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# Human-AI Collaboration for Smart Education: Reframing Applied Learning to Support Metacognition

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Chapter

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## Abstract

This chapter investigates the profound influence of intelligent virtual assistants (IVAs) on the educational domain, specifically in the realm of individualized learning and the instruction of writing abilities and content creation. IVAs, incorporating generative AI technologies such as ChatGPT and Stable Diffusion, hold the potential to bring about a paradigm shift in educational programs, emphasizing the enhancement of advanced metacognitive capacities rather than the fundamentals of communication. The subsequent recommendations stress the need to cultivate enduring proficiencies and ascertain tailored learning approaches for each learner, which will be indispensable for success in the evolving job market. In this context, prompt engineering is emerging as a vital competency, while continuous reskilling and lifelong learning become professional requisites. The proposed innovative method for teaching writing skills and content generation advocates for a reconfiguration of curricula to concentrate on applied learning techniques that accentuate the value of contextual judgment as a central pedagogical tenet and the mastery of sophisticated metacognitive abilities, which will be pivotal in the future of work.

**Keywords:** metacognition, Chatbot, ChatGPT-4, intelligence virtual assistants (IVA), intelligent personal assistant (IPA)

## 1. Introduction

Intelligent virtual assistants (IVAs) or intelligent personal assistants (IPAs) represent software agents capable of executing tasks or providing services for individuals based on directives or inquiries [1]. These encompass more recent advances, including generative artificial intelligence (AI) technologies such as ChatGPT, Stable Diffusion, Notion, and others. The enhanced capabilities of these AI tools have profoundly disrupted the educational landscape, surpassing any other emergent technology of the new millennium in speed and scale of adoption [2]. At the same time, some have countered that investors fundamentally misunderstand the technology behind language models like ChatGPT and OpenAI-powered Bing Search. For instance, Harrison [3] notes that although these AI models sound impressively human, they do not synthesize information, nor do they provide thoughtful, analytical, or accurate

answers. Rather, they function similarly to predictive text features, merely predicting the next words in a sentence based on probability.

Nevertheless, these generative technology tools have already made inroads in industry and education. For instance, surveys of one-thousand business leaders less than a month after the launch of the stable release of ChatGPT-3 in early February, found that nearly 50% of their companies have implemented the chatbot, with half of these companies reporting that the chatbot has replaced some workers. Williams [4] continues to report that companies use such automated assistants for various tasks, including writing code (66%), copywriting and content creation (58%), customer support (57%), and meeting summaries (52%). In the hiring process, the chatbot is utilized for writing job descriptions (77%), drafting interview requisitions (66%), and responding to applications (65%). With so many applications, there is little wonder why this new technology has made its way beyond the office and into the classroom, as well.

Given the fact that AI continually learns from accumulated historical data and user interactions, the potential for customized learning pathways is demonstrable, promising to revolutionize pedagogical methods across all levels of education. Furthermore, the generative capacity of these digital assistants has the capacity to grant increased access to education for underrepresented populations and individuals with learning disabilities, promoting a more equitable educational landscape [5]. At the same time, learning how to interact with AI tools will become a key job skill moving forward. Prompt engineering and generation has already emerged as one of the top 10 skills necessary for maintaining a competitive edge in the industry [6]. Therefore, these new educational avatars not only offer a revolutionary new approach to pedagogy, but their very use will be central to students' future personal and professional lives. Preparing them with these new tools should be a priority for all educators.

In order to address the pressing need, this chapter will investigate the potential applications of IVAs, particularly generative AI as educational learning companions and tutors. Practical strategies for integration into current and future educational programs shall be addressed, and a reconceptualization and recentering of metacognition (learning how to learn), as the most valuable transferable and durable skill students can now gain from education presented. Given the advent of what Clark [7] has coined 'PedAIgogy,' technology is no longer utilized for accessing knowledge but also for creating, modifying, organizing, synthesizing, and evaluating it. The new pedagogical approach involves co-creating multimedia content and engaging in complex relationships with via collaborative virtual agents. With these new automatable abilities, there will be a return to the Socratic approach to knowledge acquisition and application that will foster the development, analysis, and evaluation of co-created literature, imagery, audio, and video, as well as new research, art, teaching, and learning methods [8].

More specifically, one may take as an example how the teaching and learning of the writing process will evolve given these new capabilities. Given that a primary objective in composition coursework has been grounded in instruction of grammar, syntax, and sentence-level writing, these courses tend to emphasize the importance of clear, concise, and grammatically correct writing at the sentence level [9]. Although the standard freshman composition sequence often assumes basic proficiency at the sentence-level, the practical reality is that the grading of composition papers often places too much stress on grammar/usage errors, and in-course remedies for gaps in grammar knowledge take up at least some valuable instruction time. If students do gain a good grasp of the basics, they are sometimes able to focus on more advanced sentence-level writing skills like sentence style and rhetorical devices. Practicing

writing clear, concise, and grammatically correct sentences through various assignments is often used to reinforce these skills. Feedback is the last step in the iterative process either via peers or instructors [10].

However, given the new abilities of chatbots and digital assistants to generate drafts on any topic with the right prompting, the pedagogical focus should shift towards nurturing students as editors, rather than sentence generators. The paradigm shift has been clearly seen over the past few years where individuals or even trained professionals are increasingly ceasing to be content creators. With the wide availability of video and audio editing software on smartphones, the ease of content creation and distribution has already disrupted the media and content industry. The growth of mobile video, user-generated content, and social networks combined with advancements in AI-powered content creation, dissemination, and interaction technologies already allows for the production of high-quality content in various forms, including video, music, and augmented reality (AR), which can be rapidly shared with a vast global audience [11]. But now AI-powered tools have evolved and also now have the ability to create sophisticated written content. Therefore, these new digital assistants will assume the responsibility of generating sentence-level content, thereby producing initial drafts that humans will subsequently refine through editing. Education, particularly at the postsecondary level, must reorient the training of students to embrace their new roles as editors in this new human-AI collaborative relationship.

The integration of generative AI into education has the potential to revolutionize the way students learn and teachers teach, with the use of personalized services and individualized learning modalities becoming increasingly mainstream. However, this widespread adoption of AI in education requires adjustments to classroom practices, assessment methods, and credentialing. The importance of critical thinking, digital and information fluency, and fact-checking is becoming more crucial, and new jobs such as prompt engineering have emerged. Metacognition plays a crucial role in education, and educators can utilize various strategies to foster critical thinking and metacognitive skills. With the integration of generative AI tools like ChatGPT, teachers can create personalized and engaging learning experiences that encourage metacognitive reflection and standardize the development of critical thinking skills. The use of AI in teaching can contribute to a more effective and reflective learning environment, leading to better outcomes for students.

This chapter focuses on the paradigm shift required in writing instruction, where editing and prompt development become vehicles for enhancing metacognition, and a novel model for writing education can be envisioned where students receive tutoring while editing, ultimately leading to improved metacognitive thinking, sentence-level writing, and tailored feedback and support. The following sections will outline the future of education, importance of the development of metacognitive skills and new strategies for learning how to write.

- **Future of Education** outlines how the integration of generative AI into education is poised to revolutionize the way students learn and teachers teach. Institutions of higher education are adapting to changing societal and economic demands, while the use of AI-driven personalized services, and individualized learning modalities are becoming more mainstream. At the same time, the widespread adoption of AI in education requires adjustments to classroom practices, assessment methods, and credentialing. Finally, new jobs such as prompt engineering have appeared, highlighting the potential for innovation and growth in the field of education.

- **Metacognition in Education** focuses on how metacognition plays a crucial role in education, enabling learners to become self-aware, reflective, and effective thinkers. Examples of activities are discussed, such as constrained choice exercises and metacognitive prompts, that educators can utilize to foster critical thinking and metacognitive skills. Moreover, the integration of generative AI tools like ChatGPT can create personalized and engaging learning experiences that encourage metacognitive reflection and standardize the development of critical thinking skills. Through such tools, educators can provide individualized feedback, generate tailored learning resources, facilitate group discussions, monitor student progress, and evaluate their own teaching practices by incorporating them into the classroom.

- **Writing Education and AI** outlines the integration of AI into education and how that requires a paradigm shift in writing instruction that emphasizes editing and prompt development as vehicles for enhancing metacognition. Students must develop language skills that enable effective interaction with AI and facilitate learning from AI-generated content in order to ensure a competitive advantage in the future of work. In order to support this process, a novel model for writing education where students receive tutoring while editing will be introduced. In this approach, AI generates preliminary material for a paper, and students engage in dialog with the AI to understand the rationale behind specific choices. Through utilizing AI as a tutor and editor, metacognitive thinking and improve sentence-level writing can be developed, while also providing students with tailored feedback and support.

## 2. Future of education

In response to evolving societal and economic demands, higher education is witnessing significant trends aimed at enhancing student outcomes, employability of graduates, and institutional sustainability. Hanover Research, for instance, identifies five critical trends shaping this landscape [12]. Among these trends is the modernization of academic programs with the growing demand to incorporate career-oriented, stackable structures that closely align with the demands of the job market, thus fostering the development of employable skills among graduates [13–14]. Simultaneously, there is a growing demand for debt-free education, prompting colleges and universities to scrutinize alternative funding models to mitigate the financial burden on students [15]. On the other hand, the higher education sector is increasingly prioritizing inclusivity and support services, aiming to cultivate a welcoming environment that promotes acceptance, belonging, and achievement for all students [16–17]. These services often increase tuition fees when filled by human agents, but enhance retention rates and optimize overall outcomes, ultimately contributing to the provision of accessible and personalized education. Finally, as competition in the market intensifies, institutions are under growing pressure to deliver tangible results, leading to the adoption of data-driven approaches for resource allocation and decision-making, emphasizing the need for measurable outcomes in the educational sphere [18].

These disruptive trends affecting institutions of higher education seem to be placing demands on decision-makers that are at odds with one another. On the one hand, greater individualized support is demanded with greater accessibility and individualized learning that lead to measurable outcomes and job placement for graduates.

On the other hand, more affordable paths to a college degree make it necessary to look for solutions beyond what has been attempted in the past, which would be to hire more faculty and support personnel to meet students' learning, professional, and emotional needs. However, serendipitously, these trends are in alignment with the advent and widespread use of generative AI tools in the quickest uptake of a new technology in the past generation [19]. New IPAs like ChatGPT and Bard are already being integrated for different tasks and goals across K-16 education. With these new tools, the one-on-one model of education is becoming mainstream as AI technology democratizes access to personalized services such as tutoring, coaching, mentorship, and even therapy [20–21].

### 2.1 Personalized learning

These new use cases for generative AI finally provide a solution to the nearly four-decade old one-on-one tutoring conundrum in education. As outlined in Bloom's 2 Sigma Problem, when comparing the performance of students receiving different types of instruction – traditional classroom instruction, mastery learning, and one-to-one tutoring – students who had one-to-one tutoring, personalized to their individual needs, performed significantly better than those who received group instruction in a traditional classroom setting [22]. The difference in performance between the two groups was approximately two standard deviations (or two sigma), which corresponds to a significant improvement in learning outcomes, which raised a critical question in the field of education: how can the effectiveness of one-to-one tutoring be replicated in group instruction settings, given the limited resources and practical constraints that most schools and educational institutions face?

Since Bloom's research, educators and researchers have explored various strategies to address the issue of individualized tutoring, such as differentiated instruction, adaptive learning technologies, and the incorporation of active learning techniques [23–25]. While learning outcomes were improved in these examples, addressing the challenge of scaling within a group instruction model and addressing issues of cost of instruction persists, until now. Generative AI and other advanced technologies have emerged as promising tools to help bridge the gap, offering more personalized and accessible educational experiences for students in group settings [26]. Therefore, by addressing Bloom's 2 Sigma Problem, AI can serve as a live tutor for anyone, while human experts can now provide additional in-depth knowledge as subject-matter experts and emotional support to learners [27]. Solutions like Numerade's AI tutor, Ace, were already able to generate customized study plans based on students' skill levels using a number of popular textbooks (https://www.numerade.com/). Trumbore [28] has since argued that lessons from the development of early computer-assisted instruction (CAI) systems, such PLATO, and intelligent AI tutors like Ace, offer insights into how digital assistants like ChatGPT can now be used as a tutor for students at all levels of instruction.

In reviewing what CAI like PLATO has been able to do in delivering individualized and self-paced instruction to learners in classroom settings, outlining the learning design use cases for the latest educational avatars is possible. For instance, through the use of computers instructional material was automatically presented to learners, learning progress monitored, and users were directed to resources or feedback based on their real-time needs. With CAI, learners are able to work independently and progress at their own pace, while receiving immediate feedback on their understanding of the material [29]. If a student's answer is incorrect, the program prompts them to review

the material and make another choice, much like the functionality built into electronic textbooks in the early 2000s by Cengage and McGraw Hill [30].

Large language models and digital assistants now have the potential to serve in this role as personal tutors, offering individualized instruction to a broad range of learners [31]. By prompting students to revise and elaborate on their work, digital assistants can enhance learning outcomes, with their capacity for intricate dialog and comprehensive information delivery making them suitable tutors for students across various proficiency levels [32]. Moreover, once formative instruction and assessment can be largely automated, the time-constraints of educators become less restrictive, and more time can be spent on mentorship and apprenticeship in classroom and co-curricular settings [20].

Personalized learning is becoming increasingly attainable, as AI facilitates the customization of diverse educational elements, such as instructional methods, content formats, and curricula. AI-powered software can precisely evaluate students' abilities and knowledge deficiencies, consequently refining content to maximize engagement. Catering to a heterogeneous learner population, AI addresses the needs of advanced students, those grappling with particular concepts, introverted individuals, and those with distinct learning necessities. This transformation heralds a more inclusive and efficacious educational experience for all but will require a paradigm shift in how different subjects are taught and the student-teacher relationship.

## 2.2 Adapting to change

With the rapid advances we are seeing in the fields of AI, ML, and NLP, a new generation of AI-first tools will emerge for both teachers and students, as these groups have historically been early adopters of productivity software [33]. As such, as these digital assistants and educational avatars become more human-like with improved intelligence, both parties are likely to adopt chat-based conversational interfaces. Teachers, often overworked and underfunded, can benefit from AI tools that reduce workloads by drafting lesson plans, rubrics, assessments, syllabi, and more, thus allowing them to focus more on individual student attention. Meanwhile, students are constantly seeking creative ways to save time and gain advantages, which can be seen with the embracing of previous AI-driven resources like Photomath (https://photomath.com/en) to solve complex mathematical problems and Numerade to summarize the most salient points in a textbook's chapter [34–35]. The rapid spread of popular products in college environments through word of mouth further contributes to the adoption of these AI-first tools in education.

The broad adoption of these new emerging technologies will be accompanied by a major disruption in the educational status quo, especially considering how course materials are delivered, assessed, and even how credentialing will work. In fact, current pedagogical strategies, especially in college, prioritize the synthesis of existing information assessed through standardized testing or essay writing. The new capabilities of new generative AI can now automate the process and deliver nearly instantaneous results on nearly any topic, rendering previous instructional and assessment methods obsolete. Therefore, in order to accommodate these advancements, adjustments to classroom practices and assessment methods are necessary, similar to the introduction of the first electronic hand-held calculators (1967), the first commercially available personal laptop (1985), the broad accessibility of the internet (1996), the Google search engine (1998), and Wikipedia (2001) [36]. The development of

next-generation tools for assessing student learning outcomes and awarding credentials, along with AI-leveraging tools, is on the horizon [37].

One of the most important elements in the paradigm shift for education is the growing importance of skills associated with critical thinking, digital and information fluency. Given how large language models process and generate content, fact-checking will become a central skill in the years ahead and one of the most important one's students should be equipped with after graduation [31]. As these AI technologies proliferate, concerns surrounding factual accuracy and potential algorithmic biases resulting from mismanaged or mislabeled datasets become more critical. Since algorithms are trained on data subject to human input, selection, judgment, and biases, these distortive effects can be rapidly and exponentially amplified in AI-generated content.

Fact-checking will be essential to counter AI-generated misinformation, as studies show people often find AI-composed content credible despite inaccuracies [38]. Trust in user-generated content and non-branded sources may decline, while blind trust in known personalities and experts might increase [39]. Additionally, the growing abstraction of complex systems, like web development, risks creating a generation competent in using tools without a deep understanding of underlying details [40]. The growing ease with which generative AI provides open access to a non-specialist audience, challenges in handling edge cases and crises that require detailed knowledge for effective problem-solving will potentially increase in tandem [41]. Educating students on the abilities, limitations, and responsible uses of these increasingly powerful content generators will be at the forefront of discussions on integration in the classroom moving forward.

Regardless of potential pitfalls, the use of AI tools, such as digital assistants and generative technologies, will be instrumental in preparing students for future success as new jobs are already being created. At the same time, the enthusiasm surrounding the quick adoption of these AI advancements can be ascribed to user-driven innovation. In this context, users significantly contribute to innovation by actively engaging with emerging technologies, as exemplified by ChatGPT. The lead-user theory aids in pinpointing users who are at the forefront of crucial trends and whose innovations possess a high probability of success. Such users play a vital role in fostering the engagement and adoption of novel technologies [42]. But that is not the only reason chatbots have seen widespread adoption.

The challenge of information overload in an increasingly complex world necessitates collective sense-making. As apprehensions regarding information management escalate, there is a willingness to embrace technologies capable of synthesizing and interpreting diverse information sources [43]. The fervor surrounding ChatGPT and analogous AI tools underscores the need to address these shared concerns while recognizing how broader cultural mechanisms shape user needs and expectations. Involving users in the innovation process via co-creation and lead-user participation is crucial for the successful adoption of emerging technologies, ultimately rendering AI an indispensable component in the future of work.

As such, there have been a plethora of examples and use cases of how to integrate these automated assistants in the classroom as of late. Integrating digital learning companions into educational settings has the potential to greatly enhance various aspects of teaching, including lesson planning, updating existing materials, and improvisation during class. By using chatbots as a collaborative tool, educators can streamline lesson planning, ensure consistency with curriculum goals, and make time to foster discussions about diversity and differentiation. The human-AI teaching and

learning model can also be employed to refresh old teaching materials, aligning them with current values and pedagogy, and transforming traditional resources into more engaging activities. Furthermore, these assistants can serve as an improvisational aid, helping teachers to adapt to students' needs in real-time by offering novel explanations, essay topics, or scenarios.

Developing alongside these new integrations of generative AI into education are new jobs to be filled and a new skillset to prepare students for them. The rise of AI chatbots like ChatGPT and Microsoft's Bing AI have prompted companies to maintain up-to-date AI models to prevent hallucinations, misinformation, and unsettling threats that may be generated in their current state. This development has led to the emergence of a new professional skill called "prompt engineering," which refines chatbots' abilities to provide relevant and trustworthy responses through plain text interactions. However, experts are divided on whether prompt engineering constitutes a reliable, long-term career option or is merely a transient trend. The effectiveness of prompt engineering remains a subject of debate due to the inherent unpredictability of AI chatbot responses [6]. Regardless, the skill will be highly desirable moving forward. But exactly how does one develop the skill to become a so-called "prompt engineer"?

## 3. Metacognition

*The purpose of teaching is to inspire the desire for learning in them and make them able to think, understand, and question*- Richard Feynman.

Feynman, a Nobel Prize-winning physicist, defined science in the 1970s as "the belief in the ignorance of experts" [44]. The statement is truer now than ever and will be central to how we train students to critically evaluate AI-generated content moving forward. The ideas of Feynman reiterate the idea that the true objective of education is to cultivate metacognitive skills in students, rather than merely focusing on memorization and regurgitation of information in high-pressure academic environments. Metacognition, a term of significant importance within the realm of education and cognitive psychology, refers to an individual's awareness and understanding of their own thought processes, cognitive abilities, and learning strategies [45]. In essence, metacognition is the process of "thinking about thinking," enabling individuals to monitor, evaluate, and regulate their cognitive performance. By fostering metacognitive skills, learners are better equipped to identify their strengths and weaknesses, select effective learning strategies, set goals, and adjust their approaches as necessary to optimize learning outcomes [46]. This section discusses strategies for developing metacognition in students, while also acknowledging the irony in the role played by AI in the process. These AI tutors can be used to help develop a student's ability to learn how to learn, but educators should be doing so in order to equip students with the ability to question output by the same AIs.

Several strategies have been adopted to help students develop critical thinking and higher-level metacognitive skills. One approach would be constrained choice exercises. Constrained choice activities are an effective method for engaging higher education students in critical thinking and real-world decision-making skills development [47]. These activities involve carefully designed decision-making questions that limit students' inquiry scope, prompting them to apply abstract, theoretical knowledge to practical, real-world problems. By focusing on the most relevant concepts and encouraging students to make difficult, nuanced judgments, constrained choice activities facilitate the development of valuable workplace skills.

The structure of constrained choice activities typically includes a situation description, information for analysis, and a prompt for action or decision. The use of superlatives is essential in framing these specific decisions, forcing students to carefully analyze and decide on the best course of action. The simplicity and comparability of the resulting products of students' thinking enable easy reporting and focused classroom discussions. The benefits of constrained choice activities include promoting critical thinking, allowing for the addition of complexities or constraints during facilitation, and fostering productive classroom discussions [48]. This approach can be easily integrated into existing learning activities, requiring only subtle adjustments to activity prompts, thereby leading to improved student outcomes.

In addition to constrained choice, reflection activities also promote the development of metacognitive skills. The significance of reflection in the learning process is widely recognized, as it involves revisiting and reevaluating past experiences [48]. Reflection, simply defined as rethinking an event, is an inherent part of learning that does not always require deliberate encouragement. Factors such as perspective, mindset, background knowledge, emotional well-being, setting, and social context can influence not only how we perceive an event but also which aspects we experience or remember. For instance, watching a movie for the first-time results in a different cognitive experience compared to watching it a second time, even though the story and the observer remain the same.

Metacognitive prompts can be employed to promote reflection in the learning process. For instance, activities such as producing metacognitive journals offer students opportunities to ask and refine questions, analyze their thinking patterns, and recognize cognitive blind spots [49]. The hierarchical ordering of cognitive skills in Bloom's revised taxonomy can also be utilized to encourage students to reflect on past learning experiences in relation to their thinking and cognitive behaviors [50].

The following metacognitive prompts, based on Bloom's revised taxonomy, can help students reflect on their learning:

1. Can I identify patterns in my actions?
2. Were the strategies and skills I employed effective for this task?
3. How did my mindset influence my approach to the work?
4. Was my communication with others effective before, during, or after the learning process?
5. What have I learned about my strengths and areas for improvement?
6. How am I progressing as a learner?
7. What actions should I take next?
8. How can I best utilize my strengths for learning?
9. What steps should I take or resources should I use to address my challenges?
10. How can my learning environment be improved?

These prompts can aid students in reflecting on their learning experiences, particularly concerning their cognitive behaviors and thought processes. The integration of chatbots in this exercise is an additional way to promote metacognitive development. Having the AI interrogate metacognitive journaling processes adds an additional layer of dialogical engagement for student reflection.

Educators can also effectively utilize digital assistants to enrich classroom experiences and encourage metacognitive reflection among students. By incorporating AI into the daily learning process, teachers can create personalized and captivating learning environments. Integrating these chatbots into the classroom can be achieved through various means, including providing individualized feedback based on students' responses to metacognitive prompts, which allows them to reflect on their learning experiences and address their unique needs and areas of improvement. Additionally, these tools can generate tailored learning resources, like reading materials or quizzes, that are relevant and challenging for students based on their metacognitive reflections, learning level and style. They can also facilitate group discussions by generating thought-provoking questions or prompts, encouraging students to collaborate and learn from one another's experiences. Furthermore, educators can use digital assistants to monitor students' progress over time by analyzing their responses to metacognitive prompts, enabling them to adjust teaching strategies and provide timely support. Lastly, these new tools can aid educators in their own metacognitive reflection and professional growth by generating prompts or questions that help them evaluate their teaching practices, classroom environments, and student engagement.

## 4. Applied learning

Once students can identify the best way to learn through metacognitive exercises through restrained choice and/or reflective exercises, engaging in project-based and real-world learning should follow. Therefore, the full realization of the co-collaborative learning model AI now represents includes integrating applied learning theory and strategies in support of and to further develop metacognition in the curriculum. Applied learning is an educational approach that emphasizes the relevance and practical application of acquired knowledge and skills in real-world contexts [51]. The approach seeks to bridge the gap between theoretical understanding and practical implementation, fostering the development of problem-solving, critical thinking, and collaboration skills. Applied learning experiences can include case studies, internships, project-based learning, and other opportunities that actively engage learners in applying their knowledge to authentic situations [52–53]. With more professions expected to be proficient in AI tools, these authentic situations can be easily replicated in the classroom in scenario-based exercises.

Moreover, applied learning will become increasingly important as project-based and authentic assessment will become dominant given the user-friendly abilities of generative AI. As large amounts of content can be synthesized from existing datasets and automatically output, the importance of applied learning becomes even more pronounced. Moreover, as AI technologies advance and increasingly infiltrate various aspects of daily life, including education, learners will need to develop the ability to effectively utilize these tools in real-world settings. By integrating AI into applied learning experiences, students gain a deeper understanding of the technology's capabilities, limitations, and ethical considerations. In the context of generative AI, applied

learning can help students develop essential competencies, such as critical analysis of AI-generated content, collaboration with AI tools for problem-solving, and responsible and ethical use of AI in their work. Moreover, applied learning experiences that incorporate AI can foster creativity, adaptability, and resilience in learners, preparing them for a future where AI will play a significant role in various professional and personal domains.

In order to operationalize this new approach to education that foregrounds metacognition through applied experiences, a paradigm shift in writing instruction is necessitated. In composition coursework, the primary focus has traditionally been on teaching grammar, syntax, and sentence-level writing, which underscores the significance of producing clear, concise, and grammatically accurate sentences [9]. The instruction of sentence-level writing commences with acquainting students with the fundamental elements of a sentence, subsequently familiarizing them with various parts of speech and their effective utilization. After mastering the basics, learners can concentrate on more sophisticated sentence-level writing abilities, such as syntax, sentence structure, and rhetorical devices. To reinforce these skills, students often engage in diverse writing assignments that emphasize crafting clear, concise, and grammatically sound sentences. The final stage of this iterative process involves feedback, which is typically provided by peers or instructors [10].

Nonetheless, with the advent of chatbots and digital assistants capable of generating drafts on various subjects given appropriate prompts, the pedagogical emphasis ought to transition towards cultivating students as editors, as opposed to sentence constructors. This paradigm shift has become evident in recent years, with individuals and even trained professionals increasingly relinquishing their roles as content creators. Presently, AI-powered tools have evolved to generate intricate written content. Consequently, these advanced digital assistants are tasked with producing sentence-level content, yielding initial drafts that humans will then refine through editing. In response to this human-AI collaborative dynamic, education, particularly at the postsecondary level, must restructure its approach to prepare students for their emerging roles as editors and evaluators of information.

Instead of the current pedagogic focus on sentence-level writing, educators should emphasize editing and prompt design and refinement as vehicles for enhancing metacognition. While the reframing sounds simple enough, the approach actually requires a reconceptualization of the problem which encompasses high-level thinking about the audience, contextual factors, and generated output. Students must cultivate language skills that enable effective interaction with AI and facilitate learning from AI-generated content. One potential criticism of this approach is that the editorial role does not foster sentence-level writing skills [54]. However, a novel model for writing education can be envisioned wherein students receive tutoring while editing. This model has the potential to be more efficacious in educational settings where students require guidance and instruction to refine their writing abilities.

## 5. Human-AI collaboration

Digital assistants have the potential to promote productivity and understanding of emerging technologies simultaneously. The potential to apply across various domains is already demonstrable, but an active approach that involves inquiry, co-creation,

and collaboration needs to be adopted. Users must be engaged with the technology and strive to understand its capabilities and limitations to maximize its benefits. As such, this section will offer several practice strategies and assignments for educators and those interested in using generative AI tools to improve their metacognitive skills and learn how to critically evaluate a wide variety of content. The authors advise encouraging curiosity on both the part of the educator and/or student, and dedicate time to explore and question AI tools. Run the same question multiple times and pose the same question in various ways to obtain different perspectives. Always identify when work has been assisted by an AI tool, and do not accept or act on the first results without further investigation, evaluation and scrutiny. Seek to discover questions that produce both surprising and expected results, and learn to explain and defend why one accepts or prefers certain outputs over others.

As noted, prompt engineering, which involves generating prompts or assignments using AI, can be a useful tool in developing essential metacognitive skills in students. However, the evaluation of the output from prompt engineering requires another metacognitive level of thinking, where students must critically analyze and evaluate their work and question their input to revise and determine what and/or how output is working. Therefore, it is crucial to teach students two different skills: first, how to write a paper about a specific topic, and second, how to think about early stages of a project, prompt, or assignment. This second skill is not narrow and becomes a metacognitive skill in and of itself. An example of an assignment that may be considered in developing these skills would involve identifying a topic, generating an initial response from a chatbot, and then iteratively evaluating and refining that as follows using a chatbot of choice (**Table 1**).

| |
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| **Assignment Title:** Investigating Metacognition Development through AI-Assisted Editing |
| **Objective:** To explore the development of metacognition in students by utilizing chatbots in the process of editing and refining AI-generated content |
| **Instructions:**<br>1. Choose a topic of interest within your field of study. Develop a clear, concise prompt related to your chosen topic that will guide the chatbot in generating an initial draft.<br>2. Use the chatbot to generate an initial 250-word essay section based on the prompt you created. Save the AI-generated text as a separate document.<br>3. Review the 250-word section and prompt the chatbot for several variations by varying the prompt. Compare the results and feel free to change the essay from your initial plan.<br>4. Ask the chatbot to complete the essay with an additional 250-word section. Save the text as a full (short) essay.<br>5. Carefully read the AI-generated essay, noting any inaccuracies, unclear phrasing, or overly general language. As you read, consider the following questions (for now, do not worry about sentence-level issues):<br>• Where does the AI writing require more specific examples to support general claims?<br>• Where do you see strong factual claims that need to be checked for accuracy?<br>• Most importantly, where do you see interesting directions for inquiry proposed by the AI but which you did not initially consider?<br>6. Engage in a dialog with the chatbot to understand the rationale behind specific choices in the AI-generated content. Ask the AI questions about its choices, and use the feedback to refine your editing process further.<br>7. Continue the iterative process of editing and consulting the chatbot until you have a polished final draft. Ensure that you maintain ultimate decision-making authority over the final edited product.<br>8. Write a 300-word reflection on your experience using the chatbot as a tutor and editor. Discuss how the process influenced your metacognitive thinking and editing skills. Address the following questions in your reflection: |

| |
|---|
| • How did interacting with the chatbot impact your understanding of the topic and the structure of the essay?<br>• In what ways did the AI-assisted editing process challenge or support your critical thinking and reading skills?<br>• How did engaging with the chatbot as a tutor influence your sentence-level writing and editing abilities?<br>9. Submit the polished final draft of your essay, the original AI-generated text, and your reflection. |
| **Grading Criteria:**<br>• Clarity and coherence of the final edited essay<br>• Effectiveness of AI-generated content in addressing the prompt<br>• Quality of editing, including grammar, syntax, and overall structure<br>• Depth of reflection on the AI-assisted editing process and its impact on metacognitive thinking and editing skills<br>• Engagement with the chatbot and the extent to which feedback was incorporated into the editing process |

**Table 1.**
*Investigating metacognition development through AI-assisted editing assignment.*

In the AI-assisted editing assignment outlined above, the learning outcomes and metacognitive value for students are multifaceted. By actively involving students in the process of refining AI-generated content, this approach promotes a deeper understanding of the subject matter, enhances editing skills, and fosters critical thinking.

The primary learning outcomes of this approach include:

1. Development of critical reading and analysis skills, as students must evaluate the quality and coherence of the AI-generated content, ensuring it aligns with the intended argument or message.

2. Improvement of sentence-level writing and editing abilities, as students engage in an iterative process of refining the AI-generated text, addressing any inaccuracies, unclear phrasing, or grammatical errors.

3. Enhancement of collaboration and communication skills, as students interact with the AI to understand the rationale behind specific content choices, refining their editing process based on the feedback received.

The metacognitive value of this approach lies in the following aspects:

1. Fostering self-awareness of one's own thought process and understanding, as students must consider the purpose and structure of the AI-generated content, reflecting on how it contributes to the overall argument or message.

2. Encouraging students to engage in higher-order thinking, as they must consider the intended audience, contextual factors, and the generated output while editing the AI-generated content.

3. Promoting self-regulation and autonomy, as students maintain ultimate decision-making authority over the final edited product, guiding the AI-generated content to align with their understanding and objectives.

The AI-assisted editing approach not only enhances students' writing and editing skills but also fosters metacognitive development by encouraging critical analysis, self-awareness, and self-regulation.

Supplementary assignments and activities can enhance student engagement in the learning process by actively involving them in the creation and evaluation of educational materials. For example, when teaching the combining of independent clauses into longer sentences, rather than merely supplying students with pre-made worksheets, instructors can employ AI tools to generate five distinct worksheets, allowing students to attempt each and request a grade upon completion. This method can serve as a heuristic model for education, as it encourages students to formulate questions they need to address (see **Table 2**) [55]. However, one challenge with this approach is that, while students may be adept at reading articles and collecting information, they might encounter difficulties in identifying contentious issues or debates within the subject matter [56].

To help students identify controversies in a field more effectively, teachers can encourage them to develop their own stylistic preferences. This approach allows students to learn grammar more efficiently, freeing up time for them to concentrate on higher-level metacognitive skills. For example, in computer science courses,

| |
|---|
| **Assignment Title:** Heuristic Learning with AI-Generated Sentence-Combining Worksheets |
| **Objective:** To engage students in a heuristic approach to learning the combining of independent clauses using AI-generated worksheets, promoting active learning and self-assessment through an iterative process. |
| **Instructions:**<br>1. The teacher will use an AI tool to create five different worksheets teaching sentence combining, each with varying levels of complexity.<br>2. Students will select one worksheet to start and complete the exercises, keeping track of the time taken and their level of confidence in their answers.<br>3. Upon completing the first worksheet, students will request a grade from the AI tool and review the feedback provided.<br>4. Based on the feedback, students will identify areas of difficulty or uncertainty in independent clause combination and generate a list of questions to guide their learning.<br>5. Students will conduct independent research on the identified concepts, using articles and other resources to deepen their understanding of independent clause structure.<br>6. After the research phase, students will select another AI-generated worksheet, complete the exercises, and ask for a grade again. They will repeat this process until they have worked through all five worksheets.<br>7. Following the completion of all five worksheets, students will write a 250-word reflection on their learning process, addressing the following questions:<br>• How did the heuristic approach impact your understanding of sentence-combining concepts?<br>• What challenges did you face in identifying the variation in stylistic effect created by different combinations, and how did you overcome them?<br>• How did engaging with AI-generated worksheets and self-assessment support your learning and retention of independent clause structure? |
| **Grading Criteria:**<br>• Completion of all five AI-generated worksheets<br>• Quality and depth of the research conducted on sentence-combining concepts<br>• Clarity and coherence of the written reflection<br>• Engagement with the heuristic learning process and improvement in clause structure knowledge and skills |

**Table 2.**
*Heuristic learning with AI-generated sentence-combining worksheets assignment.*

students progress through various abstraction levels, initially learning to code before ascending the abstraction hierarchy [57]. A similar method can be applied to humanities courses (**Table 3**). In these courses, students can start by focusing on sentence-level design, gradually shifting their attention to the organization and structure of essays. Subsequently, they can concentrate on literature reviews and their integration within broader academic discussions. Utilizing a heuristic framework enables students to fluidly transition between abstraction layers, dedicating more time to higher-level metacognitive skills.

By incorporating AI for syntactic-level writing, students can further enhance their focus on advanced metacognitive skills. AI assistance allows them to generate initial drafts and engage in the editing process while exploring the different abstraction layers in their writing. Consequently, students can develop a deeper understanding of the subject matter, analyze their own thought processes, and hone their writing skills, all while leveraging AI technology to support their learning journey [58].

As such, the collaboration between humans and AI in education presents a unique opportunity to rethink the way we teach writing and related skills. While it remains essential to equip students with a robust foundation in grammar and syntax, it is crucial to strike a balance by emphasizing higher-level metacognitive skills, such as

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|---|
| **Assignment Title:** Abstraction Layers in Writing and Developing Metacognitive Skills |
| **Objective:** To facilitate students' understanding of higher-level metacognitive skills by guiding them through a series of abstraction layers in writing, from sentence-level design to broader literature analysis. |
| **Instructions:**<br>1. Sentence-level design: Students will create a set of stylistic preferences at the sentence-level based on the course material, providing a foundation for quick grammar learning and enabling them to focus on higher-level metacognitive skills.<br>2. Organization and essay structure: Students will write a 500-word essay on a topic relevant to the course. They must apply the stylistic effects created in step 1 and demonstrate a clear organization and structure in their essay.<br>3. Literature review and broader conversation: Students will conduct a literature review on the essay topic, identifying at least five key sources that contribute to the academic conversation around the issue. They will analyze the sources, outlining their main arguments and their relation to the chosen topic.<br>4. Integrating abstraction layers: Students will revise their essay from step 2, incorporating insights from the literature review in step 3. They will ensure that their essay engages with the broader conversation and demonstrates an understanding of the various abstraction layers in writing.<br>• How did the process of moving between abstraction layers impact your understanding of the topic and writing skills?<br>• In what ways did engaging with various abstraction layers contribute to the development of higher-level metacognitive skills?<br>• How did using AI for syntactic-level writing influence your focus on higher-level metacognitive skills?<br>5. Reflective analysis: Students will write a 300-word reflection on their experience moving between abstraction layers, addressing the following questions: |
| **Grading Criteria:**<br>• Quality and coherence of the stylistic effects created<br>• Clarity, organization, and structure of the essay and literature review<br>• Successful integration of abstraction layers in the revised essay<br>• Demonstrated understanding of higher-level metacognitive skills in the reflective analysis<br>• Engagement with AI tools for syntactic-level writing and its impact on the learning process |

**Table 3.**
*Abstraction layers in writing and developing metacognitive skills assignment.*

analysis and evaluation. By shifting the instructional focus from sentence generation to editing, we can leverage AI's capabilities to generate initial drafts while humans refine and polish them. This novel approach not only fosters a deeper understanding of the writing process but also cultivates critical thinking and metacognitive skills in students. Ultimately, the integration of AI into the educational landscape holds the potential to transform our learning and teaching methods, paving the way for a more individualized and effective educational experience for learners from all walks of life.

## 6. Conclusion

The integration of intelligent virtual assistants (IVAs) in education has the potential to revolutionize the learning process and equip learners with the necessary skills for the future workforce. To meet this growing demand, specific exercises, assignments, assessments, and even classes and certificates will be developed to address the need for prompt engineering upskilling. The incorporation of metacognitive skills into curricula across all disciplines will become a key pedagogical strategy, enabling students to develop evaluative skills crucial for success in the future. The use of tailored AI tools for different learning outcomes will also enhance the learning experience, allowing students to generate quizzes and gamify their learning experience, leading to increased efficiency in education. The acquisition of advanced metacognitive skills will become a core requirement for the upcoming generation of learners, much like typing was a technical skill taught in the past.

In the suggested heuristic model for education, AI generates initial drafts for papers, allowing students to engage in dialogs with the AI to comprehend the reasoning behind specific choices. This iterative interaction fosters both editorial and sentence-level writing skills, with students retaining control over the final edited product and benefiting from the AI's guidance. Implementing this pedagogical approach involves students initiating the process with AI-generated text, using it as a tutoring resource, and alternating between editing, verification, idea generation, and evaluation. This method encourages critical analysis and reading skills among students. The integration of AI as both a tutor and editor in this innovative educational model enhances metacognitive thinking, advances sentence-level writing, and offers customized feedback and support. By reorienting writing course objectives and adopting AI technologies, educators can transform writing instruction, equipping students for future workforce demands.

Moreover, the rise and proliferation of generative AI technology heralds a promising future for higher education by offering personalized learning experiences and content generation capabilities. AI-powered virtual assistants can provide tailored feedback and support to students, aiding them in grasping intricate concepts and improving their academic performance. However, it is crucial to acknowledge that AI technology cannot replace the human interaction and critical thinking skills nurtured through conventional college education. Therefore, the future of college education is likely to encompass a blend of AI technology and traditional classroom instruction, with AI complementing and supplementing conventional teaching methods. This blended approach allows students to benefit from AI's advantages while still acquiring valuable human interaction and critical thinking skills indispensable for success in the workforce. Consequently, it is essential to persist in exploring AI technology's potential in education and optimize its utilization to enhance learning outcomes for upcoming generations of learners.

As AI continues to evolve and advances are made daily in the field, driven by increased processing power and more accessible hardware to run supercomputers, its implications for education remain a moving target. The rapid progress of AI models, such as GPT-4, in various contexts highlights the importance of determining whether prompt design and engineering will become a skill students need to learn. The contrasting experiences of start-ups and users of different AI models underscore the importance of ongoing research and adaptation to fully harness AI's potential in education [59]. Ultimately, by embracing human-AI collaboration and reimagining applied learning to support metacognition, we can transform educational experiences, empower learners, and prepare them for the dynamic demands of the future workforce.

## Conflict of interest

The authors declare no conflict of interest.

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