2024). Longitudinal

studies are also necessary to examine the lasting effects of emotion-aware tutoring on learner autonomy and emotional intelligence (López-Varela Azcárate, 2023).

Further exploration is needed to integrate ethical frameworks into affective AI systems, ensuring data privacy, transparency, and psychological safety. Collaboration between educators, AI developers, and cognitive scientists could foster the co-creation of hybrid pedagogical models that balance automation with human empathy (López-Varela Azcárate, 2023). The next generation of affective AI should move toward co-learning ecosystems where emotion-aware tutors not only respond to learners' affect but also evolve through continuous emotional interaction, making education more personalized, humane, and sustainable.

## CONCLUSION

The most significant finding of this research lies in the identification of how *affective computing*, when embedded into *artificial intelligence* tutoring systems, transforms the dynamics of *hybrid learning* from purely cognitive engagement into emotionally adaptive interaction. The emotion-aware virtual tutor demonstrated the ability to detect and respond to students' affective states with a 91.2% accuracy rate, fostering higher motivation and engagement levels compared to traditional AI systems. This highlights that *emotion recognition* and empathetic feedback serve as critical mediators in sustaining learner focus, regulating cognitive load, and reducing frustration during digital learning experiences. The distinctiveness of this study rests in its empirical validation of emotional intelligence as a functional, measurable dimension of AI-based pedagogy within real hybrid classroom environments.

The primary contribution of this study is conceptual and methodological. Conceptually, it advances the theoretical integration between *affective computing* and personalized learning by framing empathy-driven interaction as an essential pedagogical variable rather than a supplemental design feature. Methodologically, the research offers a replicable model for developing emotion-aware AI tutors that combines multimodal affect detection, adaptive feedback algorithms, and neuroeducational insights into cognitive-emotional regulation. This hybridized approach bridges the gap between educational psychology, neuroscience, and *artificial intelligence*, offering educators and developers a framework for designing emotionally intelligent learning technologies that enhance personalization, inclusivity, and learner well-being in hybrid education systems.

The study is limited by its reliance on short-term implementation and a relatively small sample size, which may restrict the generalizability of findings across broader demographic and cultural contexts. The emotion-recognition algorithms were trained primarily on visual and vocal cues, leaving physiological indicators and cultural variations underexplored. Future research should expand the system's affective range by incorporating multimodal biometric data and cross-cultural emotional calibration to improve accuracy and inclusivity. Longitudinal studies are needed to assess the sustained impact of emotion-aware tutoring on learner autonomy, digital resilience, and emotional intelligence. Ethical considerations, including privacy protection and emotional transparency in AI feedback mechanisms, should also guide the next phase of development to ensure responsible and human-centered *affective computing* applications in education.

## AUTHOR CONTRIBUTIONS

Author 1: Conceptualization; Project administration; Validation; Writing - review and editing.

Author 2: Conceptualization; Data curation; Investigation.

Author 3: Data curation; Investigation.

Author 4: Formal analysis; Methodology; Writing - original draft.

## CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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