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Artificial Intelligence Revolution for Enhancing Modern Education Using Zone of Proximal Development Approach

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Abstract

Artificial Intelligence has the potential to revolutionize modern education by providing personalized learning experiences, automating administrative tasks, facilitating communication between educators and students, and enabling new forms of assessment. This paper illustrates the integration of Vygotsky's Zone of Proximal Development (ZPD) with modern education methods, integrating human instruction and artificial intelligence (AI). The ZPD model describes the terrain between what a learner can accomplish independently and what they can be taught with the assistance of an instructor. The learner is at the center of this model, whose learning trajectory is directed by the instructor and modern AI tools. The convergence of these forces within the ZPD creates a highly efficient learning process where support is adaptive and tailored to the individual. Scaffolding, the key construct in ZPD, is provided via expert instructor instruction and AI-generated personal feedback. While the instructor provides pedagogical expertise and emotional support, AI platforms provide data-informed, real-time feedback tailored to personal learning needs. This hybrid support structure facilitates incremental skill acquisition and confidence build-up, resulting in measurable progress in learning. The outcome is a transition toward self-directed learning, which is a key proof of education advancement and mental development. By incorporating the technologies into the traditional teacher-student model, the suggested model identifies the future of learner-centered instruction. It aligns teaching approaches with individualized, technology-driven learning to enable sustainable academic achievement. The model also reaffirms the role of teachers as learning facilitators, leveraging AI to optimize learning paths.

Keywords: Modern education; AI-powered systems; zone of proximal development (ZPD); student outcomes, learning trajectory

1. Introduction

Technology integration has become increasingly prevalent in the rapidly evolving landscape of education, offering new opportunities to enhance teaching and learning experiences. Among the emerging technologies, Artificial Intelligence (AI) has emerged as a powerful tool with the potential to revolutionize how we approach education. AI refers to developing computer systems capable of performing tasks that traditionally require human intelligence, such as learning, problem-solving, decision-making, and pattern recognition (Yuan & Liu, 2025).

The application of AI in education holds immense promises for improving teaching performance and student outcomes. While valuable, traditional teaching methods often face challenges in catering to individual students' diverse needs and learning styles. AI-powered solutions can provide personalized learning experiences, adaptive instructional approaches, and data-driven insights to support teachers in optimizing their pedagogical strategies.

One of the key advantages of AI in education is its ability to personalize learning. AI algorithms can analyze student data, including learning preferences, strengths, weaknesses, and progress, to tailor educational content and instructional methods to individual needs. This personalized approach can enhance student engagement, understanding, and overall learning outcomes, ensuring that each student receives the support they require to reach their full potential.

AI-powered intelligent tutoring systems and virtual assistants can provide real-time feedback, adaptive guidance, and interactive learning experiences, mimicking the role of a human tutor. These systems can adjust the difficulty level, pace, and teaching approach based on the student's performance, providing a more dynamic and responsive learning environment. Moreover, AI can assist teachers in automating various tasks, such as grading assignments, providing detailed feedback on student work, and curating relevant educational resources. By alleviating the administrative burden, teachers can dedicate more time and energy to designing engaging lessons, fostering critical thinking, and nurturing the social-emotional development of their students (Jin et al., 2025). Additionally, AI-driven learning analytics can offer valuable insights into student performance, engagement levels, and learning patterns. These insights can inform data-driven decision-making, enabling teachers to identify areas where students may need additional support and refine their teaching strategies accordingly.

Despite the potential benefits of AI in education, it is essential to recognize that AI should not be viewed as a replacement for human teachers but rather as a powerful tool to augment and enhance their capabilities. The role of human teachers in providing guidance, fostering critical thinking, and nurturing social-emotional skills remains crucial in the educational process (Razak et al., 2025). Figure 1 shows the number of publications on the google scholar related to Teaching method in Education from 2020 to 2025. Traditional teaching has consistently dominated publication numbers against modern teaching approaches between the years 2020 and 2025. This indicates a continued scholarly interest and reliance on traditional teaching approaches. There was a peak in 2024, when publications on traditional instruction hit 31,800, suggesting increased focus or research momentum in that field. Conversely, contemporary approaches to teaching have exhibited a consistent, incremental increase, mirroring their nascent yet progressive role in schooling. Articles on contemporary teaching peaked in 2024 with 6,890 entries, revealing heightened scholarly interest.

This paper aims to explore the various applications of AI in enhancing teaching performance, highlighting the latest developments, challenges, and best practices. By leveraging the power of Zone of Proximal Development model, educators can create more effective, personalized, and engaging learning environments, ultimately improving student outcomes and preparing them for success in the rapidly changing world.

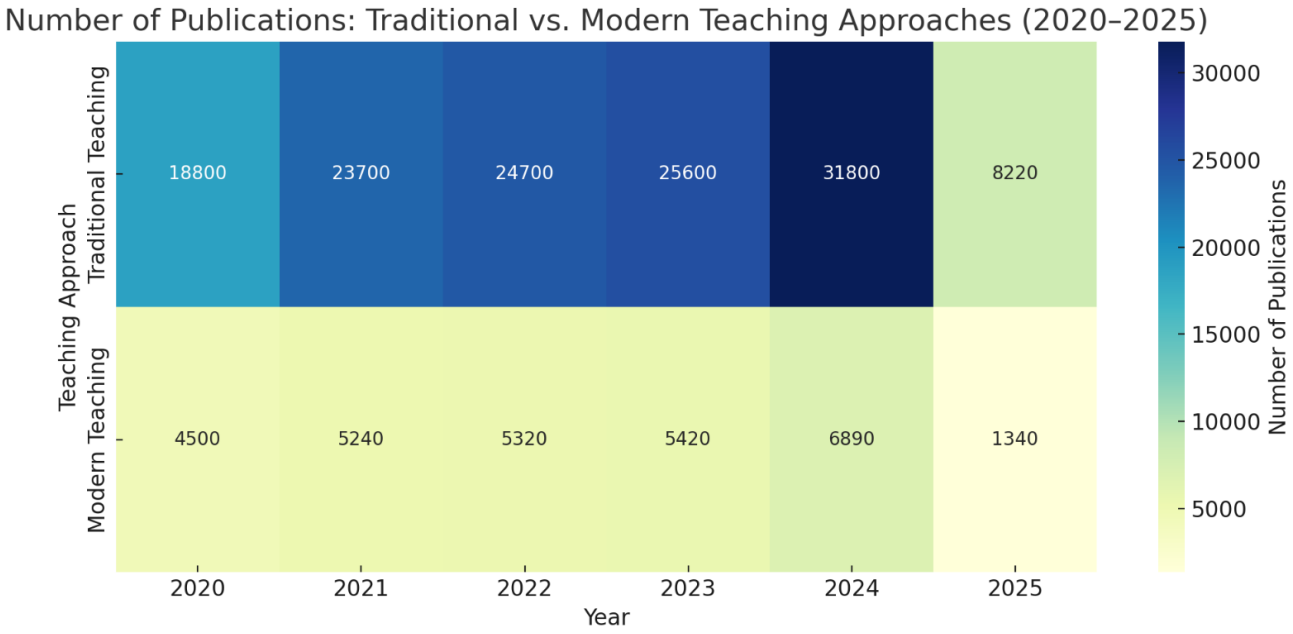

Figure 1: Number of publications on the google scholar related to Teaching method in Education from 2020 to 2025

2. Literature Survey

A multi-method analysis research by Looi (Looi & Jia, 2025) examined interactions of 51 graduate students and a ChatGPT tutor bot on education reforms. Findings suggest that ChatGPT could support personalized learning (PL) by adjusting content to individual needs and promoting deeper understanding. A model of PL affordances through ChatGPT was proposed. Another paper combines Vygotsky's theories with technology-enhanced learning design creativity. It relocates the instructor to the role of an innovative designer who brings pedagogy, content, and technology together within the Zone of Proximal Development. Outcomes underscore the importance of individualizing instruction to students' developmental levels and employing synchronous technologies to enable imaginative learning experiences, drawing on constructivist and cognitive development theories (Rigopouli et al., 2025). Anjali S. (2024) conducted a study on the influence of AI on learning by analyzing the feedback of 38 students and 15 educators.

Using supervised and reinforcement learning methods, the study concluded that AI influences behaviour by scaffolding, personalizing, and challenging. Integration of platforms in the Zone of Proximal Development maximizes learning while minimizing stress and supporting education theories. Wang (Wang et al., 2024) conducted bibliometric reviews and content analyses of 2,223 AI-in-education articles considering types of applications, prominent research topics, and methodologies. The results show various AIED applications, including adaptive learning and intelligent

assessment. It also shows theoretical diversity and interdisciplinary approaches and identifies gaps and future directions for education AI research. Cai (Cai et al., 2024) conducted a systematic review which tested 158 Scopus, Web of Science, and ERIC articles (2021–2024), examining AI in higher education using Vygotsky's ZPD. Findings reveal that AI enhances personalized learning, collaboration, motivation, and academic performance. The review emphasizes ethical application and teacher preparation and calls for longitudinal research on long-term impact. Zaretsky (Zaretsky, 2021) performed an analytical review that recasts Vygotsky's Zone of Proximal Development (ZPD) as being more than the commonly accepted definition of 1935.

The study reveals wider diagnostic and pedagogical applications for ZPD by employing theoretical reconstruction and the Reflection-Activity Approach. It positions ZPD as a methodological device, rather than an explanatory concept. Table 1 summarizes some studies in the literature survey.

Table 1: summarizes some studies in the literature survey.

Author(s), Year	Method	Sample Size	Findings
Looi & Jia, 2025	Multi-method analysis (case study with interactions)	51 graduate students	ChatGPT supports PL by tailoring content and fostering deeper understanding
Rigopouli et al., 2025	Theoretical synthesis and interpretative analysis	Conceptual analysis (no empirical sample)	Teachers act as creative designers in tech-enhanced learning within ZPD
Anjali S., 2024	Survey analysis using supervised and reinforcement learning framework	38 students and 15 educators	AI scaffolds learning, personalizing instruction, and aligns with ZPD to reduce stress
Wang et al., 2024	Bibliometric and content analysis	2,223 articles	AIED used in adaptive learning, assessment; diverse methodologies and gaps noted
Cai et al., 2024	Systematic literature review	158 studies from 2021 to 2024	AI improves PL, motivation, collaboration; calls for ethical use and long-term studies
Zaretsky, 2021	Analytical and theoretical review	Theoretical reconstruction	ZPD is multidimensional and serves as a methodological research tool

3. Zone of Proximal Development (ZPD)

The Zone of Proximal Development (ZPD) is a concept introduced by psychologist Lev Vygotsky to describe the difference between what a learner can do without assistance and what they can achieve with guidance and support from a more knowledgeable individual, typically a teacher or peer. It represents the range of tasks a learner still needs to perform independently but can accomplish with the guidance and scaffolding provided by a more knowledgeable person. In modern teaching approaches, the ZPD is used to inform instructional strategies and promote student learning in several ways:

- Differentiation: Teachers identify each student's ZPD to tailor instruction to their needs and abilities. They can scaffold learning and facilitate student progress by providing challenging but achievable tasks and activities with support.
- Scaffolding: Teachers provide scaffolding, or temporary support, to help students bridge the gap between their current level of understanding and the desired learning outcome. Scaffolding can include modelling, prompts, cues, and feedback tailored to the student's ZPD.
- Collaborative Learning: Peer collaboration is encouraged to leverage the ZPD. Students can work together to support and challenge each other, providing assistance and feedback within each other's ZPD (Al-Hamdani & Al Breiki, 2018).
- Gradual Release of Responsibility: Teachers gradually release responsibility to students as they gain confidence and proficiency. Initially, teachers provided extensive support within the ZPD, gradually reducing support as students become more independent learners.
- Formative Assessment: Formative assessment gauges students' progress within their ZPD and adjusts instruction accordingly. Teachers use ongoing assessment data to identify student strengths and growth areas, providing targeted support and intervention as needed (Al Hamdani D, 2015).
- Zone of Proximal Development Activities: Teachers design activities and tasks that are precisely aligned with students' ZPDs, offering challenges beyond their current mastery level. These activities promote engagement, motivation, and deeper learning as students strive to reach the next level of proficiency.

The ZPD is a guiding principle for educators to create dynamic and responsive learning environments that support each student's growth and development. By recognizing and leveraging the ZPD, teachers can foster meaningful learning experiences that maximize student potential and promote academic success.

4. Research methodology

A robust mixed-methods research design will be employed to comprehensively evaluate the impact of the proposed model, which incorporates AI as a tool, a constructive approach, enhanced learning, interaction, and the Zone of Proximal Development (ZPD) on enhancing student learning levels. This approach will collect and analyze quantitative and qualitative data, allowing for a more comprehensive understanding of the model's effectiveness and the factors influencing student learning.

5. AI constructivism and ZPD

The quantitative and qualitative data will be integrated using various techniques, such as side-by-side comparisons, data transformation (e.g., quantifying qualitative data), or joint displays (e.g., matrices and charts). This integration will comprehensively interpret the findings, highlighting convergences, divergences, and complementary insights from the different data sources. The integrated results will be analyzed to evaluate the effectiveness of the proposed model in enhancing student learning levels and to identify the specific factors or components that contributed to improved learning outcomes. Additionally, the analysis will shed light on the challenges encountered, areas for improvement, and potential modifications or adaptations required to optimize the model's impact.

By combining quantitative and qualitative data collection and analysis techniques (Yousif et al., 2021), this mixed-methods approach will provide a robust and multifaceted understanding of the proposed model's effectiveness. It will capture both measurable learning outcomes and rich contextual insights into the learning experiences and processes facilitated by the integration of AI, constructivism, and the ZPD.

To construct a model incorporating AI as a tool, constructive approach, enhanced learning, interaction, and the Zone of Proximal Development (ZPD) on enhancing student learning levels, you would need to identify and operationalize the relevant variables associated with each of these components. Here's how you could approach this:

a) AI as a tool

- Variables related to the specific AI technologies used (e.g., intelligent tutoring systems, adaptive learning platforms, virtual assistants)
- Variables capturing the functionality and features of the AI tools (e.g., personalization capabilities, real-time feedback, data analytics)
- Variables measuring the usability and accessibility of AI tools (Yousif J., 2013).

b) Constructive approach

- Variables related to the types of constructivists learning activities employed (e.g., project-based learning, problem-based learning, inquiry-based learning)
- Variables capturing the level of active engagement and knowledge construction facilitated by these activities
- Variables measuring students' higher-order thinking skills (e.g., critical thinking, problem-solving, creativity)

c) Enhanced learning

- Variables related to the overall learning experience (e.g., engagement, motivation, satisfaction)
- Variables measuring academic performance and knowledge acquisition
- Variables capturing the level of personalization and adaptation of the learning experience (Yousif et al., 2011).

d) Interaction

- Variables related to the types and frequency of interactions (e.g., student-student, student-teacher, student-content)
- Variables measuring the quality and effectiveness of these interactions
- Variables capturing the collaborative and social aspects of learning.

6. Zone of Proximal Development (ZPD)

A Zone of Proximal Development (ZPD) describes the difference between what a learner can do independently and what they can achieve with guidance and support from a more knowledgeable other (such as a teacher, peer, or digital tool). In essence, the ZPD is the "sweet spot" of learning, where the task is neither too easy nor too difficult, but just challenging enough to promote growth. It emphasizes the importance of scaffolding, where support is

gradually removed as the learner becomes more competent. This concept is central to effective teaching, personalized learning, and adaptive educational technologies as shown in Figure 2.

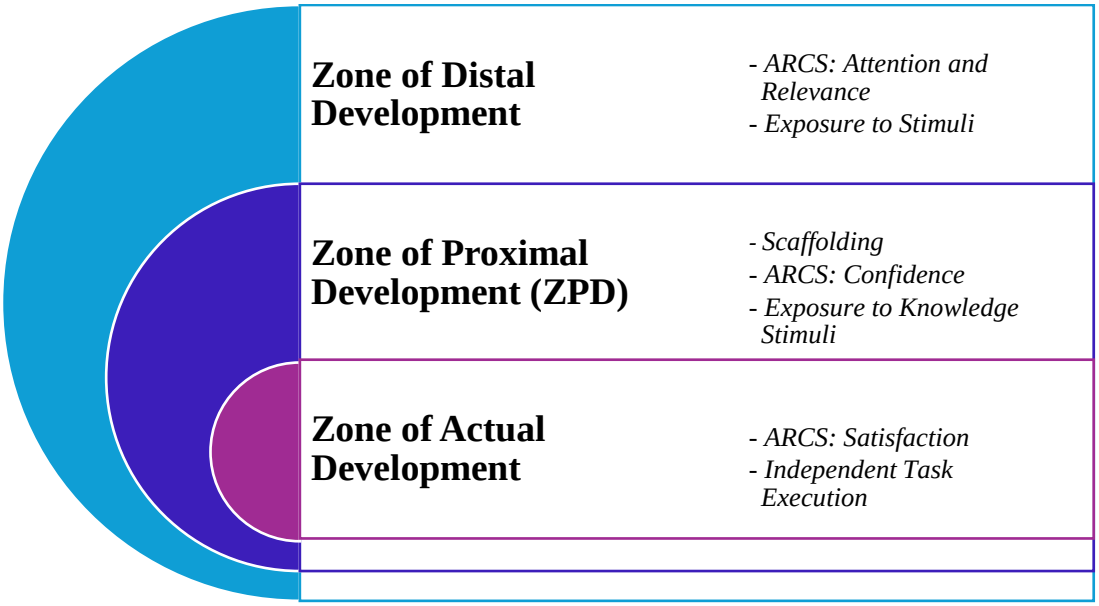

Figure 2: The layers of the Zone of Proximal Development (ZPD)

The layers in the diagram representing the Zone of Proximal Development (ZPD) are as follows (from outermost to innermost):

a) Zone of Distal Development
- *ARCS: Attention and Relevance*
- *Exposure to Stimuli*

b) Zone of Proximal Development (ZPD)
- *Scaffolding*
- *ARCS: Confidence*
- *Exposure to Knowledge Stimuli*

c) Zone of Actual Development
- *ARCS: Satisfaction*
- *Independent Task Execution*

These zones align Vygotsky's developmental theory with the ARCS model of motivation (Attention, Relevance, Confidence, and Satisfaction), emphasizing the progressive transition from guided learning to independent mastery. The Zone of Proximal Development (ZPD) includes scaffolding and confidence-building through guided support and exposure to knowledge. The innermost Zone of Actual Development represents independent task execution and satisfaction, where learners demonstrate mastery without assistance. This visual representation bridges cognitive development theory with motivational strategies to create effective, learner-centered instruction. Three concentric

zones aligned with Vygotsky's theory of learning and the ARCS motivational model. The outermost Zone of Distal Development emphasizes learners' exposure to stimuli that attracts attention and relevance.

7. Analysis and Implementation of ZPD model

The Zone of Proximal Development (ZPD) model, created by Vygotsky, is the zone of difference between what a student can accomplish independently and what he or she can accomplish with guidance. The use of the ZPD model in education gives a solid model for designing differentiated, student-directed instruction that is targeted to individual strength and builds cognitive and motivational development. A closer look at this model reveals three concentric circles: the Zone of Distal Development, the ZPD proper, and the Zone of Actual Development (Margolis A, 2020). These three zones can be designed for instruction in instructional design with scaffolding, adaptive pedagogy, and motivational theory. The Zone of Distal Development symbolizes unrealized potential. Instruction at this level centers on drawing student attention and establishing relevance through ARCS motivational factors—that is, attention and relevance—by introducing students to stimulating cues. This sensitizes learners for cognitive interaction by sparking their curiosity and creating a link with prior knowledge.

The application here consists of incorporating stimulating material, practical examples, and interactive tools such as simulations, gamification, or multimedia learning to grab attention and render learning relevant. The Zone of Proximal Development, the heart of Vygotsky's model, is where the best learning occurs. The instruction provides scaffolding—temporary support structures such as guided practice, hints, modelling, and peer support should be clear and precise (Zaretsky V, 2021). Aligning with the ARCS factor of confidence, learners acquire confidence in their capability as they are given direction that is equated to their needs. Adaptive AI solutions (Saini D, 2021). can be employed here to deliver tailored content and feedback, while teachers' formative assessment and questioning strategies are utilized to adjust support. Structured cooperative learning, mentoring, and guided feedback can help students progress from dependence to autonomy as shown in Figure 3.

The Zone of Actual Development is an accomplishment where students can complete tasks independently (Xie et al., 2023). This is similar to ARCS satisfaction, where students feel accomplishment and internal satisfaction. Implementation strategies include supporting self-learning, providing open-ended tasks, and permitting students to reflect on their accomplishments. Performance monitoring metrics and learning analytics can help teachers monitor progress and guarantee independence. In measuring and deploying the ZPD model effectively, educators and scholars should operationalize a number of striking variables: the amount of scaffolding, compatibility with learner readiness, and developing self-regulation. Both quantitative and qualitative methods can be utilized for data collection: quantitative approaches, such as measures of performance and use records of online aids, and qualitative metrics, such as rubrics of observation, learner self-assessments, and interviews. Using such an expansive approach, instruction would be both intellectually valid and motivationally engaging, sparking scholarship achievement within the learner's individual ZPD. Linking the Zone of Proximal Development (ZPD) to modern AI education tools offers a revolutionary path towards adaptive, interactive, and personalized learning environments. Vygotsky's concept of the ZPD emphasizes the importance of supported learning via scaffolding, where students can progress from what they can do independently to what they can achieve with expert support (Volkmar F, 2021). Artificial Intelligence (AI)

technologies—such as intelligent tutoring systems, adaptive learning systems, and Large Language Models (LLMs) (Milano et al., 2023)—are specifically well-positioned to serve as digital "scaffolders" within a learner's ZPD (Malik et al., 2023).

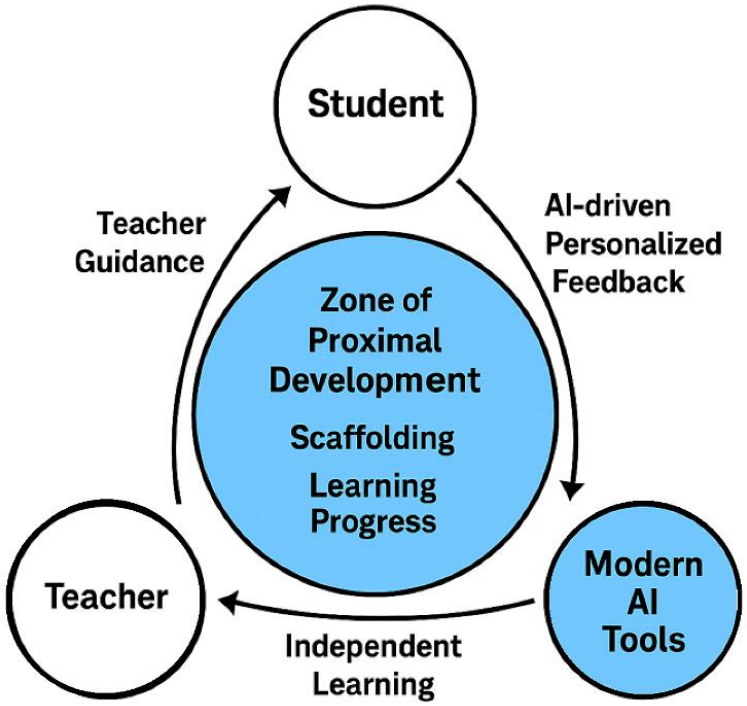

Figure 3: Interaction relationship model (Student, Teacher, AI, ZPD)

AI technologies are able to dynamically assess the current level of a student and adjust content difficulty in real-time so that teaching precisely aligns with their cognitive zone. For example, AI-based platforms like Khan Academy or Century Tech use data analysis and machine learning to supply personalized feedback and problem sets to learners to help bridge the gap between current knowledge and potential mastery. Large Language Models like ChatGPT can mimic one-to-one tutoring, instructional dialogue, and immediate query response, mimicking social interaction that Vygotsky believed essential for learning within the ZPD. In addition, AI systems can monitor learner engagement and provide motivational supports that align with the ARCS model (Attention, Relevance, Confidence, Satisfaction), which is structurally isomorphic to the layered ZPD framework. Through targeted prompts, positive feedback, and challenge calibration, AI tools enable improved cognitive development, build learners' confidence and autonomy, and eventually guide them into the Zone of Actual Development (Sætra H, 2025). In this way, AI functions as a cognitive and motivational facilitator within the ZPD, actualizing Vygotsky's theoretical model in today's classrooms. Based on the analysis of learning and ZPD models, the study suggests a conceptual model as shown in Figure 4. The Figure displays the interaction between students, teachers, modern AI tools, and the Zone of Proximal Development (ZPD) in an interactive learning context. The learner is in the middle, supported by both teachers and modern AI tools, representative of a hybrid approach to education. The Zone of Proximal Development is situated as the proximal zone

of scaffolded learning—at which learners can perform more with assistance than independently. Both instructors and AI systems make contributions to the ZPD by providing personalized feedback, scaffolding, and instructional support that enables the learner to fill current gaps between current capacity and potential development. Scaffolding, under the influence of direction, leads to measurable learning progress, which in turn makes a contribution to the student's experience through personalized feedback mechanisms (Xu et al., 2025).

This model demonstrates how ZPD, with the support of AI and human direction, bridges the gap between what students can do on their own and what they can do with support. The Student, Teacher, and Modern AI Tools converge in the Zone of Proximal Development, where learning is most effective when supported. Within the ZPD, Scaffolding is provided through Teacher Guidance and AI-powered Personalized Feedback. Such scaffolding produces measurable learning progress, eventually leading to independent learning, which is the ultimate goal of education development. The cycle comes back to the Student, who develops their abilities by way of learning progress, increasing their real development zone. As students grow in confidence and competency within the ZPD, they progress to independent learning, illustrating Vygotsky's concept of internalizing learning through scaffolded learning. The introduction of modern AI tools into this setting reflects the increasing presence of adaptive technologies in instructional personalization and engagement. It represents the synergistic model whereby human expertise and intelligent systems interact to empower learners, foster autonomy, and facilitate continued movement through the ZPD towards full cognitive development.

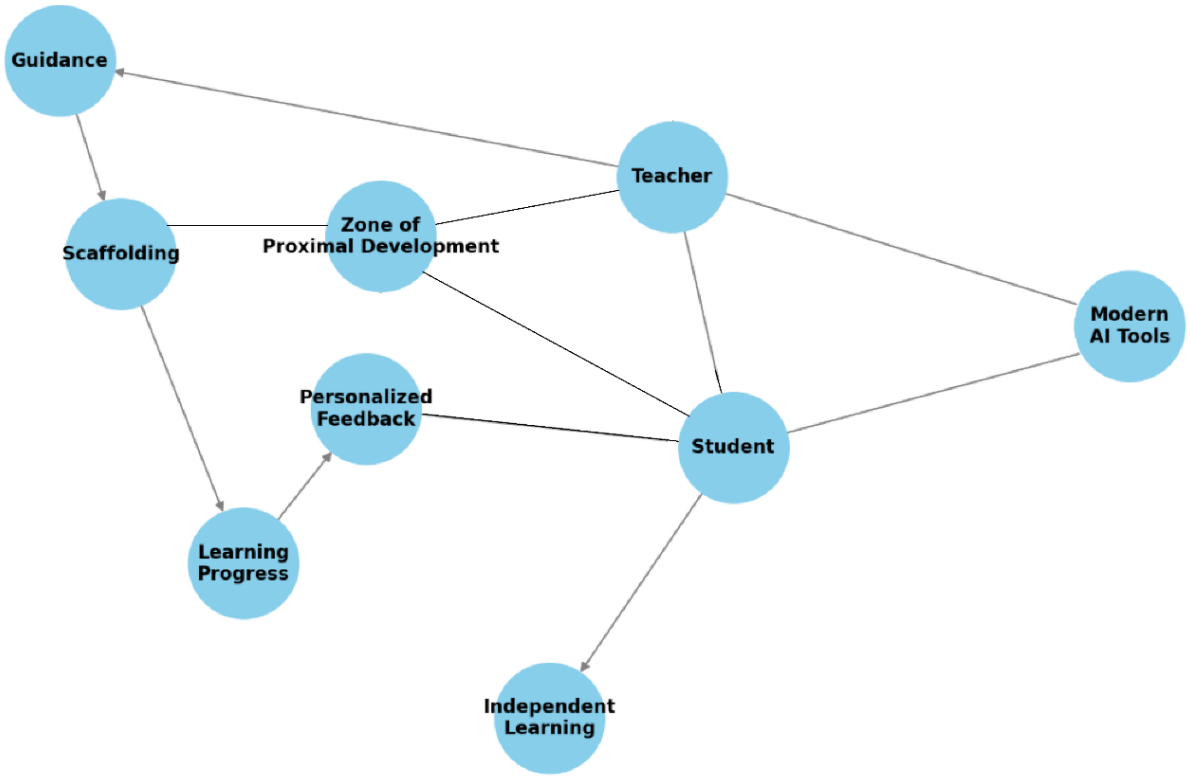

Figure 4: The relationship between Student, Teacher, ZPD, and Modern AI Tools.

8. Conclusion

A The focus of this paper is implementing Vygotsky's Zone of Proximal Development (ZPD) in synergy with current AI technologies and instruction by teachers to maximize student learning outcomes. It suggests a conceptual model that illustrates how student-teacher-AI educational technology interplay creates an adaptive learning environment in which scaffolding, customized feedback, and adaptive pedagogy can guide learners toward independence. By closing the gap between what students can accomplish independently and what they can accomplish with assistance, this model reflects an inclusive and forward-looking vision for learning.

The model shows that the learners are at the center of this model, and an ecosystem surrounds them that adapts to their needs. Teachers deliver critical pedagogical content, teachers deliver emotional support, and teachers deliver contextual intelligence. On their part, AI technologies such as intelligent tutoring systems, learning software that can adapt, and large language models (LLMs) offer dynamic, data-sourced insights and recommendations that guide students throughout the learning journey. The convergence of these supports within the ZPD ensures that the learning remains challenging but accessible, tailored, and engaging.

The model emphasizes the importance of scaffolding, not just as a temporary crutch but as a process that breeds confidence, independence, and long-term growth. As students demonstrate learning gain and independence, they cycle back into the process of learning with more challenges and opportunities, constantly expanding their zone of actual development.

This integrated model has broad-based implications for education today. It encourages inclusivity, efficiency, and sustainability in learning environments. The joining of human and artificial intelligence enables instructors to offer scalable, personalized guidance while students have responsive and interactive experiences. Longitudinal research should be the priority in future studies to evaluate the long-term impacts of this blended model on student achievement, intellectual development, and student motivation. Ultimately, the pedagogical alignment with AI-supported ZPD models has the potential to transform education into a more enabling, equitable, and innovative experience for all learners.

It's important to note that the development of a comprehensive model may involve an iterative process, where initial data collection and analysis inform refinements to the variables and measures, leading to further data collection and model refinement. Additionally, validation and testing of the model using different contexts, settings, or populations may be necessary to ensure its robustness and generalizability. Here are some examples of how AI can be employed to improve the teaching process:

- Personalized Learning: AI algorithms can analyze student data, such as learning styles, strengths, weaknesses, and progress, to create personalized learning paths and tailor educational content to individual student needs. This can improve engagement, understanding, and overall learning outcomes.
- Intelligent Tutoring Systems: AI-powered tutoring systems can provide real-time feedback, adaptive guidance, and interactive learning experiences. These systems can adjust the difficulty level, pace, and teaching approach based on the student's performance, mimicking the role of a human tutor.

- Automated Grading and Feedback: AI can automate the grading process for assignments, quizzes, and exams, saving teachers valuable time. Additionally, AI can provide detailed feedback on student work, identifying areas for improvement and offering personalized suggestions.
- Content Generation and Curation: AI algorithms can assist teachers in generating educational content, such as practice questions, exercises, and learning materials tailored to specific learning objectives and student needs. AI can also help curate and recommend relevant educational resources from various sources.
- Student Engagement and Motivation: AI-powered virtual assistants or chatbots can interact with students, answer their questions, and provide motivational support, fostering a more engaging and interactive learning environment.
- Learning Analytics: AI can analyze student data, such as engagement levels, performance metrics, and learning patterns, to provide teachers with valuable insights and recommendations for improving their teaching strategies and identifying areas where students may need additional support.
- Adaptive Assessments: AI-driven adaptive assessments can adjust the difficulty level and content of questions based on a student's performance, providing a more accurate evaluation of their knowledge and skills.
- Language Learning: AI-powered language learning applications can provide personalized feedback on pronunciation, grammar, and vocabulary and engage students in conversational practice through virtual assistants or chatbots.

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