
Using generative artificial intelligence in chemistry education research: prioritizing ethical use and accessibility

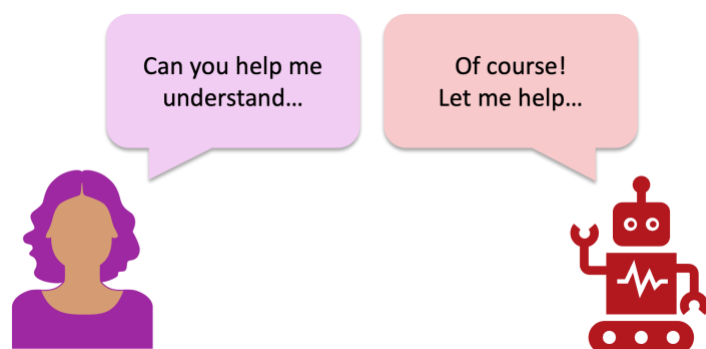
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ABSTRACT

Generative artificial intelligence (GenAI) has the potential to drastically alter how we teach and conduct research in chemistry education. There have been many reports on the potential uses, limitations, and considerations for GenAI tools in teaching and learning, but there have been fewer discussions of how such tools could be leveraged in educational research, including in chemistry education research. GenAI tools can be used to facilitate and support researchers in every stage of traditional educational research projects (e.g. conducting literature reviews, designing research questions and methods, communicating results). However, these tools also have existing limitations that researchers must be aware of prior to and during use. In this research commentary, we share insights on how chemistry education researchers can use GenAI tools in their work ethically. We also share how GenAI tools can be leveraged to improve accessibility and equity in research.

GRAPHICAL ABSTRACT



KEYWORDS

Generative AI, Education, ChatGPT, Use of AI, AI Integration, Tools, Technology, Chemistry Education Research

The field of artificial intelligence (AI) has recently experienced unprecedented growth, ushering in a new era of transformative tools and possibilities across various industries. In particular, generative artificial intelligence (GenAI) tools built on powerful deep learning algorithms possess the capacity to receive and generate human-like text, enabling them to engage in contextually relevant conversations with users. The frontrunner of large language models (LLMs), ChatGPT, represents a significant breakthrough in natural language processing, heralding a new paradigm for educators and researchers.

Tools like ChatGPT have already brought forth complex discussions and debates within education. Concerns around academic integrity have led some institutions to ban students and educators from using GenAI.¹ However, others have argued for the opposite; these AI tools exist, continue to develop, and are readily accessible to those with internet access; banning these tools risks fostering ignorance in educators while increasing the appeal and safety risks for students.²⁻⁴ Bans also threaten to exclude people with disabilities, who are often early adopters and stand to benefit the most from new technologies like ChatGPT.⁵ Therefore, it is vital for educators and educational researchers to learn about these tools to ensure they can be used in a safe and ethical manner.^{6,7}

Thus far, much of the existing literature on GenAI, including in this journal, has focused on ways to adapt and leverage tools like ChatGPT in the classroom (assessment, curriculum development, adaptive learning, *etc.*), including its limitations.⁸⁻¹⁵ However, there has been little written on the potential uses and limitations of GenAI in chemistry education research, including as a tool for enhancing accessibility and equity in research.

RESEARCH QUESTIONS

In this article, we provide an overview of how GenAI might be used ethically by chemistry education researchers to support their research, as well as to improve accessibility and equity in research. The intent of this article is not to persuade researchers to use GenAI tools, nor will it be a comprehensive review of existing technologies, as these technologies are emerging and evolving each day. Rather, we intend to provide a snapshot of existing technologies to support researchers in developing awareness of their potential uses and limitations. We define GenAI as artificial intelligence capable of generating text, images, or other media using generative models.¹⁶ Given the chatbot's

versatility and popularity, we focus primarily on ChatGPT in this article, with some discussion of other GenAI tools.

Specifically, we aim to address the following questions:

1. What are the current uses and limitations of GenAI for chemistry education research?
2. How can chemistry education researchers ethically employ GenAI?
3. How can GenAI contribute to improving accessibility and equity in educational research?

POSITIONALITY STATEMENT

We are members of the chemistry education and research communities. We are also students (undergraduate and graduate) who recognize AI's potential to both greatly disrupt and improve chemistry education research. Our article stems from both our fascination and excitement with AI's potential in education and research, as well as the challenges we have faced as learners in an educational system and society still grappling with these new technologies. In particular, our author team includes people with disabilities (PWDs) who have been early adopters of AI technologies. These members of our team have first-hand experience with the benefits that AI tools has for improving equity and accessibility in education and research, as well as the harms that can emerge when members of our educational and research communities choose to ignore and restrict access to GenAI tools.

LIMITATIONS OF GENERATIVE ARTIFICIAL INTELLIGENCE TOOLS

Before discussing potential uses of GenAI tools for chemistry education research, it is imperative to discuss the existing limitations and ethical considerations when using such tools.

Lack of real understanding. Though outputs generated by ChatGPT may appear to be highly sophisticated and conversational, ChatGPT ultimately lacks the ability to meaningfully understand user inputs and its own outputs. ChatGPT responds to user inputs by breaking inputs down into smaller units called tokens, and then using its internal knowledge and contextual understanding to generate a response. It predicts the next tokens to add to the response, expanding the response by considering patterns it learned during training. This process continues until the model decides to stop or reaches a predefined response length. The generated response is provided to the user as an answer, but ultimately: ChatGPT lacks true understanding, operates based on patterns, and does not possess consciousness or emotions.

Hallucinations. ChatGPT's ability to generate useful and reliable outputs is currently limited by its tendency to "hallucinate" (*i.e.*, make up information and present it in a way that appears factual). Similar to the process described above, users provide an input or prompt, and ChatGPT responds by generating text. However, in the case of hallucinations, the model generates content that is entirely
85 fictional or fabricated, often without any basis in reality. It can invent stories, facts, or details that do not exist. The hallucinations are created based on the model's training data and the context it infers from the input. These hallucinations are not based on genuine understanding or factual information but rather on the patterns and associations the model has learned during training.

Bias. When a user provides an input or prompt, ChatGPT generates a response by predicting the
90 next tokens to add to the input based on its training data and the context it infers. However, if the training data contains biased or discriminatory content, ChatGPT can inadvertently produce responses that reflect those biases. These biases may include stereotypes, prejudices, or unfair judgments related to race, gender, religion, or other characteristics. The model does not intentionally generate biased content, but it can reproduce bias present in its training data. Additionally, ChatGPT is also
95 limited in its knowledge scientific literature—because its knowledge base is built on readily available information on the Internet, any content that is behind a paywall (*e.g.*, many academic journals and databases) may not be included in its knowledge base.^{17–20}

No guaranteed data security or confidentiality. There is often no transparency regarding what the owners of GenAI applications do with the input data from users or how the algorithms behind the
100 tools generated a particular output. Data collected and processed by these applications might be stored in servers located in various countries, potentially making it subject to the laws and regulations of those jurisdictions. For example, stored in the United States could fall under the purview of the United States Patriot Act, which grants government agencies broad surveillance powers. This introduces a cross-border legal dimension, making it essential for users to be aware of potential
105 implications when using such applications.

Because of these limitations, guidelines for ethical GenAI use are imperative—we detail principles and strategies on this in the following section.

USING GENERATIVE ARTIFICIAL INTELLIGENCE TOOLS SAFELY AND ETHICALLY

In Table 1, we share four principles to support researchers in using GenAI ethically their research:

110 transparency, verification, responsibility, and privacy and data management (details in the Supporting Information).^{21,22}

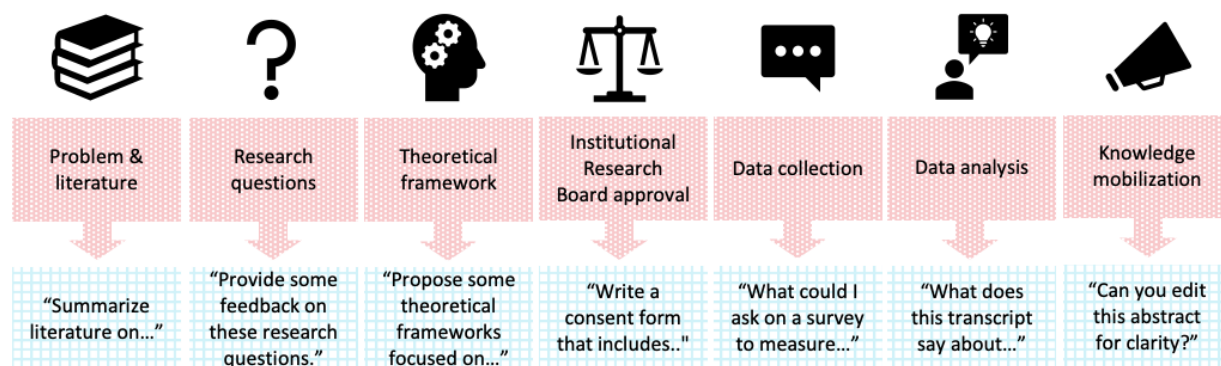
Table 1. Ethics principles and practices for GenAI. Adapted from KU Leuven (2023).

Key Ethics Principle	Ethical GenAI Practices
Transparency ^{23,24}	<p>a. Disclosure of AI Use: Researchers should clearly disclose when they are using AI, like ChatGPT, in their research. This includes mentioning it in research papers, reports, and presentations to ensure transparency about the tools and methods used.</p> <p>b. Explain AI Assumptions: Researchers should provide explanations of the limitations and assumptions of AI models like ChatGPT. This includes acknowledging the model's potential biases and limitations in understanding context.</p> <p>c. Share Preprocessing Steps: Describe any preprocessing or data cleaning steps applied to the AI-generated content, as these steps can impact the results and interpretation of the research.</p> <p>d. Document Model Versions: Keep records of the specific model versions, configurations, and training data used in the research to allow for reproducibility and future verification.</p>
Verification ^{18,23,25}	<p>a. Cross-reference with Human Expertise: Researchers should cross-reference AI-generated content with human expertise and validated sources to verify the accuracy of information before drawing conclusions or making claims.</p> <p>b. Fact-checking: Engage in fact-checking and validation of AI-generated information, especially for critical or sensitive research topics, to ensure the reliability of results.</p>
Responsibility	<p>a. Ethical Oversight: Establish ethical review processes within research teams or institutions to evaluate the potential ethical implications of using AI models and address them accordingly.</p> <p>b. Responsible Use: Exercise caution when using AI to address sensitive or controversial topics and avoid using AI-generated content in ways that may harm individuals or communities. Use as a help/support.</p>
Privacy and Data Management	<p>a. Data Anonymization: When using data for training or evaluation, ensure that any personal or sensitive information is properly anonymized or removed to protect privacy.</p> <p>b. Data Security: Implement robust data security measures to safeguard research data, including AI-generated content, from unauthorized access or breaches.</p> <p>c. Informed Consent: If human subjects are involved in the research, obtain informed consent, and clearly communicate the use of AI in data analysis and its potential impact on privacy.</p> <p>d. Compliance: Adhere to relevant data protection regulations and ethical guidelines when collecting, storing, and handling data in research involving AI models.</p>

USES OF GENERATIVE ARTIFICIAL INTELLIGENCE TOOLS IN CHEMISTRY EDUCATION RESEARCH

If researchers are aware of its limitations and how to use it ethically, ChatGPT and similar tools

115 can serve a productive role in research projects. Here, we detail (with examples) how GenAI could be used to support researchers at various stages of a traditional chemistry education research project (Figure 1). Table 2 includes examples of ChatGPT prompts that could be used for each of the stages provided in Figure 1. While there *are* other tools that can perform similar or more specific functions, for simplicity, we focus on ChatGPT.



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Figure 1: Key stages of conducting educational research (represented in red and dotted) along with examples of how generative AI could be used at each of these stages (represented in blue and grid)

Table 2. Stages of chemistry education research, with example prompts when using GenAI (ChatGPT).

Research stage	Example prompts
Problem and literature	<ul style="list-style-type: none"> I am a beginner to chemistry education research. Provide a summary of the existing research literature on [topic]. What are some unsolved problems or challenges in chemistry education?
Research questions	<ul style="list-style-type: none"> How would you revise the following research question to be more specific? Pretend you are [stakeholder]. What feedback would you have for the following research question(s)?
Theoretical framework	<ul style="list-style-type: none"> I am conducting a study with [research questions]. What are some theoretical frameworks that could help guide this work? Explain the differences between constructivism, information processing theory, and sociocultural theory in simple terms (i.e., limit jargon)
Institutional research ethics board approval	<ul style="list-style-type: none"> The following is a draft of consent form for a study on [research topic]. Can you provide feedback on things I might be missing or that could be changed? Prepare a draft/template of an recruitment email with these key points:...

Data collection	<ul style="list-style-type: none"> • What are some effective ways to recruit students to participate in a study involving [research method]? • The following are some survey items I have prepared to address [research question]. Can you (a) review for clarity and concision, and (b) suggest any items to remove or combine?
Data analysis	<ul style="list-style-type: none"> • What kind of statistical test could I use to address [research question]? • How would I conduct [statistical test] in R Studio? Can you walk me through the coding process? • I've identified the following themes from qualitative data on [research question], but I'm struggling to generative a cohesive qualitative model. Do you have any hypotheses for how these themes might be related to each other?
Knowledge mobilization	<ul style="list-style-type: none"> • The following is an abstract I have prepared for an academic conference on [topic]. Can you edit this draft for clarity and adjust the wording for [audience]? • From my research, we found [research finding]. What questions about my research might [stakeholder] have? • From my research, we found [research finding]. What are some ways to leverage these findings in the chemistry classroom to support student learning?

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Learning new information

Reviewing literature involves generating critical and comprehensive summary of existing published research and scholarly works related to a particular topic or research question. It is an essential component of academic and scientific research papers, theses, dissertations, and grant proposals. The main purpose of a literature review is to provide an overview of the current state of knowledge on a specific subject, highlight the gaps or controversies in the field, and establish the context for the new research being conducted.

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ChatGPT's ability to serve as an adaptive tutor or learning companion has been well-documented, making it a helpful tool for tasks like reviewing literature, learning new information, *etc.*^{13,26–28} This may be especially relevant and useful in a field like chemistry education research in which many emerging researchers may not be formally trained in discipline-based educational research theories or methods.²⁹ For example, the following demonstrates an example of ChatGPT's potential use as an adaptive tutor or learning companion, capable of providing insights on established ideas, theories, concepts, *etc.* for different audiences:

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Researcher:

Explain the theoretical framework of constructivism.

ChatGPT:

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Constructivism is a prominent educational and social theory that proposes that knowledge and understanding are actively constructed by individuals, rather than passively acquired from the outside world. The theoretical framework of constructivism emerged from the works of several influential scholars, including Jean Piaget, Lev Vygotsky, and Jerome Bruner, among others. It is widely applied in education, psychology, and sociology to explain how people learn, develop, and make sense of the world around them.

Researcher:

I am a first-year graduate student who knows very little about educational research. Can you explain the theoretical framework of constructivism more simply and with less jargon?

ChatGPT:

Of course! Let's explain the theoretical framework of constructivism in simpler terms:

Imagine you're like a little scientist in your mind, always trying to figure things out. Constructivism is a way of thinking about learning that says:

You learn by doing: Instead of just passively listening to someone, you learn better when you actively participate and try things out for yourself.

You build on what you already know: Your brain is like a puzzle, and every new thing you learn is a piece that fits together with what you already understand. So, your past experiences and knowledge help you learn new things.

Learning is a social experience: Talking and interacting with others helps you learn. When you discuss ideas with classmates or teachers, it helps you understand things better.

You learn best with a little help: When someone more knowledgeable helps you, like a teacher or a friend, you can learn more and go further. They give you support and guidance, like training wheels on a bike.

Figuring things out yourself is important: Instead of just memorizing facts, figuring things out on your own is more valuable. It helps you remember better and think critically.

Thinking about your own thinking is helpful: It's like being a detective of your thoughts. When you stop and think about how you are learning, it helps you learn even better.

Your culture and background matter: The way you understand things
can be influenced by your culture, family, and experiences. It's essential
to respect and consider different perspectives.

Other tools have been specifically designed to support researchers in conducting literature reviews,
such as Elicit and Assistant by scite_.^{30,31} Elicit responds to the user's questions and keywords using
an LLM (*e.g.*, GPT-3) to generate a table of semantically relevant papers and a brief response to the
user's prompt using information from the first few papers in the table.³⁰ The table's columns can be
customized by the user and are populated by AI-generated responses to the user's prompts. Assistant
by scite_ uses GPT-3.5 to engage with users in a conversational format, responding to queries ranging
from keywords and questions, requests for citations, requests for supporting and competing evidence,
reference checks, requests to visualize citation connections, and writing character-limited social media
posts, essays, and grant proposals.³¹ Both Elicit and scite_ databases access research articles through
publishing partnerships and open access journals and repositories to support researchers.

Getting research feedback and brainstorming

Research feedback refers to the evaluation, comments, and suggestions provided by peers,
mentors, advisors, or experts on a research project or paper. Feedback is an essential part of the
research process as it can help improve the quality and validity of the study. Researchers seek
feedback at various stages of their work, from the early conceptualization phase to the final draft
before publication.

ChatGPT can be used as a source of feedback for new ideas, research questions, and project
design. In essence, ChatGPT can serve as a virtual dialogic partner, providing researchers with the
ability to receive feedback from different perspectives. For example:

Researcher:

I am investigating the following research question: How are students
using ChatGPT to support their chemistry learning? What kind of
methods could be used to investigate this question?

ChatGPT:

To investigate how students are using ChatGPT to support their
chemistry learning, you can use the following methods:

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- Surveys: Conduct surveys to gather quantitative data on how often students use ChatGPT for chemistry-related questions and their perceived benefits and challenges.
 - Interviews: Conduct in-depth interviews with students to explore their experiences, motivations, and specific use cases for ChatGPT in chemistry learning.
 - Content Analysis: Analyze online forums, social media, or educational platforms where students discuss their use of ChatGPT for chemistry-related queries to identify trends and common practices.
 - Observations: Observe students in real-time as they use ChatGPT for chemistry learning, either through screen recording or in controlled classroom settings.
 - Case Studies: Select a few students and conduct in-depth case studies to gain a deep understanding of their unique experiences and learning outcomes when using ChatGPT for chemistry support.

Researcher:

I am considering using surveys. can you help me outline a timeline for a survey study on this topic

ChatGPT:

Certainly! Here's an outline for a timeline for a survey study on how students are using ChatGPT to support their chemistry learning:

Week 1-2: Planning and Preparation

- Define research objectives and questions.
- Develop the survey questionnaire.
- Obtain necessary approvals (e.g., ethics review if required).
- Identify the target audience (students) and create a contact list or recruit participants.
- Set up the survey platform (e.g., online survey tool).

Week 3-4: Pre-survey Testing and Piloting

- Pilot test the survey with a small group of students to identify any issues with clarity, wording, or survey flow.
- Make necessary adjustments based on pilot feedback.

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- Finalize the survey questionnaire.

Week 5-6: Recruitment

- Send out invitations to potential survey participants (students).
- Follow up with reminders to improve response rates.
- Monitor and manage participant recruitment.

Week 7-8: Data Collection

- Keep the survey open for responses.
- Monitor response rates and adjust recruitment efforts as needed.
- Ensure that data collection is proceeding smoothly.

Week 9-10: Data Analysis and Reporting

- Close the survey and gather all responses.
- Clean and prepare the data for analysis.
- Analyze the survey data using appropriate statistical tools.
- Prepare a preliminary report of findings.

Week 11-12: Interpretation and Conclusion

- Review and interpret survey results.
- Draw conclusions based on the data.
- Consider the implications of the findings for your research question.
- Identify any limitations of the study.

Week 13-14: Final Reporting

- Write a comprehensive research report or paper.
- Create visual representations of the data (charts, graphs).
- Discuss the implications and contributions of the study.
- Conclude with recommendations for future research or improvements.

Week 15-16: Presentation and Dissemination

- Prepare a presentation of your findings.
- Share the results with relevant stakeholders, such as educators or researchers.
- Consider submitting your research to academic journals or conferences.

Week 17-18: Reflection and Future Planning

- 275
- Reflect on the study's process and outcomes.
 - Identify areas for improvement in future research.
 - Plan any follow-up studies or research based on the findings.

280 In addition to providing broad feedback on research directions and design, researchers can use ChatGPT to create initial drafts, edit, and provide feedback on research instruments (*e.g.*, interview protocols, survey items). This can include feedback on item wording, items to combine/remove, and the extent to which items and the data they produce align with research goals (*i.e.*, evidence for validity). For example:

Researcher:

285 I am investigating the following research question: How are students using ChatGPT to support their chemistry learning? Propose 2-3 survey items to address this question.

ChatGPT:

290 To investigate how students are using ChatGPT to support their chemistry learning, you can create a survey with a mix of closed-ended and open-ended question. Here are some survey items you can consider:

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- Have you used ChatGPT to support your chemistry learning? (Yes/No)
 - If yes, how has ChatGPT specifically helped you with your chemistry learning? (Open-ended)
 - What challenges, if any, have you faced when using ChatGPT for chemistry-related questions? (Open-ended)

Analyzing data

300 Data in chemistry education research often take two forms: quantitative and qualitative.

Quantitative data refers to numerical data that can be measured and analyzed using statistical techniques, with the goal of quantifying relationships, patterns, and trends within the data.

Qualitative data refers to non-numeric data, such as text, images, audio, or video recordings, with the goal of identifying themes, patterns, and insights within the data. The following will describe how

305 ChatGPT and other GenAI tools might be able to assist in both qualitative and quantitative data analysis.

Researchers can engage with ChatGPT to quickly generate descriptive statistics, perform basic calculations, or explain statistical concepts. This can be particularly beneficial for individuals seeking immediate insights or explanations in their data analysis workflow. However, evidence suggests that
310 ChatGPT may hallucinate even when handling elementary mathematical tasks, potentially compromising the accuracy and reliability of complex statistical calculations.³² Therefore, researchers should exercise discretion when relying solely on ChatGPT for tasks involving advanced statistical manipulations, seeking verification from other statistical tools or experts to ensure the veracity of their results.

315 One promising application of ChatGPT is its ability to generate simulated or synthetic datasets, effectively serving as a virtual data source for experimentation and learning. This can significantly aid researchers in fine-tuning their analytical methodologies before engaging with real data. By employing ChatGPT to create mock datasets based on specific variable specifications, researchers can simulate scenarios, assess the performance of their analysis tools, and refine their strategies. These synthetic
320 datasets, exportable as .csv files, provide a risk-free environment for refining techniques, saving valuable time and resources.

Researchers engaging in qualitative studies can leverage ChatGPT to aid in identifying themes, generating initial insights, and organizing textual data. By providing prompts or excerpts from transcripts, researchers can utilize ChatGPT to generate potential interpretations, alternative
325 phrasings, or even novel perspectives, thereby facilitating the exploration of nuances within qualitative data.

Communicating research

Perhaps its most powerful use, ChatGPT can serve as a versatile writing support tool for researchers. For example, researchers can ask ChatGPT to provide valuable feedback on drafts of
330 abstracts, manuscripts, *etc.*, seeking input on things like clarity, concision, jargon, *etc.*

Researcher:

The following is an abstract I have prepared for an academic conference on chemistry education. Can you edit this draft for clarity and adjust the wording for an audience of chemistry educators?

335 “ChatGPT is a generative artificial intelligence tool that can serve as a learning companion for students. In particular, students can use ChatGPT to answer questions, provide feedback, and learn new information. Our research study sought to investigate how chemistry students are using ChatGPT to support their learning. We will report
340 findings from a survey study focused on this topic.”

ChatGPT:

"ChatGPT, an artificial intelligence tool with generative capabilities, offers potential as an educational companion for chemistry students. It enables students to seek answers, receive feedback, and acquire new knowledge.
345 Our research delves into the utilization of ChatGPT among chemistry students, aiming to shed light on its role in their learning process. In this presentation, we will share insights derived from a comprehensive survey study focused on this precise inquiry." ChatGPT can also generate drafts tailored to specific content and style requirements, though given the
350 ethical implications, this capability may be better reserved for tasks like ethics applications rather than manuscript or thesis writing. For example, researchers can ask ChatGPT to prepare a draft of an ethics documents with specific structure, tone, and information. The model can then craft a preliminary drafts that adhere to these specifications,
355 serving as a starting point for further refinement by the researcher:

Researcher:

Generate a template for a research consent form with the following sections: Title of study, Researchers, Funding, Invitation to participate, Purpose of the study, Participation, Risks, Benefits, Confidentiality and
360 anonymity, Conversation of data, Compensation, Voluntary participation.

ChatGPT:

Research Consent Form

Title of Study: [Insert Title of the Study]

Researchers:

365 Principal Investigator: [Insert Name]

Co-Investigator(s): [Insert Names]

Affiliation(s): [Insert Affiliations]

Funding: This research is funded by [Insert Funding Source(s)].

Invitation to Participate: You are invited to participate in a research study conducted by the researchers listed above. Your participation is entirely voluntary.

Purpose of the Study: The purpose of this study is to [Insert a brief description of the study's objectives and goals].

Participation: Participation in this study will involve [Insert a brief description of what participants will be asked to do during the study]. The estimated time commitment for participation is approximately [Insert estimated duration].

Risks: There are minimal risks associated with participating in this study. [Insert any potential risks, discomforts, or inconveniences that participants might encounter during the study]. The researchers will take all necessary precautions to minimize these risks.

Benefits: Potential benefits of participating in this study include [Insert potential benefits, such as contributing to scientific knowledge, personal insights, or any other benefits]. However, there may be no direct benefits to you.

Confidentiality and Anonymity: Your identity and personal information will be kept strictly confidential. [Insert information about how data will be stored, who will have access to it, and any steps taken to protect confidentiality]. Your responses will be anonymized in any publications or reports resulting from this study.

Conservation of Data: Data collected during this study will be retained for a period of [Insert duration] and may be used for future research. All data will be securely stored and maintained in accordance with applicable data protection regulations.

Compensation: You will receive [Insert information about any compensation, if applicable, such as monetary compensation, gift cards, or other incentives] for your time and participation in this study.

Voluntary Participation: Your participation in this study is entirely voluntary, and you have the right to withdraw at any time without penalty. Your decision to participate or not will not affect any current or future services or benefits to which you are entitled.

Consent: By agreeing to participate in this study, you acknowledge that you have read and understood this consent form, and you voluntarily

agree to participate. If you have any questions or concerns about the study, you may contact the researchers at [Insert contact information]. If you have any questions about your rights as a research participant, you may contact the Institutional Review Board (IRB) at [Insert IRB contact information].

Participant's Full Name: _____

Participant's Signature: _____ Date: _____

If the participant is under 18 years of age:

Parent/Guardian Full Name (if applicable): _____

Parent/Guardian Signature (if applicable): _____

Date: _____

GenAI could also be used to visualize research data and findings, though existing text-to-image technologies like DALL-E 2 and Midjourney tend to require highly specific prompting and/or generate abstractions that often are not useful for scientific communications (Figure 2).

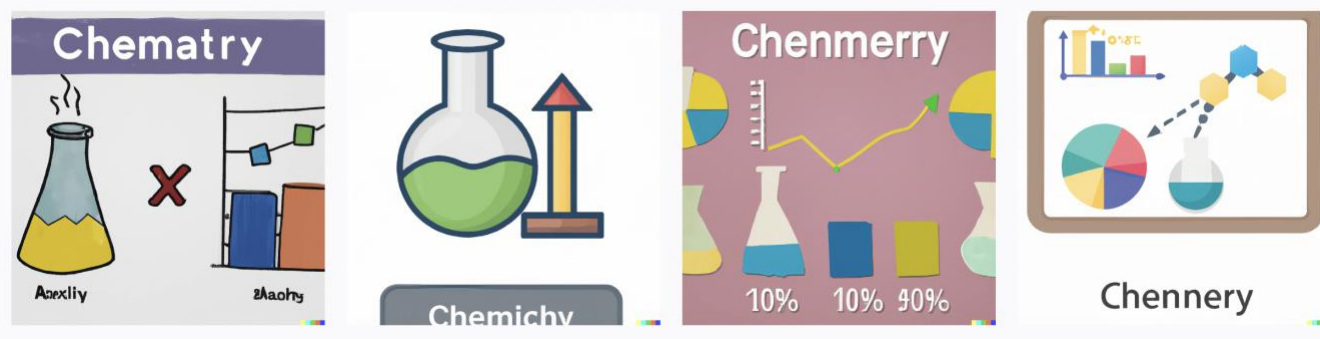


Figure 2: Output from DALL-E when prompted to generate "a bar graph with chemistry education research data".

USING GENERATIVE ARTIFICIAL INTELLIGENCE TOOLS TO IMPROVE ACCESSIBILITY AND EQUITY IN RESEARCH

The need to address accessibility and equity in research has been expressed in strategic plans and statements by research funding agencies, researchers, and educators across the United States and Canada.^{33–41} A chemistry educational research landscape that embodies equity, diversity, inclusivity, and accessibility is vital for cultivating exceptional and impactful research and learning.^{40,41} To achieve

research excellence at the global level, it is imperative to confront systemic obstacles that hinder the
430 full participation of every individual.

In this article, we focus on GenAI tools that have the potential to support (1) researchers who are English learners and/or have communication disabilities and (2) researchers with neurodivergent differences in information processing.

English learners and/or communication disabilities

435 Recent research has shown that researchers who speak English-as-an-additional language (Eng+) face unique and significant difficulties with learning and communicating research in an English dominated scientific community.⁴²⁻⁴⁴ AI tools that support academic writing can also be useful for people with communication disabilities. ChatGPT and other gen AI programs offers these researchers opportunities to focus on the scientific content of research communications rather than the scientific
440 writing. For example, researchers can input initial drafts of text into ChatGPT and ask for ChatGPT to provide feedback on the writing, allowing researchers to focus on the message they are trying to convey, rather than how to best convey that message within the norms and conventions of academic writing.^{45,46} This has the potential to lessen the technical and financial burden of editing and proofreading papers for English learners and would be a substantial step toward achieving equity in
445 science, especially those in low-income countries who often cannot afford to use typical English editing services.⁴³ Additionally, ChatGPT can simplify complex text into simpler summaries for readers who are still learning English or translate text between different languages.^{45,47} ChatGPT also has built in text-to-speech feature and offers voice tutorials that can allow Eng+ researchers to practice presenting their research.^{45,48}

450 Neurodivergence and disability in information processing

Research meetings can be overwhelming, and some may experience cognitive overload with the vast amounts of information covered, whether that be due to exhaustion from the day or neurodivergent differences in information processing. Otter AI Chat is a GenAI tool that can improve accessibility of research meetings by creating opportunities for meeting participants to collaborate, ask and respond
455 to questions, and generate content based on meeting data.⁴⁹ It can also generate meeting summaries for participants who are absent or attend late. Additionally, Otter AI Chat allows non-speaking persons with disabilities to communicate through text. With the integration of speech recognition technology to

convert text to speech and transcribe real-time speech into text, the tool can reduce communication barriers for people with hearing, visual, and speech impairments. Speech recognition technology can also be found in applications like Google Live Transcribe.⁵⁰

Listening.io and Speechify are other text-to-speech GenAI tools that make written and online text accessible to many people.^{51,52} Listening.io allows researchers to listen to academic papers, select sections of a paper to listen to, and create notes while listening to the paper. Additionally, Listening.io includes lifelike voices, complete with emotion and intonation and removes excess text such as references and citations helping the fluidity of the article. For some people who are neurodiverse and may struggle with concentration, learning by listening can be easier than learning by reading as it gives them the chance to hear and process the information differently.⁵²

Microsoft 365 Co-pilot uses generative AI technology to complete tasks in Microsoft's 365 apps, including Word, Excel, PowerPoint, Outlook, and Teams.^{53,54} For example, Co-pilot is capable of translating a written research proposal created in Word into a PowerPoint presentation. This can serve as a draft where the researcher can input additional content and flow to their presentation. Furthermore, Co-pilot can transform text between bullet points and paragraphs, condense content in slides, and generate unique slide titles. While Co-pilot's capabilities can improve work efficiency for all, it can be particularly beneficial for individuals who have cognitive information processing delays where it might take more time and effort to create research presentations. Researchers also have a responsibility of making their work accessible to various audiences. Microsoft 365 has recently created the Accessibility Assistant to help people produce more accessible and inclusive content by providing defaults to prevent issues before they occur, real-time and in-context remediation to correct issues as they arise, and simple guidance appearing in the workflow.^{55,56}

CONCLUSION

GenAI tools like ChatGPT can serve as versatile research tools for feedback, discussion, and brainstorming, offering researchers with ways to accelerate each stage of traditional chemistry education research projects (literature review, data collection/analysis, writing, *etc.*). These tools also offer (and have offered) pathways towards improved accessibility for members of our community, including people with disabilities, people who are neurodivergent and researchers learning English-as-an-additional language (Eng+).

However, as our community continues to adapt and learn about these tools, it is imperative that we recognize their limitations and be steadfast in our commitment to using them ethically.

Importantly, GenAI contributions can serve as a *starting point* for exploration, learning, and feedback, but cannot in their current iterations completely replace human creativity and judgement. Regardless of how these technologies evolve, the principles of transparency, verification, responsibility, and privacy and data management serve as a useful guide for ensuring academic integrity when using GenAI tools. By being mindful of these tenets, we as a research community can harness the potential of ChatGPT as a powerful tool to advance chemistry education research.

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ASSOCIATED CONTENT

Supporting Information

Additional text on (a) ethics principles for GenAI use and (b) use of GenAI by persons with disabilities (PDF).

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