

Using Generative AI to Implement UDL Principles in Traditional STEM Classrooms

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Abstract—This innovative practice full paper presents a guided approach to integrating universal design for learning (UDL) principles into an Explicit Instruction classroom. To address the common challenges of scope and additional time requirements of integrating UDL, we are using generative artificial intelligence (GAI) tools like ChatGPT because they have reached a level of functionality that allows a GAI tool to replace multiple specialized tools. This paper provides specific guidelines of where UDL interventions can be included in an explicit instruction lesson and how to use GAI to support them. This paper has multiple goals. First, we are focused on an approach that can help embed modern, best practices in traditional, higher ed STEM classes that use an approach that is typically close to the explicit instruction model. Second, we want to show how GAI can be used to implement UDL principles in classes in a way that does not require much additional instructor time and can help UDL adoption scale to larger classes. Example GAI prompts and “real” responses are provided for those who are unfamiliar with GAI tools, in order to help demonstrate the capabilities of the tools.

I. INTRODUCTION

Universal Design for Learning (UDL) is an educational framework that supports accessibility and flexibility for all learners, including those with disabilities [1], [2]. Developed by the Center for Applied Technology (CAST) in the 1990s, UDL draws inspiration from universal design in architecture, which seeks to create buildings and spaces that are inclusive, accessible, and equitable for all users [3]. Similar ideas were developed in Europe around the same time and are known as *Inclusive Design* and *Design for all*. Grounded in neuroscience research, three guiding UDL principles, including (1) Multiple Means of Engagement, (2) Multiple Means of Representation, and (3) Multiple Means of Action and Expression, empower students to personalize their learning path. Educators who utilize the UDL framework vary the ways information is presented and provide choices for how students can demonstrate learning. This flexibility is meant to increase engagement, reduce learner stress, and reduce barriers while maintaining high expectations for all learners [4].

We believe that UDL reflects best practices in teaching and we want to help support its adoption in higher ed STEM classes where it has gained little traction [5]. While UDL has been found to benefit *all* students, we have specifically identified STEM faculty. UDL supports learning and inclusion in a variety of ways which have become more important in higher ed as the focus on inclusion and retention has increased. For a variety of reasons higher ed has been slow to adopt UDL despite its documented success in K-12 education. A

common perception is that UDL requires a lot of additional instructor time, which could be addressed with technology but this has resulted in a large set of specialized tools that do not necessarily integrate easily. Finally, in higher ed specifically, some of the aspects of UDL should be shifted from the instructor to the student over time, helping them improve their lifelong learning abilities. Our goal in this paper is to make UDL more accessible to higher ed STEM faculty who typically lack formal training in established teaching methods and best practices.

A. Challenges of UDL

While UDL has been shown to improve learning for all students it has a number of perceived challenges associated with it [6]. There is a perception that UDL takes additional time to implement because instructors are required to create multiple versions of different aspects of assignments [6], [7]. Others find the interpretation of the guidelines challenging as they are high-level and there are a lot of different ways to accomplish the goals [7]. Because some aspects of assignments may be tailored for an individual student, they may not be applicable to others means that effort is required to make further adjustments for future students [8]. Finally, Edyburn, a critic of UDL, noted that identifying UDL is challenging because it is a philosophy more than a specific set of exercises [9]. Ten years after his initial critique, Edyburn noted that there still issues with clarity and specificity regarding UDL interventions and how to identify the key aspects that make changes effective [10]. This also makes it possible to misinterpret the principles and apply changes that hinder learning instead of helping.

Like Edyburn, Tobin, and Behling, we believe that technology is a key enabler of UDL [5], [9], [11]. Prior to 2022, this was in the form of a variety of specifically targeted technology solutions. In the next section we identify specific technology examples that support student learning.

B. Examples of UDL Technology

In order for UDL to be effective in higher education, technology needs to be considered. Paper-based technologies (such as worksheets and textbooks) are useful, but rarely provide the flexibility to access and engage in the material that is appropriate for everyone’s learning needs [9]. Various digital tools are available to optimize learning and support UDL principles.

Within the realm of engagement, to recruit interest, game-based learning platforms such as Kahoot!, Quizizz, Quizlet, and Socrative are used to review students' knowledge for assessments or to introduce a lecture [12]. Among these, Kahoot! stands out with 70 million monthly active users. Through a web browser, students participate by providing a PIN number and answering questions in real-time, aiming to accumulate points. Kahoot! fosters positive perceptions among students, enhancing engagement, motivation, concentration, and perceived learning [13]. Compared to traditional lecture slides, this game-based learning approach improved concentration levels (82%) and engagement (93%) at the Norwegian University of Science and Technology [12]. In the realm of sustaining effort and persistence, tools exist to foster interaction, collaboration, and community. Multi-modal discussion forms, such as Padlet and Flipgrid, encourage students to share ideas and exchange feedback. These tools provide a shared space to post comments, photos, links, and videos for discussion or for project work [14]. The University of Sussex utilized Padlet in first-year seminar courses by asking students to post about key readings in groups, which increased course engagement and exam scores [15]. Other tools allow instructors to provide feedback to students, such as GoReact (for video feedback), Kaizena (for text feedback), GoFormative (for real-time feedback), and Peergrade.io (for peer-to-peer feedback). There are also a wide arrangement of learning management systems and grading tools where students can receive feedback from professors including Blackboard, NeoLMS, and Sakai [16]. Other technologies encourage students to self-regulate by tracking their academic and personal goals, such as Google Keep and Notion, which allow students to create to-do lists and plan for assignments and exams [14], [17]. ePortfolio websites such as Google Sites, Weebly, Wix, and Digication allow students to share and reflect on their academic and personal accomplishments [14], [16]. There are also tools whose main focus is to reflect on learning, such as Riffbot.ai, an AI tool that asks students reflection questions [18].

Digital tools also play a crucial role in enhancing representation. In terms of perception, accessibility features such as speech-to-text and text-to-speech on operating systems software, along with read and write Chrome plugins, support language learners with reading-based disabilities [14]. For students with visual impairments, many operating systems provide a high-contrast mode and abilities to change text sizes [19]. In the realm of supporting language skills, grammar and writing enhancing software such as Grammarly provides comprehensive feedback on grammar and sentence structure, including the detection of grammar and spelling errors. At an sophomore English course at Fujian University of Technology, average writing scores increased from 58.05% to 73.9% after a combination of Grammarly and group collaboration, with students reporting they enjoyed using the software [20]. In terms of comprehension, while there are no specific tools focused solely on knowledge transfer, various mind mapping tools exist to help students highlight patterns, identify big ideas, and bridge relationships between concepts like Miro and

Coggle [21]–[23]. Using a combination of the aforementioned tools relates using multiple media for communication and using multiple tools for construction and composition, giving students the flexibility and choice in how they take part in the learning process [24].

C. UDL Technology Challenges

As previously noted, UDL needs technology in order to be a viable option. However, as we anecdotally learned during the pandemic, *more* technology doesn't necessarily make things better, and we found that adding more technology platforms caused challenges for students in different ways. We worry that a similar onslaught of support tools, which all have individual value, when combined, will do more harm than good. The tools discussed earlier are all specifically designed to provide a specific task or a set of specific services meaning that a single student might engage with one or more tools and most likely an instructor would be engaging with a lot of different tools, the combined set of what the students in the class are using. Traditionally, there were no general tools for these tasks simply because technology could not provide all of the desired functionality. Designing, developing, and maintaining each tool requires time and money on an ongoing basis. Based on our own experiences, smartphone apps can be highly personalized and can be the most beneficial but are the most challenging and resource intensive to maintain. However, we believe that with the introduction of generative AI, many of the aforementioned functionalities can be done by one tool which may solve part of the problem.

II. GENERATIVE ARTIFICIAL INTELLIGENCE

Conventional Artificial Intelligence (AI) is generally concerned with extracting information from a sample X of a particular modality. Modalities that are commonly used in AI systems are text, images, audio, video, music, human voices, programming code, mathematical expressions, graphs, diagrams, and so forth. Applications for conventional AI systems include automatic speech recognition and object recognition in images for example. Generative Artificial Intelligence (GAI) is different from conventional AI in that it has the ability to create a new, never before seen sample X of a particular modality. To that end, a GAI system is required to implicitly model the probability distribution $P(X)$ over the modality and combine this model with a mechanism that creates samples X from it. In most cases, users of a GAI system want to assert some influence over the character of the produced sample X via a so-called prompt C . For a GAI for image creation, for example, we might want C to be a text description of what the image should show or look like. In this case the GAI must be able to model the conditional distribution $P(X|C)$, whereby both X and C can each belong to the same type of modality or to a different type of modality, including combinations of modalities, i.e. multi-modal X 's or C 's.

Before we discuss some of the general problems GAI systems tend to have, it is helpful to, first, briefly introduce a few examples of state-of-the-art GAI systems. Two powerful

text generation tools, also referred to as Large Language Models (LLMs), are CHATGPT-3.5 [25] from OpenAI and GEMINI [26] from Google. Both systems produce a text X based on a textual prompt C . LLMs are frequently used in a recursive fashion, where past prompts C and outputs X are combined into new prompts C for subsequent queries. A special sub-category of LLMs are systems that have been specifically optimized to generate programming code such as COPILOT [27] and STARCORDER [28]. Both systems accept plain text as well as programming code as a prompt.

For the generation of images there are currently three systems of particular interest: DALL-E [29], MIDJOURNEY [30], and STABLE DIFFUSION [31]. DALL-E accepts text descriptions as prompts, whereas MIDJOURNEY and STABLE DIFFUSION also accept a mixture of text, images, and other parameters. A system that is equally multi-modal is the latest version of OpenAI’s chat tool: CHATGPT-4 [25]. It accepts a combination of images and text as a prompt C and can produce both images and text as an output X .

Of particular interest are also human voice related GAI systems. The state-of-the-art generation of a human voice from a text prompt can be accomplished with a software from ELEVENLABS [32]. The voice character can be varied over a range of predefined speaker types in 29 languages. The software VALL-E [33] by Microsoft synthesizes high-quality personalized speech from text with only a “3-second enrolled recording of an unseen speaker” as a prompt. Lastly, WHISPER [34] can textually transcribe audio recordings of voices in 57 languages and translate them into English.

The list of GAI examples from above is by no means comprehensive and merely serves to illustrate the breadth of available technology at this point in time. Most people, who use these tools, tend to be amazed about the quality of the commensurate output of the systems. This perceived quality, however, can also have undesirable side effects, as GAI systems also have some problems that arise from the way they are constructed.

A particular problem is that it is generally not possible to express the distribution $P(X|C)$ in a way that remains objectively true to “reality,” whatever represents a truthful response to the provided prompt, in all cases. There are, of course, some challenging epistemological questions that need to be addressed here but those are far outside of the scope of this paper. The distribution has to be learned from substantial amounts of training data. In the case of the LLMs mentioned above, the amount of data used for training can be on the order of hundreds of billions of words, mainly harvested from the internet. Depending on the employed estimation strategy for $P(X|C)$, as well as the training data, it is very difficult to avoid that the resulting model assigns an unreasonable probability to certain samples X , where unreasonable means that the probability may “not be commensurate with reality.” As a consequence, the GAI can exhibit what is called a *hallucination* and a *bias*. An example for a hallucination would be if an image creating GAI produced an image of a person with only three fingers [35]. The concept of *object permanence*

is not readily learned: if, during training, the GAI is presented with an image in which only three fingers are visible then it does not know if the remaining two fingers are just out of view or simply not there. Conversely, a GAI may also hallucinate by producing pictures of hands with six or more fingers.

In addition to hallucinations, GAI systems can also exhibit a bias. For example, in a recent study [36], the OpenAI system CHATGPT-4 was used to rank resumes. It was found that every time that a disability related award, scholarship, panel presentation, or membership was added to a resume it was ranked lower than the same resume without the entry. As such, the GAI clearly exhibited a discriminating bias against people with disabilities.

Hallucinations and bias are particularly insidious problems. Since modern GAI systems have the ability to produce output of very high perceived quality, many users are tempted to accept the output as “true” and can, therefore, be misinformed.

A technique that has garnered a lot of attention in the fight against hallucinations as well as bias is Retrieval Augmented Generation (RAG) [37]. For a RAG system we must have access to a database of information that has been vetted, and is thus judged as reliable. In a first step, every incoming prompt C is used to extract semantically similar information Q from the database. The GAI system is then, in a second step, prompted with a combination of C and Q to bias the process towards producing an output that is better aligned with the vetted information in our database.

Besides hallucinations and bias there are also other problems for GAI systems concerning: a general lack of transparency, intellectual property and copyrights, privacy and cybersecurity issues, as well as sustainability. A detailed discussion of these issues, however, is outside of the scope of this paper.

The use of GAI in conjunction with UDL has only begun to receive attention from instructors and from the research community. A chat bot that is specifically geared towards providing UDL related help to teachers was released by Beth Stark and Jérémie Rostan [38] on the POE platform [39]. The utility of GAI for UDL was recognized by several authors, especially in the context of K-12 education [40], yet very little has been proposed, so far, for higher education [41]. A very recent paper “explores whether Universal Design for Learning (UDL) can be combined with Artificial Intelligence (AI) to create a more inclusive pedagogy for students with disabilities” [42]. Noteworthy is also the very recent online workshop by Afsaneh Sharif and Lucas Wright at the University of British Columbia on “Generative AI and Universal Design for Learning in Teaching and Learning” [43].

III. EXPLICIT INSTRUCTION MODEL

As we explored how to prescribe the integration of UDL in a common, higher ed classroom experience, we determined we needed a model of what happens in that space. We found the Explicit Instruction (EI) approach is similar to what we have experienced and carried out on our own at times. Explicit instruction is a teaching method characterized by

clear, direct, structured, and systematic guidance by the teacher that incorporates modeling and demonstrations, guided and independent practice opportunities, teacher monitoring of student learning, and frequent, specific feedback on performance. This approach is particularly useful when teaching skills, strategies, and concepts [44]. We believe that many traditional approaches are somewhere between a “lecture” approach and EI. While explicit, direct instruction may mistakenly be equated with traditional lecturing, there is a distinct difference between lecturing and a dynamic Explicit Instruction model that maximizes learner outcomes. Despite criticism of EI from those favoring a more constructivist “student-led” approach, the research base in support of EI is quite extensive [45], [46]. This highly interactive instructional approach is beneficial for teaching foundational skills, strategies, procedures, and concepts across various content areas, including STEM coursework in higher education [44], [47]. When compared to traditional lecturing in STEM, researchers have found significant improvements to assessment scores and decreases in failure rates when active learning strategies are incorporated into college courses [48]. In engineering education specifically, researchers have noted that an EI model that includes an explicit, structured, interactive approach utilizing instructor modeling and guiding practice increases understanding among students, when compared with other instructional methods such as traditional lecture and computer simulations [49], [50].

Instructors using these direct methods play a central role in teaching and learning as they incorporate explicit instructional methods. Effective EI lessons take careful planning and delivery, prioritizing active student engagement until objectives have been met. This is accomplished using a “gradual release of responsibility” approach by providing varying levels of scaffolding and support as learners become increasingly independent in applying new skills and concepts [51]. Table I shows an overview of key considerations for structuring a successful EI lesson that incorporates a gradual release framework.

An effective EI model involves careful consideration of specific elements for structuring and delivering lessons. Each lesson should prioritize critical content that matches students’ needs and contributes to future academic success. During the planning phase, instructors logically sequence skills and strategies while segmenting more complex skills into smaller units until each is mastered, at which point they can be synthesized. Articulating clear learning goals and explaining the significance of the topic enhances engagement and understanding. Additionally, instructors ensure at the start of a lesson that students possess the prerequisite skills necessary to understand the new material, making it possible for them to make connections to previously mastered skills. Demonstrations of skills, along with planned examples and non-examples, are incorporated for practical application, alongside guided practice sessions featuring prompts and probing questions aimed at gradually reducing instructor intervention. Finally, instructors develop independent practice activities designed to increase fluency and sustain proficiency with application of the newly acquired skill [44].

Open	<ul style="list-style-type: none"> * State the lesson goals and discuss topic relevance * Assess and review necessary prerequisite skills
Model (I Do)	<ul style="list-style-type: none"> * Segment complex skills into manageable parts * Demonstrate/model skill, concept, strategy * Think aloud * Include examples and non-examples * Involve students using questioning * Verify student understanding * Repeat as necessary
Lead (We Do)	<ul style="list-style-type: none"> * Use prompting (verbal, visual, physical) as students practice application of skill * Monitor progress and provide targeted, contingent feedback on application of skill * Involve students using frequent questioning * Vary response types to keep all students engaged * Gradually fade prompts as students begin to demonstrate proficiency with application of skills
Test (You Do)	<ul style="list-style-type: none"> * Require independent practice of target skills * Provide opportunities for students to synthesize new skills with previously learned skills
Closing	<ul style="list-style-type: none"> * Review lesson goal * Preview upcoming content

TABLE I
STRUCTURING THE EI LESSON

With a structured plan in place that logically sequences skills and guides students to mastery, instructors consider specific elements for delivering EI lessons. Throughout instruction, instructors require frequent responses from student in a variety of ways, such as written responses, oral responses (utilizing strategies such as think-pair-share, choral responses, and partner discussions), and action responses (using manipulatives, gesturing, or role-playing). These frequent responses from as many students as possible allow instructors to closely monitor student understanding and provide appropriate affirmative or corrective feedback. This iterative process of questioning, eliciting responses, monitoring progress, and providing feedback is an integral component of EI and can be used throughout both instructor-led modeling and guided practice to maximize learner outcomes [49].

IV. APPROACH

As noted before, there are challenges to UDL adoption relating to time and scale. In this particular case, we believe that GAI can remove or at least reduce these barriers. In this section we will explain how we see GAI and UDL coming together to support EI classrooms. We will begin with a list of specific tasks that GAI does well, in our experience and opinion. For each we will provide some examples to help those who are unfamiliar with the technology. This list is not, nor can it be exhaustive. We continue to hear about and try new things with these tools. Because of the flexibility of GAI, there cannot be a specific user manual that lists out the keywords or the specific functions that a tool can carry out. The list curated here is from our own experience and is not meant to be exhaustive by any means. We encourage the reader to experiment. We have embedded example prompts in-line in this section and note them with italics.

Here are some general ways that GAI can support EI.

- **Identifying topics and goals:** ask for a list of prerequisite concepts and skills to inform your own; ask for common

pitfalls and misconceptions to help students start at the correct point

- **Delivering ideas:** ask for ideas on key points and ideas of how to deliver the content; ask for common errors or misconceptions; ask for examples; ask for feedback and suggestions on your own ideas; ask for multiple explanations to get ideas for how you could explain ideas
- **Practice exercises:** ask for ideas for individual and group exercises; ask for step-by-step solutions to problems;
- **Converting between mediums:** ask it to interpret and create visual, audio, and textual formats of data; ask it to convert one form to another (text to audio or vice versa)

Section VII contains a number of specific examples of prompts and responses from ChatGPT. The example prompts were produced through experimentation. Readers who wish to use a more systematic approach may want to consult a review paper on prompt engineering, such as [52] or [53] for example.

Looking into the future, it is likely that student work in class on all types of problems could be saved and analyzed using GAI tools. We assume that access to multiple past years of work will be available which will likely enable the following capabilities.

- Review and summarization of past work to identify topics that are typically well-received and those where students struggle.
- If “live” data is available about student work, feedback and guidance could be provided by a GAI tool, freeing the instructor to spend more time with specific students, providing support that a GAI tool cannot. Encouragement, in the case of correct answers, could be provided.
- A system could analyze student work and determine student performance on a day-to-day basis enabling more individual interventions. Specific support resources could be identified for each student, as well.

The remainder of this section will go through each process of the EI model and discuss how GAI can be used to add UDL aspects to a typical lesson. Example GAI prompts are noted in italics.

A. Content Review

During the review process, it is important to connect with each student’s collection of knowledge and past experiences. For example, ask the GAI to create a list of prerequisite topics and experiences and the level of proficiency needed for a lesson topic. *What prerequisite knowledge is useful to understand Fourier transforms?* The GAI could be used to find a collection of multi-modal resources for the group and/or for a particular student based on specific guidelines. *Find 3-5 YouTube videos and 3-5 websites that are ESL accessible that introduce aspects of linear algebra needed to understand Fourier transforms.* Instructors may be limited by their own experiences and knowledge, thus making it difficult to connect to each student’s or at least a variety of students’ interests. *Why is linear algebra useful to someone from the inner city who is interested in electronic art?* Lastly, ask the GAI to do the

mundane work that is useful but typically time consuming. *Create a glossary of terms related to linear algebra with definitions that are accessible to a first year engineering student. Include specific examples of each.*

In the case of higher ed, we believe that students should be introduced to and engaged in developing skills to do this on their own, as well as, to help them develop important lifelong learning skills and agency. In class, we might provide a couple of minutes for students to formulate and ask their own questions to the GAI to determine what is relevant to them and their experience. Scaffolding of and feedback during the process are important. This would allow students the ability to refresh on the individual topics that they don’t recall well or identify what topics need a more formal introduction because they are new. For example, a transfer student may realize that they lack sufficient background in Linear Algebra, sparking an a conversation with the instructor later on.

B. Content Presentation

The goal of this step is to present the ideas of the lesson so the focus is on making sure that the material is engaging and accessible to each student. Again, instructors may be limited by their own knowledge and experience so seeking input from a GAI could be helpful. *How are Fourier transforms related to smartphones and media? Focus the answer on people who are 18 years old and from the southwest of the US.* The GAI can also help develop the list of topics, find resources, and create additional support material. *I am teaching a lesson that introduces the Fourier transform. Provide me with a list of topics and 3-5 references for each. Create a glossary of common terms related to the Fourier transform for the lesson. Explain why the Fourier transform is useful to electrical engineering and provide 3-5 visual examples of the use of the Fourier transform. This lesson will be delivered to second year electrical engineering students.* And if you have a student whose first language is not English, you can ask the GAI to translate any aspect of the lesson into another language. *Translate the glossary into Spanish and identify topics that don’t translate accurately.* In this case, our example is typically related to procedural knowledge and so we could ask the GAI to provide a list of the steps to do a Fourier transform. *What are the steps of applying a Fourier transform? Explain each step and how it connects to the larger process.* Finally, the GAI can help support connection and transfer by making connections with other topics. *Explain how the Fourier transform relates to other concepts that a second year electrical engineering student is learning. What are other concepts that are similar?*

Since each individual student has a better sense of their own interest, they can explore this faster and more thoroughly on their own. Again, a short amount of time could be provided for students to ask a GAI about the relevance of a topic to them and their interests. Example prompts could seed the process. A GAI could also be used along the way to remind students of terms and topics that they realize they need to develop in the moment. This form of *just in time* support on their own

may save class time but there might also be other students who would benefit from the discussion.

C. Guided Practice

When creating practice for students, it is important to understand the scaffolding aspect as well as provide examples that will aid in reinforcing the concept but also provide some variety to help with transfer. *Create a list of 5 simple example problems that help teach about Fourier transforms. The examples should be from different engineering disciplines such as electrical, mechanical, and biomedical. Provide detailed solutions for each example.* Distribute the examples across the space of problems needed for the lesson: modeling, leading, and testing. If applicable to the lesson goals, GAI could be used for more just-in-time learning by students but it should support and not replace the learning process. Based on our experience, GAIs have varied levels of success doing practice problems but we expect this to improve over time. It is important that instructors are aware of this and verify the tool's output. As these tools continue to develop it is important to have discussions with the students about how they integrate into the learning process and that they have appropriate information literacy skills to evaluate the output.

At this step in the lesson the students are actively doing work and so we need to think about how to integrate GAI into their expression process. For this we can leverage the same aspects of GAI that are used for helping students access content. One challenge, for now, is converting information into a form that is accessible to a GAI. This step may require additional tools such as text-to-speech systems, for example. Looking forward, we assume that this is a temporary issue and there will be more and more ways to interact with these tools. We assume that students will be able to provide audio (speech), visual (hand drawn or app created), text, and tactile input to the tools. For example, an iPad and stylus could be used to capture student drawings which are then uploaded to the GAI tool for processing. We assume that this will extend to almost every type of interaction device including Braille. We assume that one could use Morse Code for input or output if that's the preferred method. The true value of GAI tools is that they can do these conversions without a lot of additional tools. **Ideally, this allows students to create in their preferred method and instructors to consume in their preferred method.**

D. Corrections and Feedback

As the students exercise their new knowledge and skills, they will need appropriate feedback including confirmation. Providing specific feedback to each student has long been best provided by the instructor. They can interpret the issue and make suggestions about process or address misconceptions. As expected their ability to keep up with an entire class has its limits. This is another area where GAI can support learning. While our anecdotal experience with using ChatGPT to evaluate student answers has had mixed success, RAG and assumed future improvements of the technology suggest that this is and will continue to improve. From the instructor's

perspective GAI could be used to help new instructors better understand misconceptions and student struggles. *What are common misconceptions about Fourier transforms and what are common mistakes second year engineering students make when working on Fourier transform problems? What are some ways to help fix these misconceptions and mistakes?* This type of work could be done during the preparation of the lesson and inform example and counter-example problems.

In the context of in-class feedback, we believe that giving students the ability to submit questions and answers for feedback to a GAI provides them with instant feedback and guidance. With some mix of typed information and an image of a student's work, a GAI should be able to provide feedback on correctness or identify incorrect aspects and provide guidance.

In both cases, the GAI could be used to reword or further explain feedback in a way that resonates with a student - because GAIs are *chat* based, a student or instructor could ask for questions if things don't resonate at first. *I don't understand what I did wrong, can you explain that in a different way? Why can't I do XYZ?* Additionally, information can be translated or shown in different ways using a GAI. Students can have multiple ways to input information into a GAI to get feedback. We hypothesize that students will ask more and different questions to a GAI than they would to another individual primarily because they do not think the technology will judge them.

Finally, another more comprehensive use of GAI is to help students as they work through a problem. Instead of submitting an entire answer or process, they can submit their work piece by piece and the GAI can guide them through the process, providing feedback along the way. This may help fix misconceptions and reinforce the process in real time. This approach is more radical in a way because it positions the GAI to lead the student through the process.

E. Independent Practice

As students become familiar with their new knowledge and skills, they should be asked to go work on their own in a less scaffolded way. GAI can prompt, evaluate, and provide feedback on these problems in a similar fashion. We see the line between guided and independent practice blurring if GAI is included a great deal.

F. Review

As the lesson concludes EI suggests doing a review to help the student connect to and reflect on what they've done. GAI can summarize the topic, summarize student effort that was sent to it, identify future directions for the knowledge and skills, and provide individualized feedback on areas where the student exhibits strength and weakness. Some of these require that the student's work has been entered into the GAI which may or may not be the case depending on how it was involved in the lesson and practice. If students have access to the GAI during this review phase they could pose final questions to clarify their understanding and be prompted to

identify connections between what they've learned and other areas of their own knowledge and experience. *GAI prompt for the student: How do Fourier transforms connect with your future goals and interests based on what you've learned today? What aspects of Fourier transforms seem most clear? Least clear?* This could engage the student in a final thought exercise to help connect past and current knowledge and experience.

G. Providing Context

Context helps a GAI target responses. Having a profile of each student including some information about their origin, their interests, their strengths and weaknesses, and preferred methods of interaction would help craft responses that are more relevant to them.

V. LIMITATIONS

Noting the limitations of this work is a challenge because there are so many. Prior sections have noted the challenges of using GAI. Additionally, our approach to this paper is not and really cannot be systematic. We engaged the EI model and UDL because they provide bounds for the work, versus trying to answer the questions *How can GAI support learning?* which has an infinitely long answer. There is not a finite list of GAI capabilities and even if there was it would be different for every tool and change rapidly. We continue to work and learn about the technology but a major way to find out if things will work is simply to experiment. If the tool doesn't do what you want, tell it that *No, that isn't exactly what I meant. I really wanted you to...* and engage in a conversation with it. We still feel a bit awkward to call it "you" and talking to it like a person.

The GAI responses in this paper are not 100% reproducible. You can type in the exact same prompt and get a slightly different or very different response. This is challenging for researchers who want to validate results and instructors who like controlled environments for learners. We love it and hate it simultaneously. Additionally, the GAI space is still in its infancy and embodies the cliché of being "the wild west," a space without adequate rules or norms. We expect access to the tools to change over time and examples here may simply be wrong in the future once the space has matured. We can only speculate what will happen in the next 6 months, 12 months, and beyond.

By the time you read this, everything will have changed and it will continue to change. This is very much a timely paper that may be out of date sooner than we desire. We have worked to generalize the ideas and goals of this work such that even if the specifics change, the ideas will still be useful in some number of years to come.

Finally, we have not covered "prompt engineering" in this paper and encourage all interested readers to search for resources on that topic. Understanding how to explain to a GAI what you want it to do will become a skill the same way that creating an effective web search query is an important skill today. We also expect that skill to need to evolve, so staying current is important.

VI. SUMMARY AND FUTURE WORK

Our goal has been to inform on how GAI can help with STEM instruction, specifically by supporting the integration of UDL principles in these classrooms. Because further scoping was necessary, we used the explicit instruction model because it is an established, effective method that we believe most closely matches what many (untrained) higher ed STEM faculty do in the classroom. We identified specific ways that GAI could be used in preparation of a class and in class to support students and faculty. In doing this, we included a number of specific GAI (ChatGPT) prompts and responses to inform those who have not yet explored such tools. We hope that we have piqued your interest and you will go experiment. With this knowledge, we hope that instructors will make their classrooms and lessons more accessible with minimal additional work. The future of this work depends on what happens with the tools. We will probably ask ChatGPT for ideas.

VII. CHATGPT EXAMPLES

We have not found a useful resource with specific prompts and response text so we have included the prompts and responses for the tasks discussed in Section IV. We have truncated long responses in order to save space. Because of the probabilistic nature of GAI, these results are not identically reproducible - every request will get a unique response *but* the responses, like any set of teaching resources, should provide similar information. We used ChatGPT 4.0 in early May of 2024 to produce these results.

A. Fractions with Pokemon

Prompt: how could I teach 3rd graders about fractions using pokemon cards?

Response: Teaching fractions to 3rd graders using Pokémon cards is a creative and engaging idea! Here's a step-by-step approach to make the lesson both fun and educational:

Step 1: Introduction to Fractions

Objective: Understand what a fraction represents.

Activity: Start by showing the entire deck of Pokémon cards and explain that fractions are a way to talk about parts of a whole. For example, if the whole is the entire deck, one card is a part of that deck.

Step 2: Explaining Numerators and Denominators.

... truncated

B. Nodal Analysis Instructions

Prompt: Explain the steps of the nodal analysis process at the level of the first year engineering student. Format the response in latex syntax. *We included the last part as an example of other requests you can make.*

Response: Step 1: Identify and Label Nodes

- Examine the circuit diagram and identify all nodes. A node is any point where two or more components connect.
- Designate one node as the reference node, often referred to as the ground. This node will have a potential of zero volts.

- Label the remaining nodes with variable names (e.g., V_1, V_2, \dots, V_n).

Step 2: Assign Node Voltages

- Assign a voltage variable to each node relative to the reference node. These variables represent the unknown voltages that need to be determined.

...truncated

C. Example Problem - DeMorgan's Law

Prompt: Write a simple example problem that asks students to use DeMorgan's law to solve the problem. Include a fully worked out solution. Format the response in latex.

Response: Problem: Let A and B be sets such that $A = \{1, 2, 3, 4\}$ and $B = \{3, 4, 5, 6\}$. Use DeMorgan's Law to find $(A \cup B)^c$ and show that this result is the same as $A^c \cap B^c$.

Solution: First, we find $A \cup B$:

$$A \cup B = \{1, 2, 3, 4\} \cup \{3, 4, 5, 6\} = \{1, 2, 3, 4, 5, 6\}$$

Now, we find the complement of $A \cup B$:

$$(A \cup B)^c = \{x \in \mathbb{U} \mid x \notin \{1, 2, 3, 4, 5, 6\}\}$$

Assuming the universal set \mathbb{U} is $\{1, 2, 3, 4, 5, 6, 7, 8\}$, we have:

$$(A \cup B)^c = \{7, 8\}$$

...truncated

D. Example Comment Summary Prompt

Prompt: I am giving feedback to a team of engineering students. Feedback came from several different professors who reviewed their work. This was the prompt for the feedback: Help People and the Planet: Become more competent and effective than you are now. Take a moral stance. Build relationships. Be transparent about project goals and progress. Account for all stakeholder needs, especially stakeholders without a voice. What are your thoughts on the human aspects of the project that the team discussed on this topic? Have they made a case for the benefits the project could produce?

Could you please take the points of view below and summarize it into a single statement. The statement should be positive yet critically constructive: ... *concatenated comment data here...*

E. RMS Power Example

Prompt: Explain RMS power and connect to a physical phenomenon. Format for Latex.

Response: RMS Power Explained RMS, or Root Mean Square, is a mathematical term used to describe the effective value of a varying voltage or current. RMS power refers to the continuous power handling capability of a device such as a speaker, or the average power output of an amplifier, distinct from peak or maximum power.

Mathematical Definition For a waveform, the RMS value is calculated by:

$$V_{\text{RMS}} = \sqrt{\frac{1}{T} \int_0^T V(t)^2 dt}$$

where $V(t)$ is the instantaneous voltage and T is the period of the waveform.

Connection to Power The RMS value of voltage or current is crucial for power calculations due to its direct relation to the heating effect, a fundamental aspect of power. The average power P in a resistive load is:

$$P = V_{\text{RMS}} \times I_{\text{RMS}}$$

where V_{RMS} is the RMS voltage across the load, and I_{RMS} is the RMS current through the load. ... *truncated*

F. Trying to find the right words

Prompt: What is it called when the sand at the bottom of a bridge post gets washed away?

Response: When the sand or soil around the base of a bridge post (typically called a bridge pier or abutment) gets washed away, this phenomenon is known as "scour." Scour occurs when fast-moving water removes sediment from around bridge foundations, which can expose them and potentially undermine the stability of the bridge. ... *truncated*

G. Explaining Importance

Prompt: What is a cache hit or miss and why do I care?

Response: In computing, a **cache hit** occurs when the data requested by a system can be found in the cache memory, a small, high-speed storage area. Conversely, a **cache miss** happens when the requested data is not found in the cache, necessitating retrieval from slower main system memory.

Why Cache Hits and Misses Matter Performance: Cache memory operates at a much higher speed compared to main system memory. Therefore:

- A cache hit allows for faster data retrieval, significantly speeding up the operation of the system.
- A cache miss, however, results in slower data retrieval as the system must fetch the data from the slower main memory, potentially leading to a noticeable decrease in system performance.

Efficiency: An effective cache reduces the time and energy required for data retrieval, enhancing computational efficiency. A high cache hit rate signifies effective use of the cache, reducing the load on the main memory and enhancing the system's overall efficiency. ... *truncated*

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