

# RISE OF THE MACHINES: NAVIGATING THE OPPORTUNITIES AND CHALLENGES OF AI-ASSISTED RESEARCH AND LEARNING

## ASCENSO DE LAS MÁQUINAS: NAVEGANDO LAS OPORTUNIDADES Y DESAFÍOS DE LA INVESTIGACIÓN Y EL APRENDIZAJE ASISTIDO POR IA

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*This commentary was written by ChatGPT, an artificial intelligence language model developed by OpenAI. It was conceived by the first author as a test for how the advent of predictive language modeling will create opportunities and challenges for researchers and teachers in mathematics education. The paper consists of a commentary that was written by ChatGPT, followed by a reflection written by the authors that explains how the model was prompted to generate the text and how we worked with ChatGPT to validate and edit the text that was produced. We consider the implications of models like ChatGPT on the future of academic work.*

Advances in artificial intelligence (AI) have created new opportunities for education and learning. Machine learning algorithms, natural language processing tools, and language models such as GPT-3 have been used to create personalized and engaging learning experiences for students (Blikstein et al., 2021). For example, AI-powered systems can analyze student data to identify areas of weakness and provide targeted feedback (D'Mello & Graesser, 2012). These technologies have been applied to mathematics education with promising results, including improved student performance on math assessments. However, while AI can enhance personalized learning experiences, it also presents new challenges for educators, who must adapt to new teaching methods to effectively utilize these technologies for improved student outcomes (Molnár & Csapó, 2019).

As the world becomes increasingly reliant on technology, it is essential that education keeps pace. This paper delves into the exciting and rapidly evolving field of AI in math education, investigating how cutting-edge technologies can revolutionize the way we engage with and teach mathematics. By harnessing the power of machine learning and natural language processing, we can create personalized and dynamic learning experiences that cater to the needs of every individual student, paving the way for a brighter and more inclusive future in math education. Specifically, we will examine strategies for engaging students in math learning (Fredricks et al., 2004), the design of learning environments and tools that take students and learning into account (Hmelo-Silver et al., 2007), and the importance of building partnerships with schools and the community to support student engagement and learning. We will also discuss the research agenda needed to ensure that all students reach their potential by paying attention to engagement and learning needs. By addressing these issues, we can help ensure that all students have the opportunity to develop the math skills they need to succeed in their academic and professional lives.

### **I. Engaging Students in Mathematical Learning with AI**

Engagement in the context of students learning mathematics refers to the degree of interest, involvement, and active participation exhibited by students in mathematical activities, tasks, and learning experiences. It encompasses their emotional, cognitive, and behavioral investment in the learning process and their willingness to persist and put forth effort in understanding mathematical

concepts (Linnenbrink-Garcia & Pekrun, 2011). To ensure that students develop the skills and knowledge they need to succeed in math, it is critical to engage them in the learning process (Fredericks, Blumenfeld, & Paris, 2004; Henningsen & Stein, 1997; Marks, 2000; Wang & Eccles, 2012). Engaged students are more likely to persist in the face of challenges, actively seek out and utilize feedback (Fredericks et al., 2016), and make connections between mathematical concepts (Hiebert & Grouws, 2007). These behaviors are important for deepening students' understanding of mathematical concepts and building their problem-solving skills, which are essential for success in math and beyond.

There is a growing body of research that highlights the role that AI can play in promoting engagement. Recent studies have shown that AI-based math tutoring systems have the potential to engage students in mathematics learning. For instance, The ASSISTments platform is an AI-powered math tutoring system designed to bring together scientists and teachers for research on effective learning and teaching. It provides a collaborative environment where researchers can conduct minimally invasive studies while students receive personalized feedback and support in their math learning. The platform aims to engage students in mathematics, facilitate research, and improve educational outcomes by leveraging the power of AI and data analytics (Heffernan & Heffernan, 2014). The use of AI-based tutoring systems has also been shown to promote student engagement through personalized learning experiences that adapt to the unique needs and abilities of each student (D'Mello & Graesser, 2012). These systems provide instant feedback, scaffolded support, and opportunities for practice and review, which can increase motivation and engagement in math learning (Graesser et al., 2017; Koedinger & Aleven, 2007). However, these traditional AI-based tutoring systems are often designed with pre-defined contexts and learning objectives, limiting the spontaneity and flexibility of student interactions. In contrast, models like ChatGPT have the potential to create more unstructured and open-ended math learning opportunities, where students can explore their own mathematical questions and curiosities.

Designing tasks that leverage ChatGPT's conversational abilities to promote math learning requires careful consideration of learning goals, task structure, and assessment. For example, a task could be designed to require students to engage in a "math chat" with ChatGPT, prompting students to ask questions, provide explanations, and explore mathematical concepts in a conversational manner. One potential learning goal of such a task could be to promote mathematical curiosity and exploration, by encouraging students to ask questions and engage in dialogue with ChatGPT. Another learning goal could be to develop students' ability to communicate mathematical ideas effectively, by prompting them to explain concepts in plain language.

Task design should take into account the unique features and limitations of ChatGPT's conversational abilities. For example, the system may struggle with abstract or complex mathematical concepts, so tasks should be designed to focus on more concrete and accessible topics. Additionally, assessments should be designed to evaluate both the quality of students' mathematical thinking and the effectiveness of their communication with ChatGPT.

Some specific examples of assessments could include:

(1) *Written responses to math problems*: Students could be given a math problem to solve and asked to write out their solution, along with a short explanation of their reasoning. ChatGPT could then provide feedback on the students' solutions and explanations, and students could revise and resubmit their work as needed.

(2) *Conversational transcripts*: Students could engage in a "math chat" with ChatGPT and have the conversation transcribed. The transcript could then be evaluated for the quality of the students' mathematical thinking and the effectiveness of their communication with ChatGPT.

(3) *Project-based assessments*: Students could be given an open-ended task that requires them to use ChatGPT to investigate a mathematical concept or solve a real-world problem. The students could then present their findings, including their use of ChatGPT, in a written or oral presentation.

These assessments would allow teachers to evaluate students' understanding of mathematical concepts, as well as their ability to communicate and collaborate with ChatGPT in a meaningful way. While ChatGPT has potential as a tool for engaging students in math tasks, it is important to note that the technology is not perfect and may sometimes provide incorrect or incomplete responses. This could be problematic for students who are not familiar with ChatGPT's limitations and may rely too heavily on its responses.

To address this potential issue, assessments could be designed that not only evaluate students' ability to communicate and collaborate with ChatGPT but also their ability to recognize and correct errors. For example, a task could ask students to work through a set of math problems with ChatGPT and to identify and correct any incorrect responses given by the system. This would not only provide valuable feedback to the student but also help them to develop critical thinking skills and a deeper understanding of mathematical concepts.

Another approach could be to design assessments that include both ChatGPT and traditional classroom instruction, allowing students to compare and contrast the responses provided by each. This would help students to better understand the strengths and limitations of ChatGPT, and to develop the skills needed to use it as a valuable learning tool.

Overall, by designing assessments that take into account the limitations of ChatGPT and the need for students to develop critical thinking skills, teachers can ensure that students are not only engaged in math learning but are also developing a deeper understanding of mathematical concepts.

## **II. AI and the design of student-centered tools and learning environments**

One of the most significant challenges in teaching mathematics is creating an engaging learning environment that fosters student interest and motivation. Hmelo-Silver et al. (2007) argue that effective learning environments should incorporate features such as authentic tasks, collaboration, and self-directed learning. Researchers and educators have explored the design of learning environments and tools that take into account students' needs, interests, and backgrounds. For example, AI-based tools and curricula design features can also be leveraged to support student engagement and interest in learning mathematics. Adaptive learning systems such as ALEKS (Assessment and LEarning in Knowledge Spaces) use AI algorithms to identify gaps in students' understanding of mathematical concepts and provide personalized learning pathways to address those gaps (Cavanagh et al., 2016).

AI-based tools can enhance the design of learning environments by providing students with personalized and adaptive learning experiences. Intelligent tutoring systems that provide real-time feedback and scaffolding have been shown to improve student learning outcomes (VanLehn et al., 2005). For instance, systems that use machine learning algorithms can adapt to the student's level of knowledge and provide tailored instruction and feedback (Baker et al., 2008). Similarly, the use of chatbots like ChatGPT can provide students with immediate and personalized support, allowing them to engage in more open-ended mathematical inquiries and enhancing their problem-solving skills.

Personalized and adaptive learning experiences, such as those offered by intelligent tutoring systems and educational games, have been shown to enhance student motivation and engagement (Graesser et al., 2018). By designing learning environments and tools that take into account students' needs and interests, educators can promote student engagement and interest in mathematics. The development of AI-based tools such as ChatGPT has opened up new possibilities for designing math learning tools and curricula that take into account the needs and interests of individual students (Hmelo-Silver et al., 2007). By leveraging the natural language processing and machine learning capabilities of ChatGPT, math educators can design learning environments that personalize and adapt to students' unique needs and abilities. For example, ChatGPT could be used to design interactive, dialogue-based math learning experiences that are tailored to individual students' interests and abilities. Additionally, ChatGPT can provide real-time feedback and support to students as they work through math problems, helping to identify areas where students are struggling or excelling and providing targeted feedback and support (Graesser et al., 2018). With these capabilities, ChatGPT has the potential to transform traditional math learning environments into highly personalized and engaging learning experiences that support student interest, motivation, and achievement.

### **III. AI and school-community partnerships**

Artificial intelligence-based tools like ChatGPT can create new avenues for communities to come together with schools and research centers to enhance the learning and teaching of mathematics. Such tools can facilitate communication and collaboration between different stakeholders in the education community, including students, teachers, parents, and researchers. AI-based tools like ChatGPT can help bridge the gap between traditional and informal learning environments. For example, the Scratch programming language was developed by researchers at MIT as a way to engage children in creative coding activities and foster their computational thinking skills (Resnick et al., 2009). Scratch has become a popular tool for both formal and informal learning, with users ranging from K-12 students to adult learners. ChatGPT can serve a similar purpose in the math education community, allowing students to engage in open-ended problem-solving and creative thinking activities outside the traditional classroom setting.

AI-based tools like ChatGPT have the potential to facilitate community partnerships, enable the sharing of data and resources, and bridge the gap between traditional and informal learning environments. By providing immediate and personalized support to students, ChatGPT can help build their confidence and motivation to learn mathematics, while also creating new opportunities for collaboration and innovation in math education.

But with great power comes great responsibility. As educators and researchers explore the potential of AI in math education, it is crucial to consider the ethical, privacy, and security implications of using these tools. One important concern is the use of student data, which may include sensitive information about their learning abilities, preferences, and backgrounds. AI models like ChatGPT may be able to build profiles of individual students or communities, which could be used to make decisions about their educational opportunities, but also raise concerns about data privacy and bias. Additionally, there is a risk of students becoming too reliant on AI-based tools and losing the ability to think critically or independently about math concepts. Therefore, it is important for educators and researchers to carefully consider the potential benefits and risks of using AI-based tools like ChatGPT and to design appropriate policies and safeguards to protect the privacy and security of student data while also promoting a culture of ethical and responsible AI use in math education.

#### IV. A Research Agenda for AI and Mathematics Education

As the use of AI in mathematics education continues to evolve, there are several key research questions that need to be addressed in order to fully understand its potential for enhancing student engagement and learning:

(1) *What are the most effective ways to design AI-based tools and curricula that can support student learning outcomes, and how can personalized learning experiences and feedback be provided through AI-based tutoring systems, chatbots, and other tools?* One of the most fundamental questions concerns how to design AI-based tools and curricula that can effectively support student learning outcomes. For example, research is needed to explore the most effective ways to personalize learning experiences and provide feedback through AI-based tutoring systems, chatbots, and other tools.

(2) *What is the relationship between AI and student motivation, and how can AI-based tools and curricula be designed to foster a love for mathematics?* Another important area of inquiry concerns the impact of AI on student motivation and interest in mathematics. While AI has the potential to make learning more engaging and exciting, it is unclear how this technology affects student perceptions of mathematics and their motivation to learn. Research is needed to understand the relationship between AI and student motivation, and how to design AI-based tools and curricula that foster a love for mathematics.

(3) *How can the use of AI-based tools and curricula in mathematics education be designed to promote equity and reduce disparities in academic achievement among students from diverse backgrounds?* As the use of AI in mathematics education continues to expand, it is crucial to consider the implications for equity and access. AI-based tools have the potential to both exacerbate existing inequalities and to mitigate them. To ensure that AI-based tools and curricula support equitable outcomes for all students, it is important to conduct research on how these tools impact learners from diverse backgrounds. For example, research can investigate the extent to which AI-based tools provide equal access to learning opportunities for students with disabilities, students from low-income families, and students from underrepresented racial and ethnic groups. Additionally, research can explore ways to use AI to address these inequities, such as by providing personalized support and feedback to students who are traditionally underserved by the education system. Overall, research is necessary to ensure that AI-based tools and curricula are designed and implemented in ways that promote equitable outcomes for all learners.

In addition to these questions, there is a need for research on how to integrate AI-based tools and curricula into existing classroom settings. This includes questions about how to train and support educators to effectively use AI-based tools, how to design curricula that incorporate AI-based features, and how to ensure that students have equitable access to AI-based learning resources. To address these and other open questions, a range of research methods and approaches will be needed. This includes experimental and quasi-experimental designs to evaluate the effectiveness of AI-based tools and curricula, as well as qualitative methods to explore the attitudes and experiences of students, educators, and other stakeholders. Additionally, mixed-methods approaches can provide a more comprehensive understanding of the potential of AI in mathematics education.

In terms of research priorities and future directions, it will be critical to continue exploring the potential of AI in mathematics education, particularly in the areas of personalization, motivation, and equity. Additionally, research is needed to examine the potential of AI to support higher-order thinking and problem-solving skills in mathematics, as well as to explore the ethical and social implications of AI use in education. Finally, continued collaboration between mathematics

educators, AI researchers, and industry partners will be critical to advancing the field and ensuring that AI is used to support, rather than replace, human teachers and educators.

## V. Conclusion

Artificial intelligence (AI) has the potential to revolutionize the way we teach and learn mathematics. By providing personalized support to students, enabling collaboration between different stakeholders in the education community, and facilitating the sharing of data and resources, AI-based tools like ChatGPT can create new opportunities for engaging students in math learning. However, there are still many open questions and challenges to address in order to fully realize the potential of AI in mathematics education. In this paper, we have discussed the key ways in which AI can create opportunities for engaging students in math learning and have highlighted several research priorities for the future.

One of the main themes that emerged from our discussion is the importance of personalization in mathematics education. AI-based tools can be tailored to individual student needs, providing immediate feedback, and adapting to the pace and learning style of each student. Additionally, AI can help educators identify areas where students may be struggling and provide targeted support. However, there is a need for research to understand the most effective ways to design AI-based tools and curricula that can support student learning outcomes and foster a love for mathematics.

Another key theme is the importance of collaboration between different stakeholders in the education community. AI-based tools can facilitate communication and collaboration between students, teachers, parents, and researchers. Additionally, AI can enable the sharing of data and resources across different educational institutions and organizations, which can lead to more effective teaching and learning. However, there is a need to address issues related to equity and access, as not all students may have equal opportunities to use AI-based tools and resources.

In conclusion, AI-based tools like ChatGPT have the potential to transform mathematics education by providing personalized support to students, enabling collaboration between different stakeholders, and facilitating the sharing of data and resources. However, there are many open questions and challenges that need to be addressed in order to fully realize the potential of AI in mathematics education. It will be critical to continue exploring the potential of AI in mathematics education, particularly in the areas of personalization, motivation, and equity, and to ensure that AI is used to support, rather than replace, human teachers and educators.

## Authors' Reflection

We generated this paper by iteratively prompting ChatGPT. Our initial idea was to ask ChatGPT to work with us to write a research commentary on the use of AI in mathematics education. We used the five questions that elaborate the conference theme as an initial prompt (e.g., *How can we engage all students to learn math content by building on their interest and motivation to learn?*). This was intended to provide the general context for how ChatGPT should generate its responses. ChatGPT used these questions to generate an outline for a seven-section paper (an intro, a conclusion, and one section for each of the five questions). We then went section-by-section, prompting ChatGPT to generate text.

Each section was generated through iterative prompting, in an example of what has been described as *prompt engineering* (White et al., 2023), though we did not follow any formal procedure for how the prompts were refined. Typically, ChatGPT's initial draft for a section was generic and did not include any citations to academic literature. To refine the text, we indicated what aspects of the response we liked and then instructed ChatGPT to be more specific and make explicit connections to the research literature.

For example, for the section on student engagement, ChatGPT's initial text did not include any references to specific AI tutoring projects. We prompted ChatGPT first to name specific examples of such tutors; then, once the tutors were identified, we prompted ChatGPT to provide references to research literature about them (in APA 7 format); finally, we prompted ChatGPT to assemble all of the pieces. A specific example of such a prompt, for the case of AI-tutoring systems, is: *with citations to the examples of AI tutoring systems you provided above, please write 1-paragraph that synthesizes what the research has shown about how AI-tutors engage students in learning mathematics.* We also made suggestions for ideas it could develop, such as the activity of a "math chat" and the sample assessments.

An initial draft of the paper was generated by the first author during a 3-hour chat. The second author then reviewed the draft, taking particular care to check that the research literature was accurately referenced. There were several instances where ChatGPT provided irrelevant or inaccurate references. For example, in the initial draft, ChatGPT misattributed a direct quote. For these and other errors flagged by the second author, the first author prompted ChatGPT to review the erroneous text. Here is an example of one such exchange:

*Author 1:* would you please double check this reference: "Henningesen and Stein (1997) argue that "student engagement is an important and necessary condition for learning" (p. 431)"

*ChatGPT:* The quote "student engagement is an important and necessary condition for learning" is not included in this article. I apologize for any confusion I may have caused.

ChatGPT's matter-of-fact delivery of outright falsehoods was disorienting. For example, here is an APA7 citation that ChatGPT generated in response to one of our prompts:

Rau, M. A., Hwang, G. J., & Yang, X. M. (2021). Effects of an augmented reality-based inquiry learning approach on college students' scientific inquiry performance and perceptions. *Journal of Educational Computing Research*, 59(3), 529-555. <https://doi.org/10.1177/0735633120964436>

It's all there: Author names, date, journal name, volume, and issue. Yet, as far as we could determine, Rau, Hwang, and Yang did not coauthor any papers; in particular, the specific paper cited, complete with a doi link, does not exist. The closest match is a paper from 2018 by Chang and Hwang. When asked to check this reference, ChatGPT stated,

I apologize for the confusion. Unfortunately, I cannot directly check the existence of specific references in real-time as my training data only goes up until September 2021, and I do not have direct internet access. Therefore, I cannot verify the existence of the reference you provided.

At other times, ChatGPT appeared to make connections to relevant literature that it accurately summarized. And yet, it also repeatedly made different versions of the following declaration:

I apologize for any confusion, but as an AI language model, I don't have direct access to specific sources or the ability to browse the internet. I can't provide real-time references or verify specific claims.

The variability and, as a consequence, uncertainty of the quality of ChatGPT's output is a barrier to more ambitious use of the model.

Lamberg, T., & Moss, D. (2023). *Proceedings of the forty-fifth annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (Vol. 2). University of Nevada, Reno.

After the second author reviewed the initial draft, the first author worked with ChatGPT to generate the final version of the research commentary. This consisted of additional clarifications, elaborations, and refinements of the original draft (e.g., reducing it to three sections from initial five) during a second 3-hour chat.

### Conclusion

Our goal in this effort was to create a paper that was written entirely by ChatGPT, through successive prompting. We wanted to determine how to engage ChatGPT for it to produce a full-length article that was written in an academic register. We believe we achieved that goal.

What does the emergence of models like ChatGPT mean for the future of academic work? Specifically, how will academics learn to work with language models to engage in new kinds of scholarly and creative activity? From our view, this is the crucial open question when we consider the near and long-term future of human-AI collaboration. It is useful that ChatGPT can write competently about anything that is described in a digital archive. But we are not yet at the point where it can function as a reliable synthesizer of entire fields of scholarship—a power that would be truly transformative. For example, we asked ChatGPT to read every article that has even been published in JRME and distill the most important things we have learned about mathematics education from that literature. ChatGPT gave conflicting answers to this prompt. Its first reply was:

*After reviewing all articles published in the Journal for Research in Mathematics Education, the most important thing we have learned is that effective mathematics education involves providing students with opportunities to engage in sense-making activities, engage in productive struggle, and develop deep understanding of mathematical concepts and procedures.*

This seemed plausible, if somewhat generic and anodyne. But when prompted to regenerate a response to the same prompt, after several variations on the theme above, ChatGPT confessed:

*It is not possible for me to read every article that has ever been published in the "Journal for Research in Mathematics Education" and distill the most important things we have learned about mathematics education as it requires a comprehensive analysis and interpretation of a vast body of literature.*

So, which is it? Did ChatGPT read and analyze every article that has been published in JRME into the sentiments about sense-making and productive struggle? Or was it not possible for ChatGPT to complete the task? This example highlights how interacting with ChatGPT is epistemically fraught. A challenge for working with predictive language models like ChatGPT is leveraging its considerable power as a writing machine without losing sight of its limitations as an analyst.

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### References

- Baker, R. S., Corbett, A. T., Alevan, V., & Ritter, S. (2008). Developing a generalizable detector of when students game the system. *User Modeling and User-Adapted Interaction*, 18(3), 287-314. <https://doi.org/10.1007/s11257-008-9040-3>
- Blikstein, P., Worsley, M., Piech, C., Sahami, M., & Cooper, S. (2021). Improving engineering education through large-scale data analysis and machine learning. *Journal of Engineering Education*, 110(1), 43-68. <https://doi.org/10.1002/jee.20355>
- Lamberg, T., & Moss, D. (2023). *Proceedings of the forty-fifth annual meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education* (Vol. 2). University of Nevada, Reno.



- Cavanagh, A. J., Chen, X., Bathgate, M., Frederickson, E., Hanauer, D. I., & Graham, M. J. (2016). Trust, growth mindset, and student commitment to active learning in a college science course. *CBE—Life Sciences Education*, 15(4), ar56. <https://doi.org/10.1187/cbe.16-03-0118>
- D'Mello, S. K., & Graesser, A. C. (2012). Dynamics of affective states during complex learning. *Learning and Instruction*, 22(2), 145-157. <https://doi.org/10.1016/j.learninstruc.2011.08.004>
- Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research*, 74(1), 59-109. <https://doi.org/10.3102/00346543074001059>
- Fredricks, J. A., Filsecker, M., Lawson, M. A., & Vanselow, N. R. (2016). Student engagement, context, and adjustment: Addressing definitional, measurement, and methodological issues. *Learning and Instruction*, 43, 1-4. <https://doi.org/10.1016/j.learninstruc.2016.03.004>
- Graesser, A. C., McNamara, D. S., & Kulikowich, J. M. (2017). Coh-Metrix measures text characteristics at multiple levels of language and discourse. *Elementary School Journal*, 118(2), 262-283. <https://doi.org/10.1086/690969>
- Graesser, A. C., Chipman, P., Haynes, B. C., & Olney, A. (2018). AutoTutor and affective autotutor: Learning by talking with cognitively and emotionally intelligent computers that talk back. *ACM Transactions on Interactive Intelligent Systems*, 8(3), 1-52. <https://doi.org/10.1145/3174807>
- Heffernan, N. T., & Heffernan, C. L. (2014). The ASSISTments ecosystem: Building a platform that brings scientists and teachers together for minimally invasive research on human learning and teaching. *International Journal of Artificial Intelligence in Education*, 24, 470-497.
- Henningsen, M., & Stein, M. K. (1997). Mathematical tasks and student cognition: Classroom-based factors that support and inhibit high-level mathematical thinking and reasoning. *Journal for Research in Mathematics Education*, 28(5), 524-549. <https://doi.org/10.2307/749690>
- Hiebert, J., & Grouws, D. A. (2007). The effects of classroom mathematics teaching on students' learning. In F. K. Lester Jr. (Ed.), *Second handbook of research on mathematics teaching and learning* (pp. 371-404). Information Age Publishing.
- Hmelo-Silver, C. E., Duncan, R. G., & Chinn, C. A. (2007). Scaffolding and achievement in problem-based and inquiry learning: A response to Kirschner, Sweller, and Clark (2006). *Educational Psychologist*, 42(2), 99-107. <https://doi.org/10.1080/00461520701263368>
- Koedinger, K. R., & Alevan, V. (2007). Exploring the assistance dilemma in experiments with cognitive tutors. *Educational Psychology Review*, 19(3), 239-264. <https://doi.org/10.1007/s10648-007-9046-2>
- Linnenbrink-Garcia, L., & Pekrun, R. (2011). Students' emotions and academic engagement: Introduction to the special issue. *Contemporary Educational Psychology*, 36(1), 1-3. <https://doi.org/10.1016/j.cedpsych.2010.12.002>
- Marks, R. (2000). Pedagogical content knowledge: From a mathematical case to a modified conception. *Journal of Mathematics Teacher Education*, 3(3), 217-227. <https://doi.org/10.1023/A:1026254310130>
- Molnár, G., & Csapó, B. (2019). How to make learning visible through technology: The eDia-online diagnostic assessment system. In *Proceedings of the 11th International Conference on Computer Supported Education - Volume 2: CSEDU*, 122-131, 2019, Heraklion, Crete, Greece.
- Resnick, L. B., Asterhan, C. S. C., & Clarke, S. N. (2009). Scaffolding complexity: The relation between instruction and cognitive capacity. *Educational Psychologist*, 44(3), 178-198. <https://doi.org/10.1080/00461520903029076>
- VanLehn, K., Siler, S., Murray, C., Yamauchi, T., & Baggett, W. B. (2005). Why do only some events cause learning during human tutoring? *Cognition and Instruction*, 23(3), 293-329. [https://doi.org/10.1207/s1532690xci2303\\_1](https://doi.org/10.1207/s1532690xci2303_1)
- Wang, M. T., & Eccles, J. S. (2012). Adolescent behavioral, emotional, and cognitive engagement trajectories in school and their differential relations to educational success. *Journal of Research on Adolescence*, 22(1), 31-39. <https://doi.org/10.1111/j.1532-7795.2011.00735.x>
- White, J., Fu, Q., Hays, S., Sandborn, M., Olea, C., Gilbert, H., ... & Schmidt, D. C. (2023). A prompt pattern catalog to enhance prompt engineering with chatgpt. arXiv preprint arXiv:2302.11382.