



The Potential of Using AI to Improve Student Learning in STEM: Now and in the Future

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Shin, N., Haudek, K., & Krajcik, J. (2025). The potential of using AI to improve student learning in STEM: Now and in the future. Community for Advancing Discovery Research in Education (CADRE). Education Development Center, Inc.

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Community for Advancing Discovery Research in Education

IANILARY 2025



Introduction

Brief Topic: Student Learning leveraging AI in STEM Education

Transforming Teaching and Learning: AI has been introduced to improve learning experiences and outcomes.

- Interactive Communication: Human-like text interacting with students and educators
- Personalized Support: real-time, personalized feedback to support individual student progress
- Customized Learning: Adaptive learning materials to meet individual needs

While AI offers potential, careful integration is essential to effectively support student learning in STEM education.



Driving Questions

How can AI support all students in developing a deep integrated understanding of STEM and enhancing engagement and interest in STEM?

- 1. Discuss goals for K–12 STEM education
- Present learning and motivational theories that drive our view of how AI should be used in K–12
 STEM education
- 3. Describe the potential functions of AI in support of student learning





AI as a learning partner

A learning partner is a person or entity that collaborates with another individual to enhance thinking, creativity, problem-solving, learning, or motivation.

Scaffolding learning as a developmental process



Utilizing AI to support learners in developmentally appropriate ways

 Provide support materials, encouraging hints, offering language support, or prompting self-reflection



Goals of STEM Education

Knowledge-in-Use

 Developing abilities to apply their knowledge to explain phenomena, solve real-world problems, and make informed decisions

Integrated Understanding

- Synthesizing relationships and connections among ideas and personal experiences
- Ongoing process of linking new ideas with existing knowledge and experiences

Fostering Integrated Understanding

- Cognitive development
- Metacognitive skills and strategies
- Motivational and emotional engagement
- Collaboration and discourse skills



Theoretical Foundations

Situated Cognition

- Authentic real-world context
- Seeing value in the cognitive work

Active Construction

- · Using and applying knowledge
- Experiencing phenomena
- Making meaning

Motivational and Emotional Variables

- Attitude
- Value
- Interest
- Cognitive and emotional engagement

Metacognition

- Knowledge of cognition
- Knowledge of regulation

Distributed Cognition

- Work collectively across individuals, tools, and the environment
- Share and shape knowledge between humans and their tools

Social Interaction

- Collaborative interactions with peers and more knowledgeable others
- Content-specific discourse

Cultural Foundations of Learning

- Cultures
- Home and communities
- Cultural resources

Supports from a Learning Partner

Cognitive Supports

- Promote integrated understanding of core ideas
- Promote integrated understanding of scientific practices
- Offer actionable, constructive, and comprehensible feedback

Motivation and Emotional Supports

- Promote emotional and cognitive engagement
- Align with values
- Promote situational engagement
- Offer timely and personalized feedback

Metacognitive Supports

- Promote self-evaluation
- Promote self-regulation
- Promote self-monitoring
- Promote task completion and performance progress

Collaboration and Discourse Supports

- Help students take part in discourse
 Help students listen to a different
- perspective
- Help students to synthesize various points of view and ideas

Generative AI as a Learning Partner

Adaptive Learning System to monitor learners' progress and provide personalized support based on learners' needs, characteristics, and preferences.

AI Cognitive Supports

 Provide timely feedback on learners' performance, including actionable suggestions for improving their performances

AI Motivational and Emotional Supports

 Develop learning materials based on individual needs, preferences, and characteristics

Al Metacognitive Supports

- Support learners to design their learning plan, activities, or assessment based on their knowledge
- Provide performance progress visually to review their learning

AI Collaborative and Discourse Supports

 Monitor discourse participation, analyze collaboration patterns, and prompt learners on how to improve their involvement

Outcomes

Student Learning

- Increased performance in applying STEM knowledge to make sense of phenomena
- Increased performance in applying STEM knowledge to solve illstructured problems and make informed decisions

Motivation and Emotion

- Increased engagement to explore STEM using scientific practices
- Increased value for STEM
- Increased interest in future STEM studies and careers

Metacognition

- Increased ability to learn more when needed
- · Increased ability to self-monitor

Collaboration

Increased student collaboration

Distal Outcomes

- Increased achievement
- Increased STEM career
- Increased skill in solving complex STEM problems related to societal issues
- Develop STEM identity

AI as a Learning Partner



AI to Support Personalized Learning

Personalized learning

• Learning contexts and materials based on an individual learner's needs and provides guidance or support in a timely manner (National Research Council, 2000)

Distributed Intelligence

• Emphasizes the interaction between internal cognitive processes and external resources (Pea, 1993)

Lessons Learned and Limitations of Current AI approach

- Adaptive learning system to provide individual needs
- Give predefined or programmatic responses or paths
- Use limited data about the learner to make predictions

Generative AI for Personalized learning

- Expand our research and development AI in K-12 education in transformative ways
- Variety of real-time supports appropriate to students' needs at a given moment
- Use various data: facial expressions, nonverbal bodily motion, lip-synchronized speech, and interactions with others





AI as a Learning Partner: Cognitive Support

Strategies

• Hints, sentence starters, breaking down complex tasks into steps, providing organization structures

Current use of AI

- Provide students real-time feedback about explanations and modeling as part of three-dimensional learning and assessment
- Utilize virtual reality and embodied AI with sensors to evaluate and improving nursing students' skill execution.

Potential use of Generative AI

- Conversational AI, enhance chatbots by making them more contextual and producing more natural interactions in feedback and problem solving
- Customization of difficulty levels or embodied agents in simulations, games, or AR for learners





AI as a Learning Partner: Metacognitive Support

Strategies

- Prompting self-reflection on students own learning strategies and outcomes
- Provide reminders and checklists to ensure learners have reviewed their work

Current use of AI

 Classifying problem solving strategies in physics to provide formative feedback to students

Potential use of Generative AI

 Offer prompts while monitoring student learning using heterogeneous data (e.g. eye tracking) and learning activity data (e.g. log files)





AI as a Learning Partner: Motivational and Emotional Support

Strategies

- Link content and tasks to community issues or student interests
- Offering students a variety of relevant topics and activities to choose

Current use of AI

- Monitoring student engagement with interactive Intelligent Science Stations, based on student actions
- Use GenAI-based agent to suggest follow up materials based on student interest and evaluate interest in STEM careers

Potential use of Generative AI

- AI-customized lessons based on student interests, choices, context and history
- Monitoring of heterogenous data to switch AI based agent prompting or feedback





AI as a Learning Partner: Collaboration and Discourse Support

Strategies

 Encourage learners to listen, consider other ideas. Prompt follow up questions about ideas and reasoning and elicit input from all group members

Current use of AI

- Examining group discourse when interacting with a virtual learning companion
- Monitor group discourse and engagement to help students persist in problem solving

Potential use of Generative AI

- Analyzing group discourse to encourage learners to consider previous ideas or prompt learners for reasoning or a contribution
- Voice analytics to identify disputes or ensure constructive dialogue





Future Directions: A Bright but Challenging Future

- Supporting a broad range of learners
- Role of teachers in AI-enhanced learning environments
- Need for future research
 - When and How to use Generative AI supports
 - Transferring learning experiences with AI between informal and formal settings
 - Promoting fairness and minimizing biases
 - Potential for AI agents to increase inclusivity in STEM education





- AI has the potential to serve as a personalized learning partner, providing various supports, to promote Knowledge-in-Use.
- Generative AI is not additive but rather transformative
 - Students actively construct and expand their knowledge to explore phenomena and solve complex problems
- Significant work remains to ensure this promise is realized equitably and effectively



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This work is partially based upon work supported by the National Science Foundation (Grant Numbers 2200757, 2100964, & 2201068). Any opinions, findings, and conclusions or recommendations expressed in this presentation are those of the presenters and do not necessarily reflect the views of the National Science Foundation.



Thank you

Questions?

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Shin, N., Haudek, K., & Krajcik, J. (2025). *The potential of using AI to improve student learning in STEM: Now and in the future. Community for Advancing Discovery Research in Education (CADRE)*. Education Development Center, Inc.

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