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# Incorporating generative AI into a writing-intensive undergraduate course without off-loading learning

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Received: 21 December 2024 / Accepted: 17 April 2025
Published online: 08 May 2025


**Abstract**
As generative AI becomes ubiquitous, writers must decide if, when, and how to incorporate generative AI into their writing process. Educators must sort through their role in preparing students to make these decisions in a quickly evolving technological landscape. We created an AI-enabled writing tool that provides scaffolded use of a large language model as part of a research study on integrating generative AI into an upper division STEM writing-intensive course. Drawing on decades of research on integrating digital tools into instruction and writing research, we discuss the framework that drove our initial design considerations and instructional resources. We then share our findings from a year of design-based implementation research during the 2023–2024 academic year. Our original instruction framework identified the need for students to understand, access, prompt, corroborate, and incorporate the generative AI use effectively. In this paper, we explain the need for students to think first, before using AI, move through good enough prompting to agentic iterative prompting, and reflect on their use at the end. We also provide emerging best practices for instructors, beginning with identifying learning objectives, determining the appropriate AI role, revising the content, reflecting on the revised curriculum, and reintroducing learning as needed. We end with an indication of our future directions.

**Keywords** Large language models · Writing · Education · Generative AI

## 1 Necessary skill or off-loading learning

Since ChatGPT's arrival in the public's awareness in late 2022, educators have been trying to understand the impact of the widespread availability of generative artificial intelligence ("AI") tools on the teaching and learning of writing. These new generative AI tools pose both opportunities and challenges for helping undergraduate students become better writers and communicators. On the one hand, these tools provide a powerful means of scaffolding the development and practice of writing and communication [24]. They can act like a personal writing tutor, guiding the student's planning process, reminding them of the next steps, offering suggestions for getting started, providing model texts or multiple versions of sentences, and giving almost human-quality feedback on student writing [11, 47]. On the other hand, these tools can quickly generate coherent texts on almost any topic and many students–and especially technically-savvy, writing-apprehensive undergraduate students–may be tempted to use these tools to

**Supplementary Information** The online version contains supplementary material available at https://doi.org/10.1007/s10791-025-09563-9.

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write texts that they themselves have been assigned, shortchanging students' own development as writers as well as creating academic integrity concerns [67]. Because of these changes, many instructors are evaluating their prior class activities, assignments, and most particularly assessments, to ensure that students are actually learning the necessary content and become skilled writers.

Working in partnership with the lead instructor of the existing undergraduate engineering writing and communication course (the second author), we sought to provide students guidance on the ethical and effective use of generative AI for writing and increase students' AI literacy. As part of this project, we are iteratively developing, implementing, and evaluating a pedagogically-informed AI writing tool which provides scaffolded access to generative AI and provides researchers access to the student-AI interaction data. In parallel, we are creating professional development to support instructors' use of the curriculum and tool, and instructional resources that can be used to integrate AI writing tools into undergraduate writing-intensive courses. We conducted design-based implementation research during the 2023–2024 academic year on the incorporation of AI writing tools for scientific communication centered on teacher instruction, student learning, and problems of teaching practice as identified by practitioners, students, and researchers ("DBIR"; [41]). Through iterative cycles of DBIR, we explored the best practices for teaching and learning the use of AI writing tools in scientific communication,integrated these practices into the tool and resources; evaluated the impact on student's development as writers; and improved the tools and resources. For this paper, we focus on two research questions:

- **Learning**: What emerging best practices do we see instantiated for using generative AI productively in academic writing?
- **Teaching**: What emerging best practices do we see instructors using to integrate AI into their writing-intensive courses?

## 2 Literature review

### 2.1 Writing with digital tools

Writing is culturally situated and mediated by tools [15, 61]. New technologies present new cognitive challenges and opportunities that students and teachers need to address [3, 29]. Developments in technology affect the writing process itself [8]. For example, some tools may constrain idea generation and elaboration [8]. Success with composing with new tools depends upon a willingness and ability to change modes, adapt prior strategies, and navigate the specific tool affordances that both promote and inhibit good writing [12]. Practice negotiating the use of the tools and marshaling them for the purpose of writing leads to improved writing achievement [27].

Studies of the use of digital tools to support writing have evolved over decades, ranging from analyses of digital writing compared to writing by hand [2, 7, 37, 39], [66], to the use of automated writing evaluation to provide writing feedback and improve writing quality [22, 36, 57, 63]. Our research on classroom uses of technology, and in particular AI, suggests that the value of these digital tools can be realized by understanding both their strengths and limitations, and deploying them in a way that maximizes the former and minimizes the latter [54, 55]. This includes educating teachers and learners on how the tool functions [49], and using it in a critical, reflective way that also incorporates more social forms of writing and assessment (similar to the critical evaluation and collaboration captured in Ref. [30] definition of AI literacy.

Research focused on using generative AI in writing classes is beginning to indicate some pedagogically useful ways to integrate writing and AI. In a recent laboratory study, researchers had students write with GPT 3.5 and found that students could collaborate with ChatGPT to learn and grow as writers without ceding all writing authority to the AI [5]. The benefits of using AI for writing support may be especially salient for non-native English speakers, a recent study finds that two-thirds of 2L students in a first-year English course used generative AI tools [28], see also [51, 56]. Bedington et al. [6] reported that when using AI in a professional writing course, the instructor and students had to balance the integration of AI to avoid overreliance, center authorial agency and decision-making, negotiate grading, and discussed the pros and cons of using generative AI for writing. These more general themes must be adapted to the local context and the specific students in concert with AI literate instructors [53]. This study adds to this literature by looking at a multi-quarter implementation of generative AI in multiple undergraduate writing courses by multiple instructors.

### 2.2 Instruction on the use of digital tools

Instructionally sound implementation of digital technology for learning should include five elements: understand, access, prompt, corroborate, and incorporate [50]. First, students need to understand the basics of generative AI's functions, strengths, weaknesses, and biases ([38], "Know and Understand"),instructors also need this basic information [49]. A working *understanding* of the factors that will impact the output, such as the body of material on which the AI was trained and who and what were excluded, help students notice the assumptions and biases implicit in the tool's output. This information also impacts what works well when prompting AI. Second, students need to be able to *access* and navigate AI writing tools across specific communication tasks, such as writing papers or emails, creating slide presentations, or gathering background information ([38], "Use and Apply"). Third, students need to know how to *prompt* the AI to generate the most helpful content [23]. The right prompts are required to hone in on what is needed, and quality prompts generally reflect critical thinking about the task. AI-generated text can be wrong and reference nonexistent sources and false "facts",students need to understand that and *corroborate* the accuracy of AI-generated content (see Appendix A-2 for instructional resources to support learning this important skill). They also need to interrogate the AI output for bias. Finally, students need to learn how to *incorporate* AI-generated texts in their own writing ethically and effectively, noting and citing their use of AI in the authoring process [67]. The standards for how to do so have not yet fully emerged and vary by community practice [10].

There are few research studies on the incorporation of generative AI into undergraduate writing courses, given the fairly recent introduction of relevant tools. Apart from the current study, Cummings et al. [14] used generative AI in a limited manner in a first-year writing class and found some promise, particularly for ideation and research uses. Usdan et al. [52] considered the impact of generative AI on *graduate* student writing and found that with proper instruction AI reduced writing time and increased writing quality slightly. Other published research relies on survey instruments and discusses perceptions and reported uses (see, e.g., [4, 19]), but does not look at actual classroom practices. This study provides a look at a sustained integration of AI into a quarter-long writing course.

### 2.3 The current project

This project involves a partnership between the Digital Learning Lab led by the last author, which specializes in research and evaluation of AI-based communication in education; the Office of the Vice Provost of Teaching and Learning led by the penultimate author, which directs all undergraduate instruction and provides pedagogical development opportunities focused on innovative, evidence-based, and inclusive teaching practices through its Division of Teaching Excellence and Innovation; and the School of Engineering, which prioritizes scientific communication by requiring substantially all its undergraduate majors to take Engineering 190W. We seek to understand the best practices for integrating AI writing tools into writing-intensive undergraduate courses. This project adds to the current research base by looking across multiple instructors and multiple quarters of implementation to provide a wider understanding of how integration of generative AI can evolve in pedagogically sound ways.

Our digital writing tool allows students to interact with generative AI —specifically a large language model ("LLM") — through pre-designed, embedded prompts that guide the interaction between students and AI (Fig. 1).

**What is PapyrusAI?**

PapyrusAI is a web-based tool built on top of a commercially available AI model (currently, GPT-4o) that:

- Scaffolds and supports improvement in student writing through assistance with the process of writing, such as planning and revision activities;
- Includes embedded prompts to facilitate a conversation between the student and AI that guide the student through research-based best practices for learning writing;
- Provides teacher control over the types of interactions permitted for students for each assignment, allowing gradual change of usage over time (e.g., by assignment);
- Enhances privacy protection compared to individual AI access options; and
- Comes with instructional resources to support teacher and student use and AI literacy.

**Fig. 1** Description of the key components of the digital tool created for this project

These prompts are visible to students (unless this feature is disabled by the instructor) to help students build an accurate mental model of generative AI — it must be prompted before the interaction is started — and illustrate model prompts for students to emulate [59, 60]. Students can interact freely with the AI after the initial prompt (Fig. 2), but the instructions that guide the interaction were created and tested by the researchers. The embedded prompts are focused on pedagogically effective interactions, based on tutoring [25], writing [20, 21, 64], and HCI research. For example, the AI is instructed to ask the student questions and not to simply write for the student. Our design itself purposely incorporates some friction in using the AI-generated text, requiring the student to actively take content from our tool's interface into the writing software, rather than being able to simply accept or reject suggestions [59, 60]. Instructors have the ability to determine which prompts the students have access to and can change access options as the course progresses,current options include assistance with planning, drafting, revising, and presenting (Fig. 3). Our development efforts initially prioritized the following design principles [59, 60]: making the tool reliable (design responsibly), transparent (design for mental models), pedagogically sound (design for appropriate trust and reliance), and simple for both instructors and students to use (design for co-creation and imperfection).

## 2.4 Method

During the first year of the project, the 2023–2024 academic year, we observed Engineering 190W classes, interviewed instructors (both those incorporating the AI and those not yet doing so), conducted student focus interviews, gathered student writing artifacts and instructional artifacts, and surveyed the students to learn more about how they were already using AI for writing purposes. Working with the instructors, we explored the ways that AI writing tools were being — or might be — used by instructors and students consistent with the goals and constraints inherent in the context of the course, and learned the key student learning objectives from the course instructors. We developed the initial curriculum that provided students with foundational AI literacy and the base platform of the tool. We also expected the instructors to continue non-AI based best practices. The most common approaches to supporting students on planning and revising their writing involve writing organizers, mind maps, and feedback from teachers and peers. Generative AI is available 24/7 and provides immediate responses, unlike teachers and peers who have limited availability and patience, allowing students to question and reiterate as often as needed, with no social consequences.

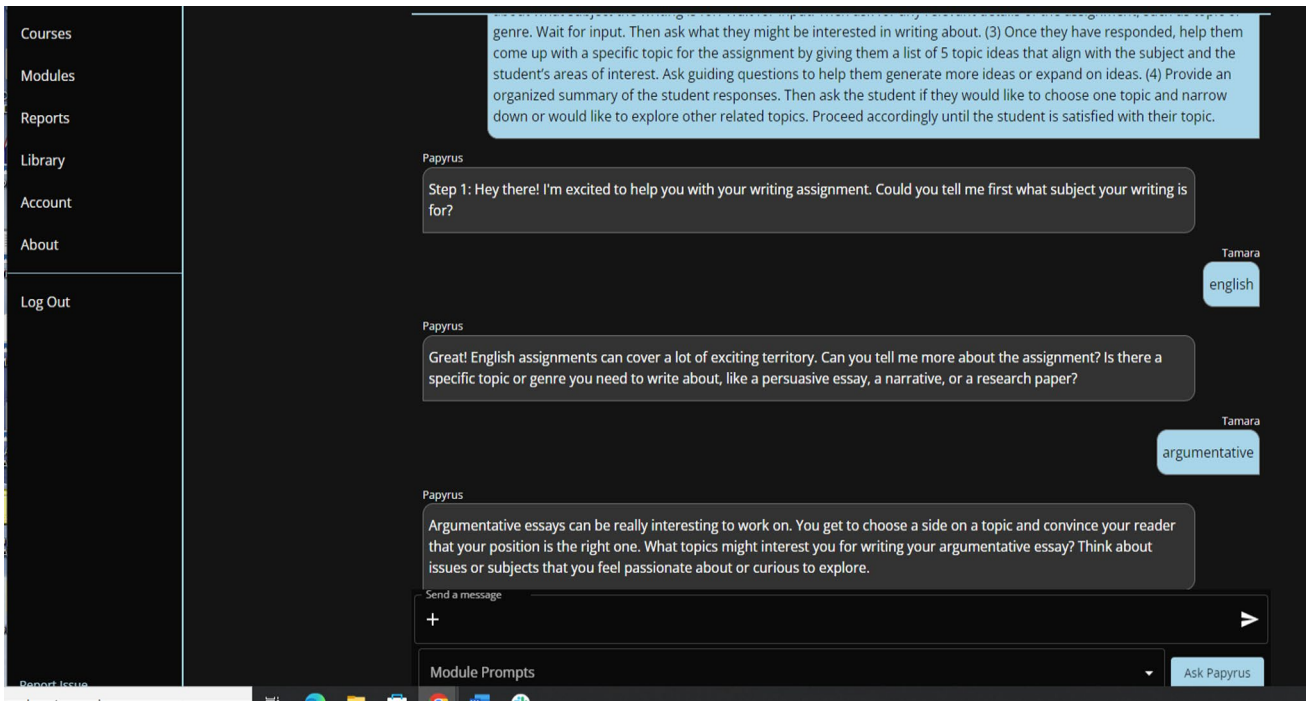


**Fig. 2** Tool screenshot showing conversation, including initial embedded prompt in light blue at the top [Picture cropped to preserve anonymity]

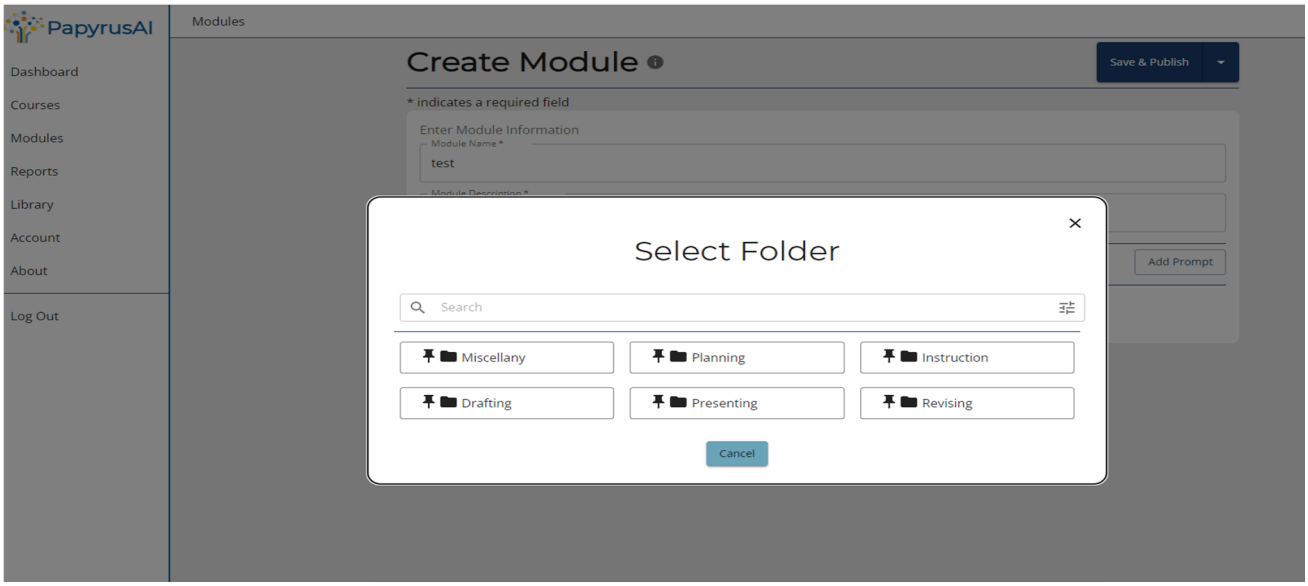


**Fig. 3** Instructor view screenshot of types of embedded prompts available for use in the tool

The qualitative methods in this phase borrowed from phenomenological and design-based practices. This information guided both our development efforts and provided baseline data that we can use to track progress in future quarters.

## 2.5 Setting

The University of California, Irvine is federally designated as a Hispanic-Serving Institution and an Asian American and Native American Pacific Islander-Serving Institution. Engineering and computer science majors are 42% Asian, 15% Hispanic, 13% White, and 2% African American. 25% of the students are international students, primarily from China (51%), India (12%), and South Korea (7%). Students are overwhelmingly male in this field (72%). 30% of these students qualify for the Pell grant and 38% are first generation college students. The Engineering Department requires an upper division professional communication course that is designed to provide students with the tools to plan, research, organize, write, and edit various forms of oral and written technical communication that they will need as professionals. The course is a graduation requirement for almost all engineering majors and complies with the requirements of the campus for upper-level writing courses. Students must produce 4,000 words or more of finished work.

## 2.6 Participants

The second author is the lead instructor of the course and participated in implementing the instructional resources and tool as they evolved across the entire academic year (3 quarters). In the first quarter, Fall 2023, Harnick-Shapiro implemented curriculum and pre-made prompts that students could use with ChatGPT's free version. For Winter 2024, she piloted the minimum viable product developed by the team, which contained premade prompts and provided access to GPT-4.0. In Spring 2024, 3 additional course instructors were provided with the tool and curricular materials for use at their discretion. Each instructor taught at least two sections of approximately 20 students each. Our instructors were one White female, one White male, and two Asian males. They were all appointed lecturers at the university, 3 full time and 1 part time. Two of the instructors also taught at a second institution. All of our instructors have a master's degree.

## 2.7 Data analysis

The data, consisting of interviews, class observations, teaching and learning artifacts, and artifacts from the DBIR (see Appendix A-1 for details) all underwent a similar coding process. Coding was based on the flexible coding methods of Deterding & Waters [17], which are optimized for qualitative data analysis software and large amounts of data. Flexible coding is also more reflective of studies, such as the current one, that are grounded in prior research and not purely

inductive. In our case, we had an understanding of key issues typically involved in incorporating technology into classroom settings. The flexible coding method essentially is the reverse of grounded theory [13]. For example, in our analysis of instructor and student artifacts, researchers looked for patterns in how the AI writing tools were used in instruction and student responses. Best practices were initially defined as those that were efficient, replicable, aimed towards improving writing quality, authentic to engineering genres, and likely to increase student motivation, persistence, and self-efficacy based on current writing research.

We also made extensive use of memo-writing to preserve and analyze information. For instance, the first author kept copious notes on the project meetings both electronically and on paper, which were then reviewed and transcribed for coding of key information. Interviewers wrote memos upon the conclusion of each interview in order to capture their thoughts on aspects of the interviews that were unique or particularly interesting. The first author did all of the coding for this article, discussing emerging themes with the second and fourth authors to provide a check on her analysis. These authors participated in substantially all of the relevant meetings along with the first author, the fourth author conducted the observations and interviews, and the second author was the lead instructor for the course. We conducted participant checks with our full instructional team to ensure that we were appropriately interpreting their experiences. We looked for disconfirming evidence of trends [65].

## 3 Results

Based on our work with instructors over the past year, we have noted emerging best practices for using generative AI productively in academic writing and for integrating generative AI into writing intensive-courses. We caution that there are likely many different patterns emerging that are productive, but these are the patterns found in our context at this time as generative AI is becoming increasingly available to students and instructors.

### 3.1 Learning: Emerging best practices for using generative AI in academic writing

Three areas emerged with respect to the most effective student use of generative AI. These related to students' need to develop skills in three areas: prompt, corroborate, and incorporate (Fig. 4).

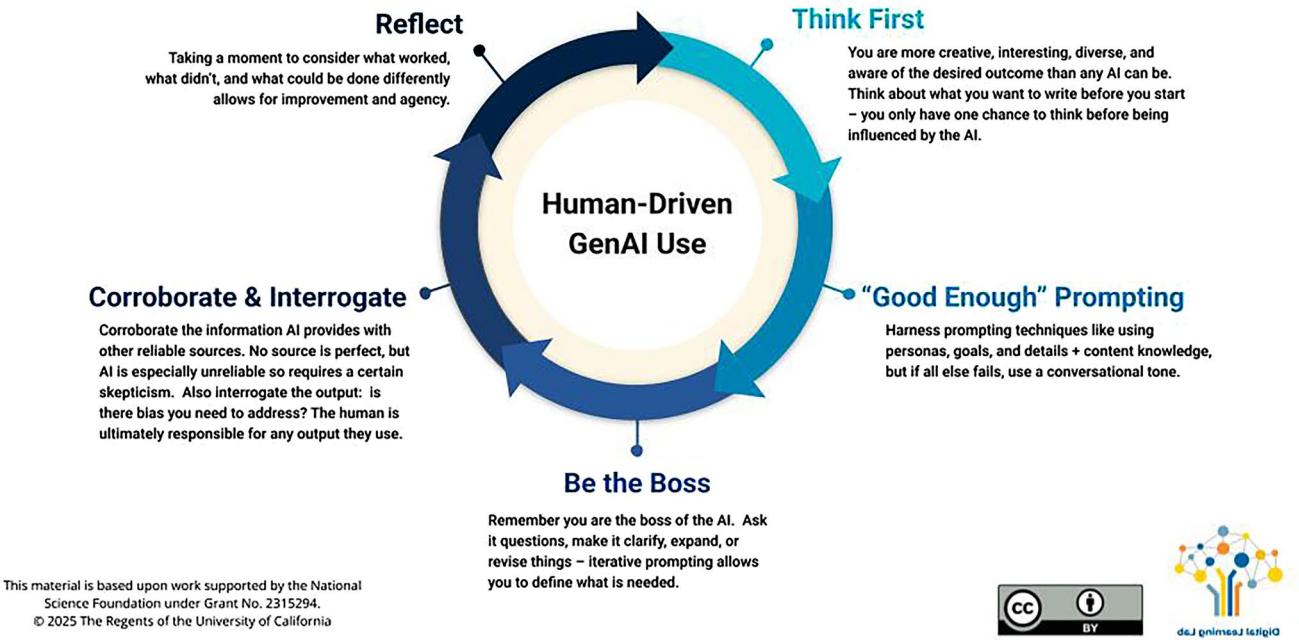


**Fig. 4** This process diagram of Human-Driven GenAI Use incorporates the main findings from our first year as to the most promising ways to use generative AI in writing

#### 3.1.1 Prompt

Our initial instructional framework called for students to "prompt" using "strategies and search optimization to generate the most helpful content." We now recommend that instructors emphasize an *iterative prompting strategy* with prompting as a multi-stage process, beginning with a "good enough" prompt followed by iterative refinement until the user's needs are met by the AI output.

Good Enough Prompting.We are finding that students benefit from some explicit instruction on prompting techniques. Instructors need to provide some foundational information to ensure that all students are prepared to be successful at prompting, because there is no baseline education for this in the current K-12 curriculum. Most importantly, students need to understand that they should just write *something*. Picturing the AI as a person and prompting the tool conversationally is a reasonable way to start the interaction: treat AI like a person, but tell it what kind of person it is [35].

Being the Boss. After the initial conversational turn, the tool allows students to converse freely, for instance asking the AI questions for clarification or to expand upon something. We are finding that instructors need to stress the importance of not simply accepting the initial AI output in order for students to assert agency over the writing process and ensure that the AI output is useful. Students need to be explicitly told to "talk back" to the AI and interrogate its output, asking for elaboration, clarification, expansion, or revision for example (this is consistent with evolving research on AI conversations, see [46, 58]). Students may need some explicit modeling and practice of this co-creation process.

To effectively cause the AI to refine its output, students need to have some knowledge of what output they need and what it should contain. This requires both content knowledge and critical thinking on the part of the student. One instructor is planning on modeling more of this iterative prompting in the next term,

> I'm going to have some exercises today in class to show how it works with editing a paragraph and show how pushing back is important and not just turn them loose and here, sign in, there you go, there's the tool… [I]f it doesn't give an answer, do they just stop there? That's the best it can do. No, there's pushback. I think that is something that has to be emphasized more, and I'm going to concentrate on it.

The instructor also plans to spend class time explicitly modeling and having the students work through the revision of a paper, "I want them to actually just to see and be involved in how it's used. I think that more proactive and real-life demonstration, I'm anxious to see if that encourages them to use it more."

Another instructor noted that the time it takes to get what they actually want from the AI tool is significant and involves just the type of learning he wants to encourage,

> I said at the end of day, you're probably going to spend a lot of time just making sure you query the AI in the proper way in the detail you want. That's perfect. Accomplish the same goal, I want you to do it. I think after a while, you're going to realize it's probably easier for [you to] just do it, because not only do they have to see what they have and figure out the questions to get the right answer or at least the details they want, but they still have to validate the output.

Students need the confidence to continue, and in fact lead, the interaction. For some students, this is uncomfortable, while others lack the language in which to push back to improve the AI output. We are also seeing that some of our multilingual students can corroborate a source but may not have the language skills to interrogate the AI output and may defer to the apparent linguistic sophistication of the AI. As these students release agency to the tool, they may also lose the thread of their own ideas, knowledge, and experience. We are finding that explicit discussion of the need for this push back is allowing instructors to stress student agency and the privileges and responsibilities of authorship in productive ways. As one instructor tells his students,

> Even if you don't think your English is good enough, I want to hear that, because to me it's more important to, and I tell my students too when they read other people, you want to hear your fellow student talking to you, not some weird research paper that you think sounds more sophisticated or generative AI that flows better. I want to generally hear a voice and I want you to tell me exactly your point of view with details and evidence.

Instructors have also noted that when the AI feedback was highly generic and students assessed whether it was valid or not, they engaged with their text more meaningfully during revision than the instructor had seen in prior terms. Learning this process, building these habits, and having an increased sense of ownership in their writing could have benefits that go beyond any single writing assignment.

One and done prompting, "here is the assignment, please produce a text," leads to little if any learning. But when the student starts critically thinking about the AI output and whether or not it meets the needs of the assignment, and what might be done to improve the output, then the student is co-creating with the AI and accessing the student's own agency. In fact, many of the students explicitly mention "agency" in their final reflections about the use of AI for writing in one instructor's class. This co-creation creates a space in which learning can occur. It also mirrors the process of writing, where drafting and revision occur iteratively to hone the text. One additional pedagogical benefit — students are learning to articulate what should change in a text, learning the vocabulary and process of the community of writers in an explicit and transparent way. The second author has explicitly noted that the conversations in her class around the writing process have changed over the course of the project, with students more explicitly discussing their writing process in class in productive ways and learning that there is no single required writing process.

## 3.2 Corroborating and interrogating

Corroborating the accuracy of the AI output was a part of our instruction from the beginning, both because it was an organic part of Engineering 190W to check sources and because especially in the early models hallucinations were relatively common. Librarians, historians, and media literacy experts have been teaching for decades that students need to read laterally, considering the source and context of their evidence. We found that this process continued to be a critical step that the instructors regularly emphasized during the course. Allowing students to use generative AI provides a natural opportunity to explicitly require them to engage in this essential step and builds the instinct and muscle to be critical thinkers in other contexts as well. Because in the context of AI we are dealing with computers, not other humans, verifying the AI output's accuracy is a low-stakes way to practice these skills. The AI is never offended when we question its accuracy.

Instructors were provided with resources to help students understand the biases built into the generative AI both from the training data and human training. As the models improved over the course of the year, it became less likely that a student would organically come across an egregious falsehood or example of bias during their interactions. Instead, instructors may need to look for opportunities to share research examples or construct activities that showcase this issue in order to build students' understanding of the very real need to critically interrogate AI output. This is an area we found was underdeveloped in our materials this year, and we are planning to build additional instructional resources to support students' understanding of this limitation of generative AI.

### 3.2.1 Thinking first

Last spring we began to suggest that students "think first" before turning to the LLM. While not necessary in every instance, we wanted to be explicit about when and why students might find it useful and to understand the cost of not doing so. Students intrinsically know and apply a myriad of information to the task at hand, including knowledge of their own interests, an understanding of the personality of the instructor, what has been emphasized in the class to date, and a million other details that will factor into their initial thoughts on how to best approach the task. When the task is turned over to the AI, students are likely to continue down the path AI selects. We know from psychology that once people start to believe something, it is extremely hard for them to change course [26]. In addition, people form stronger beliefs from those that are confident and appear knowledgeable [26]. AI is exceedingly confident and, unlike people, rarely indicates anything less than 100% confidence in the output,they do not use indicators like hedging language for example [48]. The strength of the persuasiveness of AI-output is likely to increase as the text output becomes even more fluent and accurate. Therefore, building the habit of thinking first will support student agency when using AI.

### 3.2.2 Reflecting

Our instructors valued reflection prior to our project and continue that practice in working with the AI. All of our instructors in some way have the students reflect at key points in the writing process on the role of AI and its impact on both the writing process and product. This reflection provides an opportunity for students to remain consciously in charge of their use of the AI. They are prompted to consider how effective the AI was when they use it, how it helped or hindered their writing process, and how they might (or might not) use it differently next time. Instructors also noted that the use of AI sometimes disrupted the reflection that normally occurs while writing. Some students, however, stated in interviews that they decided to not use the AI tool at some points in the writing process because they did not want to then have to

reflect on their use — the extra labor associated with the AI tool became a disincentive to use. Instructors will need to consider the appropriate balance between constructive reflection and busy work as they come up with the best practices for reflection with an authentic purpose.

#### 3.2.3 Productive struggle vs. unnecessary friction?

We found that some students did not want to engage with the AI writing tool because to get useful output took time and effort; they chose to either not use it or to use a tool without scaffolding (e.g., ChatGPT, which did not ask them Socratic questions or have prohibitions against writing for them). When an instructor asked why a proficient writer was not using the AI, the student replied that he already had a really good writing process down and it seemed to be a disruption to go into PapyrusAI and "do those extra button pushings, it didn't seem to help me. I didn't really want to go that route."

Several times our instructors discussed the challenges that weaker writers faced in using the AI tool effectively. One instructor summed it up, "poor writers [are] poor writers with prompts." However one instructor noted that the embedded prompts were very important for some of the students who crafted very poor prompts of their own and received poor quality output; the embedded prompts led to improved output so that students could experience the value of better prompting and potential of AI. Nonetheless, some students still did not seem to benefit from the AI as significantly as we had expected. One instructor theorized on the problem of taking up the AI feedback,

> I'm thinking it's their awareness. The poor writers don't have a good level of awareness of what really needs to improve. Therefore, they could not effectively use [the tool]. They couldn't take advantage of its power. Those who could take advantage of its power, already good writers, and knew how to push on and ask it very specific things, and got the results they wanted.

Because this awareness is not universal, we need to ensure that AI does not widen achievement gaps, with good writers using the tool more skillfully (often referred to as the "Matthew Effect," [34]). One instructor reflected,

> As it turns out, the writers, especially on the lower end of the bell curve, really did not have a high level of awareness of their writing deficiency. They knew they weren't the best writers, but they didn't know in what respect. Their awareness of specifically what they needed to work on was really not apparent to them. They were not really sure about what they should ask or what prompt they should use.

The team is considering what additional scaffolding or instruction might help students use the tools more effectively earlier in the quarter before the student has received multiple rounds of comments and is more aware of what in their writing needs improvement. Perhaps, for instance, more explicit guidance from instructors on what prompts to use and when would be beneficial in the beginning of the term.

Another instructor expressed uncertainty about why students were not more enthusiastic about using the tool after brainstorming with it once for a class assignment,

> About 50% thought it was useful. I'm not sure what I was expecting. Maybe they're not sure how to interrogate it yet. I think there's two ways to think about any tool, it's the way to use it. Is it too hard? Is it not what they're used to? Then do they get the value out of it? I'm not sure how to unpack that to decide which one's which. What I do like is that they already have that sense that it can't answer everything for you and they know there could be some errors. To me, that's important. While they think it's a great tool, they also realize it's not 100% correct.

We will be sorting through student data to investigate whether the tool's friction is productive effort required for learning or unnecessary friction. As noted at the beginning, we are walking a line between offloading necessary learning and teaching students to effectively use AI for writing. This seems to be a place where that tension is observable. We will be working with instructors this year to understand if, when, and why the motivation to use the AI drops off.

On the positive side, however, one of our instructors noted that students are becoming more aware of and explicit about their own writing processes, discussing their process in class discussions for example. We hypothesize that the language and pedagogy embedded into the tool's prompts provides some students with the language to discuss their writing process — the tool often explains what it is doing and why it is doing something, or the types of things to be considered in a particular type of revision work, e.g., asking about the audience's interests or prior knowledge. The prompts model effective writing processes transparently in many respects, providing students with an opportunity to not only engage in the practices but also learn the language around the practices.

### 3.3 Teaching: emerging best practices for integrating generative AI into writing-intensive courses?

Developing good courses is hard [62]. Synthesizing what we have seen worked–and did not work–this past year, we have learned some things about how to infuse generative AI into the curriculum (Fig. 5).

First, we note that our implementations were in *already designed courses* —instructors were disrupting existing, functional courses. Second, while we generally believe that AI should not be a one-time, one-off assignment or lecture if the point is to teach effective use of AI for writing, one of our instructors began with use of AI in a single assignment. This was deemed necessary so as to not disrupt his course plan and ensure that student learning was prioritized. Ultimately, when possible and especially when developing new courses, we believe intentional use of AI should be considered as part of the course design and, where determined supportive of student learning objectives, woven through the course in appropriate ways. As one of our instructors noted, "It's throughout the conversation, because I really dislike [AI as a] discrete topic that you start and end here because life doesn't work like that, it's all intermingled." As students get more familiar with the use of AI outside of the classroom, instructors will also need to revisit the issue of what foundational knowledge is still required.

To begin with, we found it helpful to ensure that the DBIR team understood, and centered, the student learning objectives for the course. We continue to advise new instructors to do the same — identify (or remind themselves of) the student learning objectives for the course, both with respect to the content area and, if applicable, AI literacy. Generative AI should not overtake the course goals, but rather enhance or supplement pre-existing content and activities.

Our instructors noted that a lot of invisible work was needed to incorporate the AI intentionally into their courses and one even called the process of figuring out where to incorporate the AI "inorganic." One thing our participating instructors reported noticing is that the activity of reviewing their course through the lens of where and how to incorporate generative AI caused them to externalize and be explicit about some of the learning objectives and curriculum that had previously been hidden. The instructors had to re-think assignments and course design in a way that was disruptive but also led to new insights. This disruption was different from situations in which the instructor had to "fix" something wrong in a course, instead the AI was a more neutral impetus. As one instructor put it, it is an "emotional and intellectual challenge to dig into what was already considered a 'good' assignment and transform it." A second instructor sought to expand usage of the AI in ways that would be productive but also fit into his class learning objectives, which prioritize developing student agency and unique voice. Another instructor was still struggling with how to integrate AI into his course because of concerns regarding how much scaffolding, or as he put it "hand holding," was too much; navigating

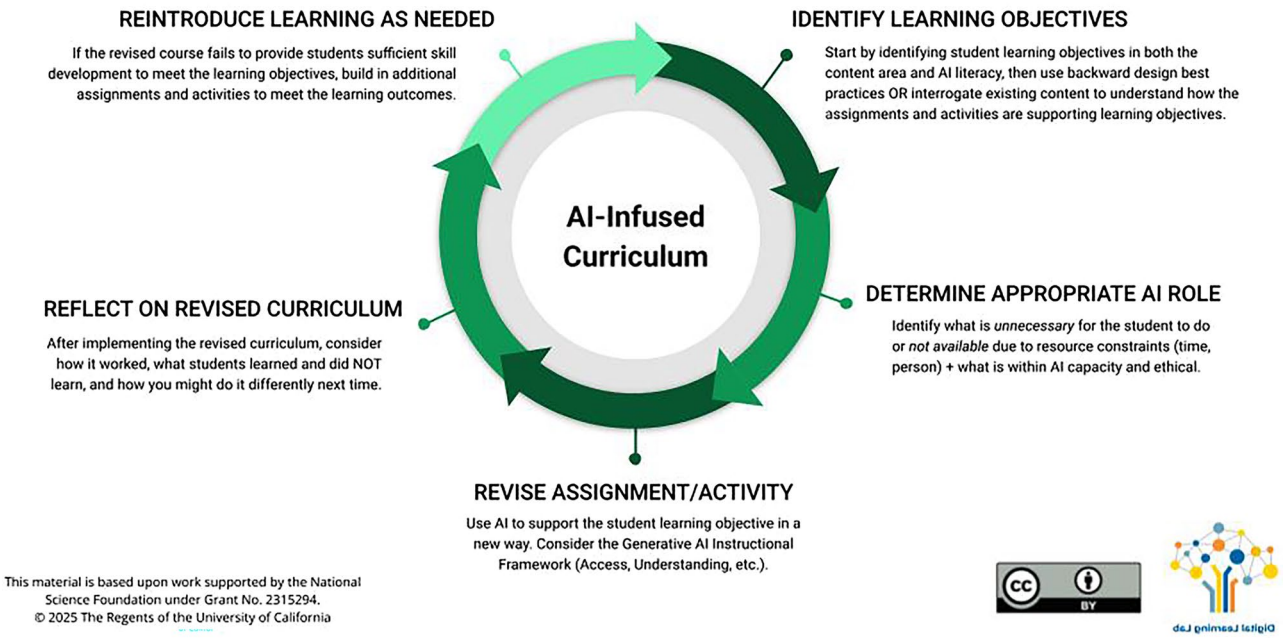


**Fig. 5** Description of the process for infusing AI into existing curriculum

the difference between having students be challenged and having them struggle. The fourth instructor included specific instructions in assignments on when and how to use the tool,

> Because I felt that if I just said, "Use PapyrusAI to revise your paper" would be not enough, even though they have pre-programmed prompts. I felt I needed to be a little more definitive about how they would use it. By putting it into specific steps in the assignment, I felt that that would be proactive enough to get them to use it because, hey, it says in step one to use this prompt or use this module.

Ultimately, our instructors implemented the AI in ways that reflected their own teaching values and were thoughtfully and critically engaged in ensuring students' learning stayed central to the writing process. While there can be no guarantee that every use of generative AI was, in fact, effective at achieving this goal, we note the continued effort by instructors to pay attention to the issue. As we continue our research, we will be working alongside our instructors to reflect on how students responded and the impact the tool had on student learning.

Once these learning objectives are at the forefront, instructors can use the principles of backward design [62] to create or interrogate existing activities, assessments, and content to ensure that they are supporting the objectives. This review may lead to the identification of content that is not necessary. Since time is a limited resource, our instructors have needed to remove or reduce some activities and assignments to carve out time for new, AI-enabled curriculum and activities. If time permits the addition of new or revised activities, instructors need to determine the appropriate role for AI to play. For example, if the learning objective is for students to learn how to write an outline, we would not simply turn over the writing of an outline to the AI. We might, however, have the AI provide feedback on the outline once the student has written it. When attempting to determine what role the AI should play, instructors can consider what is unnecessary for the student to do, what cannot be done due to a lack of resources (e.g., multiple rounds of teacher feedback), what is within the AI's capacity, and what is ethical for the AI to do. These factors will influence when and how AI might be infused throughout the course.

We encourage our instructors to start with the uses of AI that are the easiest to implement and most likely to effectively harness the AI's strengths — what we term the low-hanging fruit (see Appendix A for examples of successful activities). For example, AI is quite good at acting as a brainstorming or thinking partner. This leads to effective use of the AI in coming up with topic ideas, counter arguments, evidence for positions, and consideration of different perspectives. One particularly effective use has been when students use AI to facilitate their brainstorming for a group paper topic that integrates different engineering disciplines. These uses are often part of the planning or pre-writing part of the writing process. LLMs are obviously also good at writing text, but we have two caveats: students should only draft with the AI in situations where (1) the truth does not matter, or (2) the writer knows enough (or has access to the underlying information) to gauge the accuracy of the output. What sort of situations have we seen where these caveats have been met? One possibility is using the AI to summarize content, like an article, and then have the student fact-check it for accuracy. This ensures that the student practices the habit of corroboration and has access to the accurate information. Another possibility is for the AI to summarize the student's *own* writing or planned presentation so the student can take an outsider's view of what is being "heard" and reflect on whether that is what the student intends to communicate. The AI can also create a reverse outline of the student's writing to help the student analyze the structure of their writing and make sure the flow and logic makes sense from a higher-level view.

## 4 Discussion

Incorporating AI into the teaching and learning of writing is disrupting practices that have long been in place. As we work with instructors and students to find productive ways to incorporate AI into the writing process, we are trying to be transparent about the trade-offs between doing everything without AI and off-loading writing completely to AI. By critically analyzing the evolving practices and explicitly discussing them in our writing-intensive course, teachers and students are learning ways of thinking that will support productive decisions as the technology and community norms continue to evolve. The value of understanding their own writing process will empower students beyond any single course. Ensuring students have agency to make reasoned and reasonable decisions around the use of AI teaches them a process that will support them in making ongoing decisions. To support this work, we have revised our instructional framework for human-centered use of AI (Fig. 6).

Generative AI use in writing-intensive undergraduate courses can be done in a human-driven manner. Emphasizing that students should think first, reflect, and use iterative prompting emphasizes the human's role in co-creation


**Fig. 6** Revised instructional framework for human-driven generative AI

[59, 60]. The *person* retains agency and does the critical thinking necessary to guide the process and the ultimate output. This allows educators to ensure that students have the opportunity to learn the essential skills of writing and thinking, while also becoming proficient, knowledgeable users of this new writing tool.

As we all become more familiar with using generative AI, we are finding that some specific knowledge is necessary (e.g., basic prompting skills, [40]) but that even more important are general principles that guide usage, such as the need to prompt iteratively and encourage students to use their own agency to refine the AI output. These general principles outlast the almost daily changes in the models and interfaces that can make specific prompting guides, for example, obsolete.

Similarly, infusing generative AI into the curriculum in a pedagogically sound manner requires the instructor to retain agency over the process of determining appropriate uses of AI and centering student learning objectives. By doing so, students do not shortcut their necessary learning (see, for instance, the contrary example in Ref. [1]), but are introduced to the use of generative AI in a scaffolded, supported learning environment. Instructors are also learning that generative AI can be especially helpful in teaching students certain aspects of writing that have long been challenging, such as audience awareness and perspective taking. For instance, when preparing for a class debate students used the tool to generate positions and the instructor found that this pre-work "exposed to the students a lot more different perspectives than I would be able to do without it because it's just a time constraint." This work with the AI allowed students to contribute more to the subsequent group planning, "I like that AI prepares as a way for them to think to themselves a little bit before they get back in the group. There's another layer of understanding, learning and reflection a little bit before they then participate in discussion. I think that opens up the opportunity for much more perspective."

One instructor noted the value of the embedded prompts requiring the student to provide information, for example about the intended audience or role to be played in a debate, which required the student to think. He said, "it's really facilitated class instruction."

Generative AI's ability to take on personas or roles can be harnessed to help students visualize how things like tone, word choice, and sentence structure change depending on the setting. Exposure to generative AI during their undergraduate education also means students are prepared to enter the workforce as intentional users of generative AI, with an understanding of both its affordances and limitations. However, we are still finding our way with respect to how and when to incorporate AI into the course. Some lower-performing students are not taking advantage of the tool, which surprised an instructor, "Wait a minute. You just got permission to use a powerful tool, and you didn't jump at the chance?" We need to continue our efforts to parse out what barrier to successful use our students faced and determine what role instructors should play.

### 4.1 Limitations and future directions

This study is limited to a single institution and single course. Because of this, it is not generalizable to other institutions, particularly with different student demographics (e.g., younger students), nor to different content areas. In addition, our instructors had been teaching this course for multiple years, teachers new to teaching or teaching new courses would have additional burdens likely to impact their ability to integrate generative AI. As our research progresses, we as implementing the tool in additional content areas and grade levels, from middle school to community colleges and beyond. We are also interested in looking more deeply into the impact of the tool on student writing quality and processes. This article solely focuses on the instructor-side of the implementation, and we look forward to sharing student voices in our future work.

## 5 Conclusion

While some are calling for generative AI to be banned from education [31], we believe that such a ban is both ineffective and inequitable. Banning or ignoring AI writing tools will fail to prepare our undergraduates for the professional world where such tools will be both embraced and valued. Indeed, AI literacy is a requisite for both future employment and civic engagement [38] in today's and tomorrow's world.

Though the long-term impact of generative AI on writing instruction is difficult to foresee, we start from the premise that these AI writing tools are both flawed and fallible, due to their algorithmic biases and technical shortcomings [9], but that they also have powerful affordances, including the ability to assist the large numbers of scientists and engineers around the world who need to publish and present their work in English but are not native speakers of the language. AI literacy is especially necessary for minoritized students, who already face a lack of access and participation in technology-related fields and are more likely to fall prey to misinformation and unfair decisions made by AI [44]. If we do not teach people in marginalized communities to use these tools well, the more tech-savvy elite will disproportionately benefit from them. We therefore adopt an approach of teaching students the critical AI literacies needed to understand and use these tools and ethically employ them for their own ends.

This paper allows us to share what we have learned in the first year of our DBIR work, providing information to support other writing-intensive courses as they consider how they might include generative AI in productive and ethical ways. PapyrusAI helps students improve their academic writing by allowing them to interact with AI in a "walled garden" that provides access to AI in a structured, scaffolded, and bounded way. Students receive personalized support by using the embedded prompts in the platform while writing, with a particular focus on helping them effectively plan and revise their writing, as noted above both underutilized parts of the writing process of developing writers [21, 33, 45]. Improving these parts of the process of writing leads to improved writing quality on subsequent writing as well as the specific underlying writing assignment [32]. In addition, learning to write *with* AI provides experience that will support their future writing with AI. Students' future academic writing will have to deal with the existence of generative AI. We already see widespread adoption of AI in business and the world at large [16]. Students from lower socioeconomic backgrounds often have less opportunities to use digital tools in authentic, productive, and creative ways [43, 54]. Thus, learning if, when, and how to effectively use generative AI as part of a writer's process is a key new part of literacy. If students are not exposed, they will not become adept at the important considerations (possibly) underlying its use. If we can help students build effective habits and understanding of AI's affordances and limitations, they will be prepared to make better choices in the future.

PapyrusAI also provides learning opportunities so that students actually experience the power—and limitations—of AI (e.g., [18, 38]) in support of their authentic classwork. By interacting with AI through a guided process, students gain valuable knowledge related to AI's strengths, weaknesses, biases, and uses, and skills for prompting, incorporating, and interrogating its output. This invaluable AI literacy will be relevant in their future study and careers. Repeated interactions with the tool provide students with the experience and confidence to interrogate other forms of AI in the future, knowing that the AI will make mistakes and that their input and refinement of the questions asked of the AI significantly impacts the quality and relevance of the output.

**Acknowledgements** We thank the instructors and students who participated in this study and provided us with their insights on how to use generative AI for writing in productive ways.

**Author contributions** T.T. wrote the main manuscript text and was PI for the NSF grant funding the project. B.H.-S. was the lead instructor for the course. D.R.R. led tool design. W.T. was the primary qualitative researcher, conducting observations and interviews. W.T., with T.T. and B.H.-S. led implementation strategy and curriculum development. M.D. provided advice on best practices for innovative teaching and learning. M.W. led initial framework design and project oversight. All authors reviewed and revised the manuscript.

**Funding** This work was supported in part by NSF Grant No. 2315294. Any opinions, findings, conclusions, or recommendations expressed in this work are those of the authors and do not necessarily reflect those of the NSF.

**Data availability** The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

## Declarations

**Ethics approval and consent to participate** The need for ethical approval was waived by the IRB of the University of California, Irvine because of the nature of the study and self-exemption documentation was filed (2023–2565, approval date January 17, 2023) as permitted by the institution for research conducted in an educational setting involving normal educational practices; educational tests, survey, interview, observations of public behavior; and benign behavioral interventions with adult subjects. The research was carried out following the guidelines of the IRB for such studies. Informed consent was obtained from all individual participants included in the study.

**Consent for publication** Not applicable: No identifying information for participants is included in this article.

**Competing interests** The authors declare no competing interests.



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