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A Pilot Study Inquiring into the Impact of ChatGPT on Lab Report Writing in Introductory Engineering Labs

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Abstract

This exploratory study focuses on the use of ChatGPT, a generative artificial intelligence (GAI) tool, by undergraduate engineering students in lab report writing in the major. Literature addressing the impact of ChatGPT and AI on student writing suggests that such technologies can both support and limit students' composing and learning processes. Acknowledging the history of writing with technologies and writing as technology, the development of GAI warrants attention to pedagogical and ethical implications in writing-intensive engineering classes. This pilot study investigates how the use of ChatGPT impacts students' lab writing outcomes in terms of rhetorical knowledge, critical thinking and composing, knowledge of conventions, and writing processes. A group of undergraduate volunteers (n= 7) used ChatGPT to revise their original engineering lab reports written without using ChatGPT. A comparative study was conducted between original lab report samples and revisions by directly assessing students' lab reports in gateway engineering lab courses. A focus group was conducted to learn their experiences and perspectives on ChatGPT in the context of engineering lab report writing. Implementing ChatGPT in the revision writing process could result in improving engineering students' lab report quality due to students' enhanced lab report genre understanding. At the same time, the use of ChatGPT also leads students to provide false claims, incorrect lab procedures, or extremely broad statements, which are not valued in the engineering lab report genre.

Introduction

Technology integration in education has significantly transformed traditional teaching methods, offering a variety of tools and resources that enhance student's learning experience. Students can benefit from access to a wealth of information, fostering self-directed learning and critical thinking skills. The global reach of the internet has facilitated online learning (Banihashem et al., 2023), breaking down geographical barriers and connecting students and teachers from different parts of the world. Incorporating artificial intelligence (AI) in education marks a transformative shift, enhancing personalized learning experiences by tailoring content to individual student needs (Fitria, 2023; Sichterman et al., 2023; Noroozi & Sahin, 2023). Generative artificial intelligence (GAI) is a type of artificial intelligence technology that can create a wide range of content, ranging from text to videos (Johri, et al., 2023; Dobrin, 2023). ChatGPT, one of the GAI tools developed by OpenAI (OpenAI, 2022; Van Dis et al.,

2023; Abdullah et al., 2022; Wu et al., 2023; Bahrini et al., 2023) surprised the public by providing human-like responses to prompts. Upon its public launch in November 2022, it took only five days for a million users to log in. According to the latest available data (Lefkowitz, 2019), ChatGPT reached over 173 million users within six months of its appearance to the public. It should be added that, in 2023, ChatGPT is no longer the only player in the field of generative AI, as Google has released its own GAI tool, Google Bard (https://bard.google.com/?hl=en), and Microsoft has introduced its new artificial intelligence (AI)-powered Bing search engine (Mehdi, 2023). However, this paper focuses on ChatGPT, a significant GAI tool considered by the public.

The emergence of ChatGPT has and will continue to impact the atmosphere in college education (Qadir, 2022; Adesholar & Adepoju, 2023; Roose, 2023; Keller, 2023; Tutella, 2023; UCLA Academic Senate, 2023; MIT CMS/W, 2023; Cu, 2023; Barnett, 2023; University of Michigan CRLT Blog, 2023). The results of a survey of 1000 four-year college students in the United States in January 2023 showed that almost 30% of them had used ChatGPT in their written assignments. According to this study, 75% of the students believe that using ChatGPT for their assignments is considered cheating, but they do it nevertheless (Intelligent, 2023). In an informal poll by The Stanford Daily in January 2023, many students (17% of 4,497 respondents) in the institution acknowledged that they had already used ChatGPT on their final exams. Most of those students stated that they used ChatGPT only for brainstorming and outlining; however, approximately 5% reported submitting AI-generated materials with almost no edits (Cu, 2023).

Many college professors have accepted that the emergence of GAI tools like ChatGPT will impact student writing and learning, and many schools have begun to communicate about it at the institutional level. At Princeton University, professors are advised to explicitly state their policies on using ChatGPT in their syllabi. Cornell University leaves it up to each professor to decide what works best for their courses (Chun, 2023). Some universities, as well, have developed guidelines for such AI tools. For instance, the University of California Los Angeles's "Teaching Guidance for ChatGPT and Related AI Developments" recognizes the concerns regarding academic integrity and states that "unless the instructor indicates otherwise, the use of ChatGPT or other AI tools for course assignments is akin to receiving assistance from another person and raises the same concern that work is not the student's own." The guideline encourages the faculty to clarify their expectations and policies in their course syllabi (UCLA Academic Senate, 2023).

Engineering educators, too, are communicating about how ChatGPT might influence their students and classes in their majors (Qadir, 2022; Roose, 2022; Blose, 2023; Manning, 2023; Ribeiro, 2023; Jack, 2023). They believe ChatGPT could enhance students' engagement with vast amounts of new information, provide personalized feedback on any questions, and accelerate their problem-solving processes. At the same time, they are commonly concerned about the content generated by ChatGPT being inaccurate, biased, outdated, or uncertain about its origins (Limna et al., 2023; Nikolic et al., 2023; Kocon et al., 2023; Farrokhnia et al., 2023; Lo, 2023). They also worry that students' use of ChatGPT might decrease their critical thinking and creativity, attention to ethics, and interpersonal skills (Limna et al., 2023; Nikolic et al., 2023; Imran & Almusharraf, 2023; Firat, 2023; Elkhodr et al., 2023; Farrokhnia et al., 2023; Lund et al., 2023; Ray, 2023; Mhlanga, 2023).

Regardless of the controversy over ChatGPT and its impact on professional communication education in college, it seems likely that many college students, including engineering undergraduates, might consider using it as a tool for their writing assignments. Dayton and Buck claimed that ChatGPT can help improve student writing quality, but they also suggest that professors need to redesign their conventional assignments by replacing definition-oriented assignments with writing tasks that require students to think, analyze, synthesize, and apply what they have learned in class to specific situations. Along these lines, the authors further encourage developing new assessment strategies. For example, they suggest giving more credit to students' thinking skills rather than the technical correctness of the writing (Dayton & Buck, 2023). Designed to guide a range of educators about GAI, Dobrin's recently published book focuses mainly on ChatGPT. Many of his suggestions can be helpful for educators who assign writing to students; however, he clearly argues that instructors should explore how GAI technologies are utilized in their discipline-specific classes (Dobrin, 2023). Indeed, studies on how engineering undergraduates use ChatGPT for their writing-intensive courses can provide a valuable example of the impact of GAI on undergraduate student writers' discipline-specific contexts.

This study focuses on undergraduates' lab writing in entry-level or gateway engineering laboratory courses, providing one such engineering-specific practice in college education. Lab reports in gateway engineering courses have a unique position in engineering education. These lab courses are often students' first experience writing a genre with engineers as the primary audience (Kim & Olson, 2020); therefore, many engineering undergraduates are assigned to write lab reports even as they are new to understanding the expectations and conventions of the technical audience in these courses. Engineering lab report writing often requires clear and concise language, an objective and formal tone, a well-organized structure, and extensive use of graphs and tables, all of which are common features in engineering communication. Additionally, lab reports are one of the most common forms in engineering practices. Their typical organization with an introduction, methods, results, discussion, and conclusion, also known as IMRDC, is widely accepted for writers to use to convey new findings effectively to technical audiences (Kim et al., 2023). Writing satisfactory quality lab reports can be challenging for engineering undergraduates in the gateway engineering laboratory courses; however, lab report writing offers them a chance to practice this engineering-specific genre (Kim & Olson, 2020; Shapiro, 1991; Genau, 2020; Alba-Flores, 2018; Gravé, 2019; Wiebe et al., 2021; Johnston & Douglas, 2024; Carter et al., 2005; Kim et al., 2019). Many studies and surveys noted the undergraduates' use of ChatGPT for their writing assignments; however, understanding of how ChatGPT impacts engineering undergraduates' lab report writing is lacking. Our comparative study is uniquely designed to evaluate engineering undergraduates' lab reports with and without the aid of ChatGPT. Their lab writing outcomes were evaluated in terms of rhetorical knowledge, critical thinking and composing, knowledge of conventions, and writing processes. In what follows, we provide a brief literature review of the development of ChatGPT and its impact on undergraduate writing, followed by the research questions that guided our study. Next, we describe our research methodology and design, as well as our data collection and analysis processes, which include analysis of student lab reports and a student focus group. Our Results and Discussion sections follow, presenting our key findings and insights from the study. In closing, we identify study limitations, draw some conclusions, and offer recommendations based on the research outcomes.

Literature Survey

Development, Applications, and Limitations of ChatGPT

ChatGPT is an advanced general-purpose chatbot (Adamopoulou & Moussiades, 2020) that employs the state-of-the-art natural language processing (NLP) architecture called Transformers to generate human-like responses to prompts (Abdullah et al., 2022; Vaswani et al., 2017). Transformers were initially designed for translation tasks. Previous translation tools mainly relied on recurrence neural networks (RNNs) (Li, 2022), wherein the text model looks at every single word in the sentence when deciding how to translate each word, which is called the attention mechanism. But what if we don't need an actual translation of the sentence, and we just need to understand the underlying meaning in the sentence? The self-attention mechanism (Vaswani et al., 2017) introduced in Transformers made that possible and eventually led to the birth of GPT (Generative Pre-trained Transformer) models. A GPT model is "generative" because it can generate text or other forms of data. It's called "pre-trained" because, before fine-tuning for specific tasks (such as text classification, question answering, language translation, code generation, etc.), the GPT model is trained using a vast body of text data so that it can learn language patterns and relationships without relying on explicit human annotations. During this phase, the model learns how to predict the likelihood of each word in a sequence based upon the context of the surrounding words. The training process of the GPT model entails adjusting the "parameters" of its underlying neural network in order to minimize its prediction errors.

ChatGPT is capable of what is called In-Context Learning (ICL), a method of prompt engineering that allows the language model to learn and complete tasks via imitation (Wu et al., 2023). The latest version of ChatGPT is based on GPT-4 (released in March 2023), which is much more advanced than its predecessor, GPT-3.5 (released in March 2022), and requires a subscription fee. GPT-4 can take text and image inputs simultaneously, making it capable of performing more challenging tasks (OpenAI, 2023). For example, in an experimental study, GPT-4 received a mean score of 90.19% on a junior-level course (Stochastic Decision Models) midterm exam. In comparison, the mean score for GPT-3.5 was 73.5% (Bahrini et al., 2023). Similar results were reported in other experimental studies (Wu et al., 2023; Arredondo, 2023). Due to its ability to generate human-like conversations, ChatGPT has a wide range of potential applications, including automated translation, virtual tutoring, language practice, grammar correction, customer service automation, content creation, code debugging, scientific research, and education (Abdullah et al., 2022; Wu et al., 2023; Jack, 2023; Qadir, 2023; Nazari et al., 2021; Shoufan, 2023). ChatGPT can benefit college students by helping them learn complex skills (Ranjbaran et al., 2023), providing personalized learning experiences (Firat, 2023; Farrokhnia et al., 2023), and assisting them with their test preparation and writing tasks (Ray, 2023; Elkhodr et al., 2023).

ChatGPT is indeed a potent tool, but it has its limitations. First, it can sometimes generate incorrect results. OpenAI's official website states, "ChatGPT sometimes writes plausible-sounding but incorrect or nonsensical answers" (OpenAI, 2022). This may be due to errors and noise in the training data (Wu et al., 2023) or ambiguous questions in the prompt. In response to ambiguous queries, ChatGPT usually tries to make the best guess on what the user meant to ask, and then the model generates some results based on that guess. ChatGPT is also sensitive to the way queries are phrased. That means ChatGPT's responses can vary depending upon how the user states

the prompt (OpenAI, 2022; Wu et al., 2023). Another limitation of ChatGPT is that its pre-trained model has no knowledge about any information that became available on the web after September 2021. There are also ethical concerns about using ChatGPT, such as the ownership of the generated text and compliance with copyright laws, as ChatGPT might use data from third-party sources without proper attribution (Lund et al., 2023).

Impact of ChatGPT or Other Artificial Intelligence Tools on Writing Education for Undergraduates

The rise of digital technologies has accelerated digital learning that supports reading and writing skills (Turunem, 2019). A 2012 review showed a growing trend of online environments using multiple technological tools and platforms to support argument-based computer-supported collaborative learning in the 21st century (ABCSCL) (Noroozi et al., 2012). For example, online peer review scripts provided scaffolding that improved the quality of students' writing in an ABCSCL study (Lafiti & Noroozi, 2021). While AI has been utilized in various ways to enhance college writing education, the implementation of such AI tools is often studied in the context of English as a Second Language (ESL) classrooms. John & Woll (2018) conducted a comparative study on the effectiveness of AI tools on students' handwritten essays in a college-level francophone Teaching English as a Second Language (TESL) course. This study focused on Grammarly, Virtual Writing Tutor, and Microsoft Word's grammar-checking functions. Grammarly outperformed the other two AI tools regarding overall grammatical error detection from the TESL student samples. Lei (2023) studied the feedback from Grammarly Premium on English language learners' essays assigned in English-intensive courses at a Taiwanese college, suggesting that Grammarly Premium could identify a range of errors up to a discourse level. According to Dizon & Gayed (2023), Grammarly's predictive text and real-time corrective feedback supported novice Japanese English language learners, while the implementation of Grammarly resulted in statistically significant improvement in student users' grammatical errors and lexical richness over the non-Grammarly users in class.

With the development of ChatGPT, researchers have called for studies focused on students' use of the technology and its impact on their writing performances (Ranjbaran et al, 2021; Barrot, 2023; Li, 2023). After ChatGPT was released in 2022, many students and researchers started getting help from this tool in their writing tasks. Conducting an investigation into undergraduate students' perceptions of ChatGPT, one study that included self-reported data from 534 students at a Polish university indicated that most students are comfortable adopting ChatGPT as a new technology (Strzelecki, 2023). A case study investigating the usefulness of ChatGPT in providing feedback for undergraduate academic essays found that it was useful at providing quantitative feedback, but less accurate when it came to qualitative feedback (Wang et al, 2024). Another study suggests that while ChatGPT is efficient in its ability to find information, organize, and draft components of texts, more research is needed to determine what it can and cannot do related to human intelligence as a writing technology (Zhai, 2022).

The relationship between writing and technology is a significant area of research in writing and composition pedagogies. Considering writing a technology of literacy (Ong, 1982), earlier studies investigated the ways in which computer technologies have impacted and become embedded within writing instruction (Ohmann, 1985; Selfe, 1999; Selber, 2004; Banks, 2006). Such studies suggest the importance of supporting students in developing a critical understanding of the role of technological tools in writing processes and practices. As a result of these

and other studies, the position statement on Principles for the Postsecondary Teaching of Writing by the Conference on College Composition and Communication includes "emphasizing relationships between writing and technologies" among its Guiding Principles for sound writing instruction (CCCC Position Statement, 2015). Acknowledging that written communication will continue to include new tools and evolving genres, this statement emphasizes the importance of writing pedagogies that help students understand and negotiate the affordances and limitations of writing technologies such as ChatGPT.

Current scholarship in composition studies concerning AI-assisted writing suggests that we remember this history of writing as a technology and technology as a tool of writing, as well as the importance of lessons learned about the relationship between writing and technology. When we focus only on the negative impact on student learning and writing, we assume a limited and often linear understanding of writing and writing processes (Graham, 2023). Recognizing writing processes as recursive and varied, however, allows for the possibility of generative writing pedagogies and assessment practices that can make room for the use of AI in composing processes while also problematizing its use (Vee, 2023). Scholars argue for the role of informed writing pedagogies in understanding what AI-assisted writing can and cannot do. Furthermore, teaching with informed writing technologies means resisting hunting for plagiarism when dealing with students' use of AI and large language model (LLM)-generated writing and instead modeling critical digital literacies to clarify for students the ethical obligations of source use with digital tools, including having conversations about user data and intellectual property in the use of AI and LLM technologies (Johnson, 2023). Designing activities that can assist students in understanding the potential inaccuracies, biases, and ethical issues involved further supports critical digital literacies (Anderson, 2023). Collectively, this literature review suggests that students' engagement with AI-assisted writing is a complex, technologically-infused writing environment that would benefit from further research for both students and instructors. In what follows, we share the research questions that guided our ChatGPT study.

Research Questions

Many engineering undergraduates use ChatGPT when they are assigned to write lab reports in their majors. Engineering undergraduates' use of ChatGPT in the context of lab report writing is largely unknown. To better understand the impact of ChatGPT on engineering undergraduates' lab writing, this study addresses the following research questions:

- How does the use of ChatGPT impact engineering undergraduates' lab writing outcomes in terms of 1) rhetorical knowledge, 2) critical thinking and composing, 3) knowledge of conventions, and 4) writing processes?
- What are the students' perspectives on ChatGPT for their engineering lab report writing?

To answer these questions, we conducted pre-post testing by directly assessing sample lab reports from a group of engineering undergraduates (n = 7) from two gateway engineering lab courses in electrical and mechanical engineering. We also conducted a follow-up focus group to learn students' experiences and perspectives on ChatGPT in the context of engineering lab report writing and engineering education.

Method

The Institutional Context

This study took place in the engineering programs at Washington State University Vancouver (WSU-V), one institution of the multi-campus system of WSU, the state's land-grant university. More than half of WSU-V undergraduate students meet Pell eligibility requirements, which indicates low household incomes; 45% are first-generation college students. WSU-V offers two ABET-accredited (ABET, 2021) engineering programs: electrical and mechanical. These two programs have approximately 350 undergraduate students, 40 graduate students, and 15 full-time faculty members. The summary of the pedagogical context of the courses is given in Table 1.

Table 1. Summary of the Pedagogical Context of the Courses

Engineering Lab Course	ECE 214: Design of Logic Circuits	Mech 309: Introduction of Engineering Materials
Course Credits	2 lecture credits, 1 lab credit (3 lab hours/week)	2 lecture credits, 1 lab credit (3 lab hours/week)
Instructional Structure	Lectures by the instructor; Labs by the instructor and graduate TAs	Lectures by instructor; Labs by graduate TAs
Typical Students and Their Majors	Sophomores in electrical engineering	Juniors in mechanical engineering
Number of Lab Reports Assigned in the Course	11	6
% of Lab Report Scores in Total Grade	30%	33%
Time Between Lab Report Assignment and Lab Due	1 week	2 weeks

The participating lab courses at WSU-V include a sophomore-level Design of Digital Circuits Lab course and a junior-level Introduction of Engineering Materials course. The course descriptions of the two engineering lab courses for the study are as follows:

ECE 214 Design of Logic Circuits: This is an introductory course to the design and application of combinational and sequential logic circuits, with the delivery of lectures and labs. It covers binary and hexadecimal numbers, Boolean logic and theorems, logic gates, logic simplification using Karnaugh maps (K-maps), combinational logic analysis and design, sequential logic analysis and design, and an overview of programmable logic. There are eleven labs, and their topics include basic logic gates, binary addition and subtraction, Boolean theorems, logic simplification, binary-coded decimal (BCD) to 7-segment conversion, combinational logic optimization, decoders and counters, latches, shift registers, flip-flops, and state machines. Each lab requires lab reports written by individual students.

Mech 309 Introduction of Engineering Materials: This course is an introductory materials science course covering

the structure of materials, phase equilibrium, phase transformations, mechanical failure, and mechanical properties. This course also has lectures and six labs. The six labs' topics include material identification, elastic deformation, tensile testing, material properties, metal strengthening, and heat treatment. Students develop and conduct engineering materials testing using scientific instruments such as an x-ray diffractometer, strain gauges, data acquisition systems, a universal tensile tester, hardness testers, optical microscopes, etc. Lab reports are required for individual students in each lab.

Data Collection

This study was conducted with student volunteers from the two engineering lab courses listed in Table I, which were offered in the fall term of 2022. The student participants (n = 7) consisted of one woman, six men, two students of color, one English language learner, and two older returning students. Each participant signed a consent form approved by the institution's internal review board (IRB).

The independent variable in this study is the use of ChatGPT when revising two labs for each course. Original lab report samples from two labs of each course were collected during the fall term, which provided the baseline. These original lab report samples were assigned and written before ChatGPT's free public testing began on November 30, 2022. In May of 2023, the seven student participants were asked to rewrite their labs using ChatGPT after completing a one-hour introductory session about ChatGPT offered by the co-authors in the engineering majors. The collected rewritten lab reports are identified below as the revision samples. Using ChatGPT during the revision process was mandatory, and the student volunteers had up to two weeks to revise their reports of the two labs. During the two weeks, no writing instructions or interventions were provided. The experiments and discussions presented in this paper are based on GPT-3.5 because all of the participating students used the free version of ChatGPT to complete their revisions. This study was designed to be blind to the prompt design; therefore, the participating students could use any prompt when interacting with ChatGPT.

The two engineering labs chosen for ECE 214 were Lab 5: Speed Warning Device, which required a memorandum, and Lab 8 - LED racquetball and tennis, which required a technical report. For each lab, there was a lab manual describing the expected task and providing information about grading, lab write-up expectations, ABET course outcomes (ABET, 2021), and an assessment rubric. Furthermore, a report template with IMRDC formatting was provided to students for each lab report type. For MECH 309, Lab 4 - Mechanical Properties and Lab 6 - Phase Transformation were chosen for the study. Lab 4 required a technical report focusing on data presentation and analysis, while Lab 6 required a research paper focusing on data interpretation using outside sources to align with ABET course outcomes (ABET, 2021).

After collecting the revisions, a focus group was conducted via Zoom by one co-author, a rhetoric and composition faculty member from outside the engineering programs. The focus group aimed to solicit the student participants' experiences and perspectives about ChatGPT when they used it for their lab writing revisions. The focus group questions were not given to the participants beforehand and consisted of three types of questions: engagement questions, exploration questions, and exit questions. The focus group questions are included in Appendix B.

Research Instrument and Student Lab Report Sample Evaluation Process

A total of 28 lab report samples were collected from the seven participating students. We conducted a comparative textual analysis for all the collected student lab report samples to observe the impact of ChatGPT on students' lab report revisions. An inclusive assessment rubric (Table A in Appendix) was developed and adapted from the four categories originating from the 2014 Writing Program Administrators Outcomes Statement for First-Year Composition or WPA Outcomes (Lowe, 2014): 1) rhetorical knowledge, 2) critical thinking and composing, 3) knowledge of conventions, and 4) writing processes. We chose criteria that align with the WPA Outcomes (Lowe, 2014) because the outcomes represent the kinds of writing knowledge and practices that students develop in first-year general education writing courses and will further apply and adapt when completing writing tasks across the curriculum and into their majors. The outcomes speak to the complexity of writing as iterative and adaptive processes that students perform as writers, including engagement with tools and technologies. As such, we adapted these outcomes to use as criteria to map and identify the types of revisions that students made to their original lab reports while using ChatGPT. In conducting this comparative textual analysis of lab reports before and after ChatGPT use, we have focused more on the updated content in the revisions, which the students' interactions with ChatGPT influenced.

Results and Discussion

This section presents the results of the comparative textual analysis between the original and revised student lab report samples according to the four dimensions of the assessment rubric. Focus group results are also included in each subsection, providing additional qualitative data from students' perspectives to inform the direct assessment of the student writing samples. The holistic assessment results are introduced with a discussion at the end.

Rhetorical Knowledge

Rhetorical knowledge refers to an understanding and application of the principles and strategies of rhetoric, focusing on the negotiation of purpose, audience, context, and conventions while creating and revising texts (Lowe, 2014). Under the category of rhetorical knowledge, audience awareness for a technical engineering audience was most improved with the revisions. This improved audience awareness was primarily located in revisions made to the introduction section of the lab reports. Examples of enhanced audience awareness included providing more context to indicate the lab experiment's overall purpose and including detailed information that defined or elaborated on technical terms relevant to the study and lab report write-up.

The following example resulted from one student's improved discussion of lab significance and context in light of engineering practices in the introduction section. The writer added the tensile testing lab's overall contribution to engineering practices at the beginning of the revision report's introduction section before introducing tensile testing. Adding such introductory information by using an outside source strengthens the introduction by articulating the purpose of tensile testing in the context of engineering practices.

Example A	
Original Lab Report Sample	Revision
Tensile testing is a common test in engineering fields to empirically determine properties of materials for use in various applications. [1] Some important properties that can be determined from tensile testing include the elastic modulus, yield strength, ultimate tensile strength (UTS), fracture strength, and ductility. In this lab steel coupons were tested with hardness testing and tensile testing to experimentally determine the properties of annealed and cold worked steel of a given designation.	When designing a structural member, machine component, or some other product the engineer must consider several characteristics of materials including how easily it can be machined or formed, its cost and availability, the reaction of the material with the environment of use, and physical properties such as ductility and strength [1]. Testing is employed to evaluate the performance of materials under the conditions in question. One common mechanical test is tensile testing which places a material specimen (coupon) under increasing tensile load until failure while measuring the applied force and deformation of the sample [2]. Using the load and deformation data engineering stress may be plotted versus engineering to determine the yield strength, ultimate tensile strength (UTS), fracture strength, elastic modulus, and ductility of the material tested [2].

The next student's revision also shows an improved discussion of lab goals in the introduction section. The revision better explains the lab's overall goal, which is simplifying a circuit design to reduce the production cost through fewer and/or cheaper electronic components. In the original lab report sample, the student went too much into the details of how this circuit was supposed to work while not attending to the broader context.

Example B	
Original Lab Report Sample	Revision
The goal of this lab was to create a circuit that will cost 89 cents or less with a 4 bit input and a 2 bit output. The 4 bit input is split into two parts, the first 2 bits will be the speed limit and the second 2 bits will be the speed the car is currently traveling. The 2 bit output signify two separate things, the first LED will indicate whether the car is speeding and the second LED whether the car is speeding 10 mph above the speed limit or if the speed is above 65 mph.	As you know, the overall cost of the design is a key factor in its success, and our goal is to keep the cost as low as possible while still meeting all the necessary requirements. I'm pleased to report that we've been able to identify several ways to reduce the cost of the design, and we're confident that we can meet the target cost of 89 cents or less. One of the main cost considerations in the design is the choice of chips we use. We've done extensive research and testing to identify the most cost-effective chips that meet all the necessary performance requirements. By carefully selecting the right chips and minimizing the number of chips we use, we believe we can achieve significant cost savings.

The next two student samples show improvement in audience awareness in the revised text by supplying more defined or detailed technical terms in the lab reports. In the revision of Example C, for example, the writer added definitions of a phase and phase diagrams from credible outside sources. All of the definitions were technically sound, and the introduction section in the revision supplies in-depth technical information, which is often expected by a technical audience.

Example C	
Original Lab Report Sample	Revision
Phase transformations of materials are phenomena that we witness often without giving them a second thought. The most common phase transformations relevant to daily life would be the transformation of water from solid to liquid or liquid to gaseous phases. For a material like water there are simply three phases distinct to the naked eye which for a given pressure, only depend on the temperature of the water. This type of phase system is called a unary system because only one substance is considered. The transformation and distinction between phases become decidedly less obvious to the eye when considering metals and metal alloys.	Phase diagrams are a useful tool to visualize how materials change with temperature and chemical composition. In the context of metallurgy, a phase refers to a specific chemical composition, bonding, and arrangement [2]. More than one phase may be present in a metal at a given time [2]. In steels considered at a steady state, the phase may change with the weight percent of alloying elements present or with the temperature of the metal [1]. When the effects of time are considered the phase of steel is also dependent on the time for which a sample stays at a given temperature, the rate at which the metal cools, and how much it cools from its heated state [1].

In the revision of Example D, the writer added a paragraph describing the use of K-maps in simplifying Boolean logic and why that is important in this lab. The provided description creates a meaningful link between what students learned in class about K-maps, and how it can be used in a practical application to reduce the overall cost of the design in the revised results and discussion section. The original lab report did not contain this useful information.

Example D	
Original Lab Report Sample	Revision
None	The use of K-maps is particularly important in this lab because they allow for the simplification of Boolean algebraic expressions. Simplifying the expressions reduces the number of gates required to implement the circuit, which in turn reduces the overall cost of the circuit design.

We see this emphasis on audience awareness in the students' focus group responses as well, where many students note that ChatGPT was helpful in defining concepts and/or providing more detailed information on particular concepts. Multiple students shared that they might imagine future uses of ChatGPT to explain a concept that they

are not fully understanding. Other students agreed that they might use it for definitions, finding sources, and searching for more details on a specific technical topic. One student, for example, noted, "if I'm not understanding a certain concept, I could ask it to just explain it to me differently." Other students shared that it provided additional sources as well as additional information for introductions and conclusions. Sometimes, however, the additional technical information included from the student's use of ChatGPT suggestions detracted from rhetorical knowledge and audience awareness, as in this example located in this revised results and discussion section:

Example E	
Original Lab Report Sample	Revision
None	Adding alloying elements to base metals enhances the properties of the metals by altering their microstructures, like in the case of adding carbon to iron to make steel. This combination results in cementite and its presence increases its hardness and wear resistance.

In this example, the writer added two sentences about the addition of alloying elements in ferrous materials. The second sentence contains the wear resistance of cementite, which is important but irrelevant to the lab topics. Elaborating on the definition of the newly introduced technical terms during the lab improved audience awareness in the revision; however, the added technical information about cementite detracted from the lab report focus.

Knowledge of Conventions

Knowledge of conventions in academic writing refers to understanding and applying the rules and guidelines that govern macro- and micro-structures of genres, including overall organization to sentence-level style and editing. Under the category of knowledge of conventions, we see some improvements in students' revisions in the use and awareness of the IMRDC macrostructure, genre conventions, and style. These improvements were somewhat inconsistent across the student samples, however. In the following example, the revised results and discussion section illustrates an improved understanding of the purpose of the section in the IMRDC structure. The writer explained the lab data (the effect of the tempering process on the microstructures of AISI 1045 and 4041 steel coupons) in the original report. In the revision, the writer added one paragraph to elaborate on the findings from the lab data and make a claim about the tempering process from a broad view at the end, which is appropriate for the discussion section in the lab report genre.

Example F	
Original Lab Report Sample	Revision
None	It is important to note that the specific tempering temperature and time used can significantly impact the resulting microstructure and mechanical properties of the steel. Different tempering temperatures can lead to

Example F	
Original Lab Report Sample	Revision
	the formation of different amounts of equilibrium phases, such as ferrite and cementite, and can affect the steel's hardness and strength. The tempering process must be carefully controlled to achieve the desired properties for the intended application.

In comparison, however, in another revision a student removed the lab's crucial technical information in the discussion section, which is expected to elaborate and interpret the lab data. The writer introduced the truth table and the K-map and reinforced the output data in the original report's discussion section. However, this information was removed in the revision to, presumably, update the discussion to make it more concise.

Example G	
Original Lab Report Sample	Revision
The truth table and the K-map of both F (which is the symbol for speeding) and G (which is the symbol for speeding 10 mph above the speed limit or going above 65 mph) can be seen. … Using this expression the logic diagram above the circuit was successful and the goal of making a circuit at 89 cents was achieved.	None

In Example H, we see the student's negotiation of the overall content of the conclusion to show awareness of what belongs there and what does not. Typically, the conclusion section in the lab report genre summarizes the lab's purpose, process, and key findings, and then moves to make appropriate recommendations. In this sample, the writer used a first-person point of view to detail the lab procedures in the original report. In the revision, the conclusion was updated with the use of concise language and editing to remove the use of first-person to use third-person instead.

Example H	
Original Lab Report Sample	Revision
Our group was assigned 1018 designation steel with one annealed coupon and one cold worked coupon. We successfully tested the coupons with the automatic Rockwell hardness tester and found the cold worked coupon was harder than the annealed coupon as expected with average hardness values of 91.57 HRB and 54.77 HRB respectively.	Hardness testing revealed the cold worked coupon was harder than the annealed coupon as expected with average hardness values of 91.57 HRB and 54.77 HRB respectively.

This inconsistency in conventions is illustrated in how multiple students negotiated the use of first-person based on their engagement with ChatGPT. In a few cases, for example, students appropriately edited out the use of a first-person, improving their awareness of knowledge conventions, as illustrated above and below. In the excerpt below, the writer consistently used the first-person view on the original lab report sample; however, they completely removed it in the revision.

Example I	
Original Lab Report Sample	Revision
Since E could not easily be computed and since the elastic to plastic transition region had a relatively flat slope the compared with the rest of the curve, I took the yield strength as the stress value where the behavior clearly changes from sharply upward slope to relatively flat.	The yielding point was taken to be the point on the plot where the data switch from roughly a vertical slope to a nearly horizontal slope.

In another case, one student included first-person in their revisions when they added more details on the lab procedures. The example below illustrates the addition of the lab procedures using the first-person point of view in the revision. The writer of Example J avoided using the first-person point of view in the methods section; however, the revision includes instances of "we" throughout the report.

Example J	
Original Lab Report Sample	Revision
None	In this lab, we will simulate a fun racquetball/tennis game using flip-flops, shift registers, and LEDs. … In the first part of the lab, we will analyze the schematic provided for the racquetball game and implement it on the provided hardware platform. We will test the game and make sure that it functions as expected.

An awareness of this inconsistency in the knowledge of conventions is supported by some of the focus group responses from students. Some students shared that ChatGPT helped improve writing style, flow, language, and precision. For example, one student observed, "I would ask it to rewrite for me, and I actually felt that it was more concise and polished than what I had written." Another student shared their experience trying to edit for conciseness and plain language: "I told it to rewrite one of my sections in the lab, and then it switched and gave me a concise and more professionalized version… And then I told it, can you rewrite to use simpler words? And it did." However, one student noted that ChatGPT didn't seem to know that the use of pronouns was not a lab report convention. Furthermore, students noted that ChatGPT wasn't very helpful for document design and lab report formatting expectations, while it did seem to help writing summaries and conclusions. As one student

explained, “I don’t think it’s able to generate graphs or tables.” Many students agreed they used ChatGPT more to write a summary or conclude the report.

Critical Thinking, Reading, and Composing

In the context of academic writing, critical thinking, reading, and composing include making connections between claims and evidence, evaluating and using primary and secondary sources, and performing interpretation and analysis of information such as technical data in lab writing. Improvement in the areas of critical thinking, reading, and composing was the most consistently lacking as a result of using ChatGPT while revising. In particular, revisions in this category included examples of omitting the necessary information, adding irrelevant information, and making inaccurate claims.

Example K, below, shows how a student’s negotiations in composing with the aid of ChatGPT could lead to missing essential details of the critical technical information. The original report sample contains the definition of “dangerous speed” in its results section; however, the revision fails to explain what the term “dangerous speed” means in the context of this lab experiment. Without this critical piece of information, the reader of the revision cannot fully understand the circuit design details presented in the following sections of the report. Instead, the writer focused on indicating the names assigned to the two outputs in their revisions.

Example K	
Original Lab Report Sample	Revision
The second output “g” corresponds to whenever the car is driving at a “dangerous speed”, which it means when the car going over 65 mph or more than 10 mph above the speed limit.	Two outputs that are going to looking for are output ‘f’ which means exceeding speed limit and output ‘g’ which means Dangerous speed.

In Example L, the methods section in the revision includes vague language and lacks needed details. Methods sections are expected to describe the procedures used in the lab both accurately and concisely. In the original lab report sample, the writer in example L clearly described the steps they needed to take to simplify the circuit and reduce the production cost. However, the revision only contains general terms and statements such as “research,” “testing,” and “optimizing” to indicate the lab activities. This revision fails to include needed details on how the lab activities were conducted. For example, the primary simplification tool, which was the K-map for this lab, is no longer mentioned in the revision. With the aid of ChatGPT, the student removed lab-specific information in the revision to make the lab procedures more generalized.

Example L	
Original Lab Report Sample	Revision
The first step is to create a truth table for when the LED lights should be on or not. Then using that truth table create a K-map to simplify both equations. Then	We’ve done extensive research and testing to identify the most cost-effective chips that meet all the necessary performance requirements.

Example L	
Original Lab Report Sample	Revision
using the simplified logic draw a diagram with the IC you need. When that is done add up your total cost and then try to reconstruct your diagram each time trying to be cheaper then the last.	In addition to chip selection, we've also been optimizing the design to reduce the overall complexity and minimize the number of components needed.

In another example, Example M, below, shows how a student added incorrect roles and functionalities of components in the lab's circuit design. The function of shift registers is to simulate the ball's movement, not the paddles. Also, the LEDs should display the location of the ball, not the players' scores. Although the student conducted the hands-on practice during the lab, the content in their methods section is distinct from the specific circuit design provided. This example suggests that interaction with ChatGPT can result in students including confusing content in articulating their lab activities.

Example M	
Original Lab Report Sample	Revision
None	Shift registers will help us simulate the movement of the paddles. … The LEDs will be used to display the scores of both players.

The next example also shows the removal of lab-specific technical statements in the revision. The original report sample of Example N contains the critical lab-specific information in the original report's conclusion section. The writer revised the conclusion section to highlight the fact that the primary goal, i.e., reducing the production cost, was achieved. The revised conclusion, however, fails to summarize the steps they took to achieve that goal and ends with a non-technical statement about the excitement of the lab progress and the anticipation of the next lab.

Example N	
Original Lab Report Sample	Revision
This lab's goal was to first construct a basic expression and logic diagram then optimize and synthesize the circuit using the lowest costing IC's possible. The key finding was the use of NOR gates and a OR gate. While the OR gate is the cheapest logic gate that could be used as a non-universal gate the use of the NOR gates was fundamental to be able to produce the circuit constructed.	Overall, we're confident that we can meet the target cost of 89 cents or less for the speed warning device while still delivering a high-quality product that meets all the necessary requirements. We're excited about the progress we've made so far and look forward to sharing more updates with you in the coming weeks.

The following two examples present the addition of new claims in the revised text that are not technically sound.

In Example O, the writer added one paragraph to compare the two steel types used in the lab. They did not include this information in the original report; therefore, it is encouraging that they generated this comparison in the revision with the aid of ChatGPT. The revision has a claim about the hardenability of the two steels, which is based on the lab data with the support of technical information covered in class, and most of the statements are technically sound. However, the last sentence contains faulty information. The 1045 steel has a higher carbon content than the 4140 steel.

Example O	
Original Lab Report Sample	Revision
None	Between the 1045 and 4140 steels it was found that 4140 steel had a higher hardenability than the 1045 steel specimen. This was due to 4140 having higher amounts of allowing elements than 1045 steel and the 1045 steel specimen having lower carbon content.

Example P also includes an inaccurate claim added in the revision. The writer made two claims in the original lab report sample after listing the computed mechanical properties from the cold-drawn and annealed coupons. Both claims are straightforward and technically sound. The writer added a new claim based on the data analysis from the lab that a material's higher hardness resulted in a lower Young's modulus in the revision. This claim is technically flawed because the Elastic modulus and hardness values are unrelated (Callister & Rethwisch, 2023). The use of ChatGPT during the revision process encouraged students to make additional claims rooted in the lab data and strengthen their lab data evaluation; however, in multiple cases, these claims included erroneous information.

Example P	
Original Lab Report Sample	Revision
These mechanical properties demonstrate that the Cold Drawn coupon was tougher than the Annealed coupon. The percent reduction of area demonstrated that both coupons had very similar geometries and both were put under the same load.	These mechanical properties demonstrate that the Cold Drawn coupon was tougher than the Annealed coupon. The higher yield strength and UTS of the Cold Drawn coupon can be attributed to its higher hardness, which resulted in a lower Young's modulus and higher UTS. The percentage reduction of area demonstrated that both coupons had very similar geometries and both were put under the same load.

Focus group responses also show a mix of student views on ChatGPT's contribution to critical thinking, reading, and composing. One student shared that they found the sources mostly useful, but what ChatGPT produces does not match their writing intent: "It's not like doing any of the bulk math calculations, any of that stuff. And I think that that's probably most of what the critical thinking of a lab report is, I would say." This student also noted the importance of understanding the material, and pointed out that students might get lost if they over-rely on

ChatGPT to find and summarize their sources and source use in lab report writing. Another student explained that ChatGPT is limited in interpreting/doing analysis: "the only time I use it for the analysis, I [asked] can you find me specific examples of how this information is used? Can you talk a little bit more about this microstructure? It was very specific, little pieces of information to add into the analysis, but it doesn't, it's not able to do the actual lab for you."

Other students noted that ChatGPT is a helpful resource for quickly fixing mistakes and defining terms, but it doesn't actually analyze data: "I was only able to use it once for my analysis sections, and that's when I actually asked it…. it can't do any visual analysis on any graphs or pictures. It's very limited on its numerical analysis. And so, you have to do all that yourself still." Another student explained how ChatGPT deleted part of an equation because it didn't seem to understand its function in the lab report section.

Writing Processes

In this context, writing processes refer to the steps and activities undertaken in planning, drafting, revising, editing, and finalizing written work, such as engineering lab reports. Each of the subsections above (A. Rhetorical Knowledge, B. Critical Thinking, Reading, and Composing, and C. Knowledge of Conventions) illustrate examples of student participants engaging in various revision and editing processes. Collectively, as addressed above, these examples illustrate revision and editing writing processes that sometimes improved and sometimes did not improve the quality of the student write-up with the use of chat GPT in revision processes.

Focus group responses from the participating students provide additional insight into how they used ChatGPT in their lab report revisions for this study, how they have used ChatGPT in other contexts, and how they imagine they might use ChatGPT in future academic writing assignments. Overall, students shared in the focus group that ChatGPT can be a helpful tool to assist in revision, but it cannot be relied on unconditionally. One student noted that they enjoy engaging in the technical information of a lab report but sometimes struggle with the lab report writing. For this student, ChatGPT helped with writer's block and getting started with the writing process. Another student agreed that ChatGPT made their writing process more productive: "When I'm writing a lab report or essay, trying to find credible secondary sources is usually one of the most time-consuming tasks. In comparison, if you're clear on what information you desire, ChatGPT can find it for you relatively quickly with the proper citations to boot as well."

Another student shared that they think it can be a valuable tool for getting started and generating ideas; however, you need to build from there. This student provided the following assessment: "Sometimes it might miss the whole focus or purpose of the report. And if you don't realize that, then you know it's not going to work out." Multiple students confirmed using ChatGPT for rough drafts and introductions in particular. They agreed that it could be helpful for getting a draft started, yet many students also concurred that it is not as helpful in suggesting significant revisions. Students further shared that they used ChatGPT to edit for concise and error-free language that flowed well.

Holistic Assessment Results and Discussion

We conducted a holistic assessment of all the writing samples to investigate the impact of ChatGPT on engineering undergraduates' lab reports as a whole. Implementing ChatGPT in the revision writing processes resulted in improving engineering students' lab report quality. Revisions from all the participating students included improved structures at the macro-level or the section level that enhanced attention to the genre conventions of engineering lab reports. In most cases, the revised introduction and conclusion sections were the most improved sections to meet the lab report genre expectations, represented by Examples A, B, C, H, and I above. These participating students improved their introductions to better identify the lab purpose, while revisions also included providing more context with the addition of technical background information from outside sources. Through their interactions with ChatGPT, students made updates to their lab report introductions that more effectively considered the expectations of their technical audience. Other studies on the use of ChatGPT for generating science and engineering lab reports have also found similar results, stating that ChatGPT can generate high-quality writing in the introduction section of reports (West et al., 2023; Nikolic et al., 2023).

Similarly, we found a noticeable improvement in the students' revised conclusions. As a macrostructure, the conclusion section of lab reports includes an overview of the laboratory's purpose, followed by a summary of the lab processes and significant results, finishing off by situating a lab's meaning and/or significance in the context of engineering practice. Overall, students' interactions with ChatGPT made their lab report revisions display improved awareness of these conclusion genre characteristics. ChatGPT is an AI language model trained on a vast amount of text data from a wide range of sources and genres (Dobrin, 2023; Van Dis et al., 2023). If the user specifies the desired genre as a lab report, ChatGPT can generate text that aligns with the expectations and conventions of a lab report. Note that the two lab courses were the participating students' first engineering lab courses assigning formal reports; therefore, students did not have significant experience in writing college-level engineering labs beforehand. The participating students were novice writers in the engineering lab report genre, whereas ChatGPT can possess a well-trained sense of genre awareness.

The participating students' improvement in methods, results, and discussion sections was also observed in revisions, but it was overall limited. Revisions had an increased amount of technical information over the original lab report samples. Most commonly, students elaborated on definitions of technical terms and added lab data analysis results and interpretations in revisions, as shown in Examples D, E, F, J, O, and P. Through interacting with ChatGPT, students can engage with various ranges of technical information within a reasonably short period of time. When the required information is unique to specific labs, though, the interactions with ChatGPT can inadvertently mislead the writers. For example, the methods sections of some revisions contained lab procedures that were incorrect or irrelevant to the labs offered (See Example M). ChatGPT's training process uses statistical patterns within vast amounts of text data (Dobrin, 2023; Van Dis et al., 2023); therefore, it appears to generate text about widely performed lab procedures unless the user's prompts provide specific details.

We also observed that students' revisions included general technical information or inclusive statements, which might have originated from ChatGPT. Some technical information in revisions became too broad and/or irrelevant

to the specific lab topics, as shown in Examples A, L, and N. Some students even removed their unique views or analysis results, written in their original reports, in their revisions. ChatGPT, as a general-purpose language model, is flexible enough to generate text for a wide range of tasks; however, its flexibility doesn't assist students who are expected to write their unique findings and/or niche technical information related to specific labs offered in specific lab report assignment. Therefore, students should be aware that, as stated by OpenAI (2022), due to biases in the training data and the over-optimization issues, the language model used in ChatGPT often tends to be "excessively verbose". The text generated by ChatGPT will probably be longer and broader than it needs to be for lab report writing. The technical audience does not value such a verbose writing style. They expect clear delivery of accurate and precise technical information on specific lab topics (Winsor, 1996; Beer and McMurrey, 2019). Including broad or general technical information provided by ChatGPT, which is irrelevant to the specific lab topics, lowered the quality of the revisions.

On rare occasions, we also observed false claims or technically flawed information included in revisions (See Examples M, O, and P). ChatGPT's failure in logical reasoning has been reported (Borji, 2023). When negotiating connections between the claim and technical evidence, which is the lab data for the lab report genre, one needs to have a firm understanding of technical concepts, formulate a hypothesis about the relations between the two, and assess the soundness of the hypothesis. When the writer's interaction with ChatGPT leads to a failure in any of these processes, they can draw false information. This study agrees with the results from an experimental study (Amaro et al., 2023) that shows many students continue to trust the content from ChatGPT when revising their lab reports despite being aware of the likelihood of ChatGPT generating incorrect information and fake references. ChatGPT's logical reasoning and context comprehension are still limited, and a few students reported detecting unreliable analysis results and limited comprehension of complex technical concepts by ChatGPT during the focus group. Therefore, engineering undergraduates should critically review the content from ChatGPT to see if it is technically sound and fits within the lab context. Educators need to help students understand how ChatGPT works and, more importantly, find effective ways to communicate the limitations of ChatGPT to their students and encourage them to properly validate the information they receive from ChatGPT (Amaro et al., 2023; Mrabet & Studholme, 2023; Mhlanga, 2023). As addressed earlier, promoting critical approaches to digital literacies in writing instruction is one way to support such work (Johnson, 2023).

Participating students expressed that ChatGPT provided positive contributions during their revision process. They agreed on the need for a series of sophisticated and iterative from the user/writer to refine the AI-generated text to produce appropriate content for their lab reports (Wang, 2023). This is partly due to ChatGPT's limitations in understanding context (Farrokhnia et al., 2023). The study done by Nikolic et al. (2023) showed that in order to get reasonably accurate lab report writings from ChatGPT, students need to input a significant amount of information about the experiment instructions, the pre-laboratory lesson, etc. In some cases, this task may become too tedious, so that it might actually be more useful for students to either write the entire report themselves or just use ChatGPT as an assistant that can receive a set of notes and use its knowledge of the lab report genre to convert those notes into an error-free, well-composed writing. Another way to get assistance from ChatGPT in students' lab writing processes is to efficiently use ChatGPT to conduct relatively simple computations or required statistical analysis (Humphry & Fuller, 2023). This strategy may allow students to spend less time on calculations

and focus more on other writing tasks, such as interpreting results and making meaningful conclusions.

Since the launch of ChatGPT in November 2022, a number of guides, policies, and position statements have been developed to inform and support college instructors in negotiating ChatGPT or other GAI in their classrooms. In writing studies, in particular, the focus is on how to reaffirm best practices for writing instruction in the use of technologies. Attention to the relationship between writing and technology is embedded within the WPA Outcomes Statement: "Writers' composing activities have always been shaped by the technologies available to them, and digital technologies are changing writers' relationships to their texts and audiences in evolving ways." Our findings suggest that ChatGPT can be used as a technological tool to support student writing in so much as students and instructors do so as informed users who understand its limitations, pitfalls, and potential for misinformation. In general, engagement with ChatGPT is minimal in supporting students' critical thinking. ChatGPT can effectively assist students in their writing tasks (Elkhodr et al., 2023), but it cannot replace the human writer (Nikolic et al., 2023; Imran & Almusharraf, 2023).

Conclusion

This study aims to investigate how engineering undergraduates use ChatGPT when revising their lab reports in gateway or entry-level engineering lab courses. Our direct assessment shows that ChatGPT, with a well-trained sense of genre awareness, positively impacted audience awareness in lab report revisions. Notably, the introduction and conclusion sections were most improved in revisions due to the students' addition of technical background from outside sources and updates of necessary content in those sections. We observed an enhanced demonstration of the knowledge of conventions through improvements to the IMRDC macrostructure, genre conventions, and style in the revisions, but these improvements were inconsistent across student samples. Critical thinking, reading, and composing was the least improved area in the revisions. Some revisions included in-depth and reasonable lab data analysis and interpretation; however, some revisions contained false claims, incorrect lab procedures, or verbose statements, which are not valued in the engineering lab report genre. Limited improvement may belong to the limitations of ChatGPT by itself or the students' lack of familiarity with ChatGPT. Nevertheless, our findings suggest that using ChatGPT as a tool for revising lab reports can improve engineering students' lab report quality as well as enhance students' understanding of the lab report genre.

Recommendations

Based upon our findings and conclusions, we provide suggestions for future research. First, given our small sample size, future studies that include broader student participation would be useful for developing a deeper understanding of how students engage with GAI-assisted writing. A broader sample size that also includes students at various stages in their undergraduate writing career could also be beneficial in better understanding students' engagement with the technologies at different intervals in their academic writing experiences. Because of the context within which we developed this study, our study focused on students' revision of lab reports that were already written as the results of their interaction with ChatGPT. Future studies that focused on the students' interaction with ChatGPT throughout the entire writing process, from planning to finalizing, would provide

additional valuable insight into the range of students' composing processes and where and how they might employ ChatGPT from the beginning to the final product.

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Appendix A. An Inclusive Assessment Rubric

1. Rhetorical Knowledge

Emerging	Developing	Mastering
The writer shows little awareness of the context or audience, and the report is unsuccessful in most places. The writer's choices are sometimes appropriate to the assignment or may be limited or oversimplified responses to the assignment. The writer demonstrates little or no control over the various modalities that are attempted in the report and seems only minimally aware of the demands of engineering engaged in the assignment. Overall, the writer shows little awareness of the audience's needs, and treatment of the task and purpose are basic or inadequate.	The writer's understanding of the context and audience supports a generally successful report. Overall, the writer makes choices that are appropriate to the assignment, but the writer's understanding and application of the lab report genre may seem incomplete or inconsistent. The writer shows a general awareness of the demands of engineering and makes a generally successful use of the field's characteristic methods. Attention to task, purpose, context, and audience are generally appropriate, with some lapses (e.g., the writer may invoke the wrong audience, or provide irrelevant information, etc.).	The writer analyzes the context and audience and uses that analysis to comprehend and/or create the report. In approaching the task and purpose, the writer makes choices that are appropriate to the assignment and the lab report genre. In developing the response to the assignment, the writer employs the methods commonly used for communication in engineering. The writer considers task, purpose, context, and audience in setting a style and usage appropriate to the assignment.

2. Knowledge of Conventions: Macro-structure

Emerging	Developing	Mastering
The report's structure may be incomplete, inappropriate, or missing. The writer does not establish objective (or a central hypothesis) or may provide one that is oversimplified. Contextual information is missing, inconsistent with the objective (or hypothesis), or incomplete. The report frequently wanders away from the central idea, and the arrangement of evidence may seem random or purposeless. The writer does not seem to be in	The writer provides a structure appropriate for a lab report. As the report begins, the writer establishes objective (or a hypothesis) that acts as the focus for the report. The writer forecasts a structure for the report that may be oversimplified or inadequately described. Overall, the objective (or hypothesis) is central to the report, but in places the writer may wander away from that central idea. The writer appropriately arranges ideas, data,	The writer provides a purposeful structure that clearly articulates the experiment's purpose. As the report begins, the writer provides foundational background and context for that central idea; clearly states the objective of the report; establishes the writer's perspective or approach; and engages the subject matter in a way that addresses the appropriate audience. The writer's formulation of the objective (or hypothesis) is consistently at the

control of the report.	and analysis, though in places the arrangement may be superficial. The writer's control over the shape of the report may be inconsistent.	center of the developing analysis. The organization supports not only the writer's development of ideas, evidence, data, and analysis, but also the reader's understanding throughout the report.

3. Knowledge of Conventions: Genre conventions and style

Emerging	Developing	Mastering
Choices of style, diction, tone, and voice are inconsistent with or inappropriate for a lab report. The writer's stylistic choices may seem random. Errors are frequent and seriously detract from meaning or prevent the reader from adequately understanding the writer's meaning. The writer omits some citations for sources, and may inconsistently label tables, figures, and other visual material.	The writer's sentences are generally appropriate to the topic, but in cases may seem random or uncontrolled. Style, tone, and voice are generally appropriate, with some lapses. Errors in mechanics and grammar are generally minor, but may be sufficiently frequent to distract a reader. The writer's diction and syntax are sometimes effective. Voice and perspective may vary in ways that detract from the writer's treatment of the task. Source citations are uniformly included, but may be incomplete. Figures, tables, and other illustrative material are generally well-formatted and labeled.	The writer employs sentence structures and appropriate language to ensure that ideas are clear throughout the report. Writer uses style, tone, and voice that are appropriate for a lab report. Errors in mechanics and grammar are minor and infrequent. The report employs a syntax and diction appropriate to the lab report genre. Throughout the report, the writer's voice and perspective remain consistent with each other and with the task. Citations of source material are clear and consistent, and citation style is appropriate to engineering and the lab report genre. Figures, tables, and illustrations are correctly and usefully labeled.

4. Critical Thinking and Composing: Evidence

Emerging	Developing	Mastering
The writer relies on information that is not relevant to the report or that is narrow or trivial. Evidence is missing, mislabeled, or is not clearly connected to the experiment's central hypothesis. Evidence may not sufficiently	Most of the time, the writer provides appropriate evidence to support and clarify the analysis. In places, the connections between some of the evidence and the objective (or hypothesis) being explored may be weak or	The writer clearly establishes connections between the objective (or hypothesis) and the evidence in the report. Evidence is accurate, credible, and portrayed fairly. As appropriate, reports include statistical, analytical, numerical,

support or clarify the writer's claims.	missing. The evidence sometimes lacks substance or variety.	visual (including data tables, plots, pictures, etc.), multimodal, or observational evidence to fully explore the objective and supporting analyses. Evidence is presented and interpreted appropriately to the targeted audience.

5. Critical Thinking and Composing: Critical Thinking

Emerging	Developing	Mastering
The writer oversimplifies ideas. Analysis, evaluation, or interpretations may be missing or underdeveloped. The writer may provide a shallow or basic analysis of the topic. The report provides little guidance to the reader, or the writer seems unaware of the audience. If there is a conclusion, it may be irrelevant to the analysis or provide little or no closure. The writer's analysis is limited, or the writer may "let the data do the talking."	The writer analyzes, synthesizes, interprets, or evaluates ideas and texts to develop an approach to the task that addresses the existing knowledge (theory or hypothesis) and supports an analysis of the topic and the writer's perspective. Overall, the writer accommodates the reader's need to understand the topic and the development of the analysis. The writer provides closure by summarizing the analysis, but may draw limited or inconsistent conclusions from the analysis.	The writer synthesizes, analyzes, interprets, and evaluates significant and well-chosen ideas, information, and data. The writer addresses the existing knowledge (theory or hypothesis), providing an in-depth analysis consistent with the complexity of the experiment. The writer guides the reader to understand the complexities of the experiment and its central theory or hypothesis. The writer draws meaningful conclusions and reflects on the experiment as a whole, in ways that provide closure and bring the analysis to a satisfying ending.

Appendix B. Focus Group Questions

1. How familiar with ChatGPT were you before this activity?
2. Was the information ChatGPT provided useful? Did ChatGPT introduce new technical information you did not know previously?
3. Was using ChatGPT time-consuming or make your writing process more efficient?
4. How did you get started? What information did ChatGPT provide? What kind of prompts or questions until you like the responses from ChatGPT?
5. What did you learn about lab data analysis and interpretation when using ChatGPT? How did ChatGPT promote your critical thinking with your lab data (analyze and evaluate lab data using technical knowledge from class and outside sources to make logical arguments)?
6. What did you learn about engineering lab report writing from this process? in terms of 1) rhetorical knowledge, 2) critical thinking and composing, 3) knowledge of conventions, and 4) writing processes.
7. What concerns or reservations do you have about using ChatGPT?
8. How do you want to use ChatGPT in your engineering college courses?
9. How do you want to use ChatGPT in your non-engineering college courses?