Exploring the Potential of Generative AI in Shaping Engineering Education: Opportunities and Challenges

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Abstract—**Engineering education equips students with the necessary knowledge and skills to thrive in rapidly evolving field of engineering and computer science. However, updating the curriculum to be current with the latest advancements can be challenging for educators. The curriculum and activities (both co-curricular and extra-curricular) activities must be designed such way as to educate a global engineer with multidimensional attributes. The faculty and administrators must be willing to adapt to the fast changes in technology and learning habits of our students. In this day and age of ChatGPT, Bard, Perplexity and other generative AI tools, educators have to adapt and focus on creative ways of engaging students towards lifelong learning with strong work ethics and professional skills. This paper explores the potential of generative artificial intelligence (AI) in revolutionizing engineering education by designing and offering up-to-date content. It examines specific examples in various engineering domains and discusses the benefits of generative AI in accreditation efforts and faculty time allocation.**

Keywords—**engineering education; generative AI; prompt engineering.**

JEET Category—**Choose one: Practice**

I. INTRODUCTION

Generative Artificial Intelligence (AI) is an emerging field that utilizes machine learning algorithms to generate content based on patterns and examples from existing data, such as text, images, or even entire simulations. It enables the creation of new and valuable content without explicit programming. In the context of engineering education, generative AI can revolutionize the way educational materials are generated, updated, and delivered to students (Cardona et al., 2023; Johri et al., 2023).

Generative AI plays a crucial role in engineering education by addressing the challenges of content generation and delivery. Creating up-to-date and relevant content in engineering fields has traditionally been time-consuming and resource-intensive for educators. However, generative AI offers an innovative solution by automating content generation. It allows educators to provide students with dynamic and tailored learning experiences reflecting the latest advancements in their fields (Yu & Guo, 2023). However, one should also be cognizant of the pitfalls of AI in terms of the misinformation and biases generated including academic misconduct in teaching and learning by both students and educators.

A. Advantages of Generative AI in Content Generation

1) Enhanced Relevance and Currency

One of the advantages of generative AI in engineering education is its ability to generate relevant and up-to-date content. By leveraging machine learning algorithms based on Natural Language Processing, generative AI tools such as ChatGPT, Bard, Midjourney, Perplexity, etc. can analyze vast amounts of data from various sources, such as research papers, industry reports, and real-world case studies. This enables the creation of educational materials that reflect the field's current state, incorporating the latest theories, technologies, and industry practices.

2) Personalized and Adaptive Learning

Generative AI enables personalized and adaptive learning experiences for students. By analyzing individual learning patterns, generative AI algorithms can generate customized educational content based on each student's specific needs and preferences. This personalization enhances student engagement and promotes effective learning outcomes. For example, generative AI can adapt to the difficulty level of problem sets or provide additional resources based on the student's performance and learning pace.

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3) Efficient Curriculum Updates

Updating the curriculum is a significant challenge for educators in rapidly evolving engineering fields. Generative AI simplifies this process by automating the generation and integration of new content. When new research findings or technological advancements occur, generative AI algorithms can quickly analyze and extract relevant information to update the curriculum. This ensures that students are exposed to the most recent and accurate knowledge, preparing them for the demands of the industry.

4) Simulation and Virtual Experimentation

Generative AI can create realistic simulations and virtual experiments that provide students with hands-on learning experiences. For instance, generative AI algorithms in electrical engineering can generate virtual circuit simulations where students can design and test electrical circuits in a safe and interactive environment. Similarly, in mechanical engineering, generative AI can create virtual simulations of complex machinery, systems or manufacturing processes, allowing students to explore and understand the intricacies involved.

Overall, generative AI holds immense promise and potential to transform engineering education. Through content generation, providing personalized learning experiences, and facilitating efficient curriculum updates, generative AI enhances the relevance, currency, and engagement of educational materials. It empowers educators to deliver dynamic and up-to-date content to students, preparing them for the ever-evolving engineering industry demands. Incorporating generative AI in engineering education can revolutionize the learning experience and equip students with the knowledge and skills necessary for success in their future careers.

II. Generative AI in Electrical Engineering Education

A. Current Challenges

Electrical engineering (EE) education faces challenges in keeping up with the rapidly evolving field. One of the key challenges is the timely development and delivery of up-to-date course materials that incorporate the latest advancements in electrical engineering. Traditional content generation methods often lag behind the industry, leading to outdated educational resources. Additionally, hands-on learning experiences, such as simulations and practical applications, can be limited due to resource constraints and the complexity of electrical systems. However, generative AI offers promising solutions to address these challenges.

B. Applications of Generative AI in EE

1) Up-to-date Course Materials on Energy Systems

Generative AI can be applied to develop and update course materials on renewable energy systems. With the rapid growth of renewable energy technologies, electrical engineering students must stay abreast of the latest developments in this field. Integration of renewable sources (that are inherently sensitive to weather elements) to serve an independent load profile via limited storage will continue to be a challenge for the foreseeable future. Generative AI algorithms can analyze vast amounts of data from research papers, industry reports, and renewable energy databases to generate up-to-date course materials. This ensures students are exposed to the most recent theories, technologies, and best practices in renewable energy systems.

2) Smart Grids: Tutorials and Simulations

Generative AI can facilitate the creation of tutorials and simulations for understanding smart grids. Smart grids incorporate advanced communication and information technologies to optimize electrical power generation, distribution, and consumption. Developing comprehensive tutorials and simulations for smart grids can be challenging due to their complexity. However, generative AI can generate interactive tutorials and realistic simulations that enable students to explore and analyze the behavior of smart grid systems. This enhances their understanding of this cutting-edge technology.

3) IoT Applications in Power Systems: Hands-on Learning Experiences

The Internet of Things (IoT) has revolutionized various industries, including power systems. Generative AI can significantly create hands-on learning experiences for students to explore IoT applications in power systems. By utilizing generative AI algorithms, educators can develop virtual environments where students can design, simulate, and analyze IoT-enabled power systems. This provides them with practical experiences integrating IoT technologies into power systems, fostering their skills in this emerging area.

4) Sensors and Data Fusion

Fusion of data from a multitude and large number of sensors to drive a specific application is always a tricky process. Generative AI can be used to address multiple applications simultaneously via selective and smart fusion of data from a limited number of sensors. This will result in compact, efficient, smart, and cost-effective systems. Students will have a chance to learn and design practical and complex systems for real-life applications, reducing abstractness in the curriculum.

C. Benefits and Implications

The integration of generative AI in EE education offers several benefits. Firstly, it ensures that course materials remain up-to-date and relevant, reflecting the latest advancements in the field. This enhances the quality of education and equips students with the knowledge and skills necessary to address real-world challenges. Secondly, generative AI enables the creation of interactive and immersive learning experiences, such as simulations and practical applications, which enhance student engagement and understanding. Thirdly, generative AI tools can help optimize faculty time commitments by automating content generation, allowing educators to allocate more time towards student mentorship and personalized guidance.

However, implementing generative AI in engineering education also raises important implications. Faculty and educators must ensure the generated content is accurate,

reliable, and aligned with the desired learning outcomes. Careful monitoring and validation are necessary to maintain the integrity of the educational materials. Additionally, there may be a need for faculty training and upskilling to utilize generative AI tools in their teaching practices effectively.

III. GENERATIVE AI IN COMPUTER ENGINEERING AND COMPUTER SCIENCE EDUCATION

A. Evolving Landscape

Computer engineering and computer science fields are experiencing rapid advancements and innovations. It is essential to provide students with up-to-date and industry-relevant education. However, traditional content development approaches often struggle to keep pace with the dynamic nature of computer engineering and computer science. Generative AI presents a promising solution to address this challenge.

B. Leveraging Generative AI in Content Development

Generative AI can be effectively leveraged to develop educational content that aligns with the evolving landscape of computer engineering and computer science. By analyzing large volumes of data from research papers, industry reports, and coding repositories, generative AI algorithms can generate coding exercises, programming challenges, and interactive simulations that reflect the latest trends and technologies in the field.

1) Coding Exercises and Programming Challenges

Generative AI can assist in creating a wide range of coding exercises and programming challenges that cater to different skill levels and topics in computer engineering and computer science. These exercises can cover algorithms, data structures, software development, and artificial intelligence. By utilizing generative AI, educators can ensure a diverse and constantly updated pool of coding exercises, enabling students to practice and strengthen their programming skills.

2) Interactive Simulations for AI, Data Science, and Cybersecurity

Generative AI can also develop interactive simulations that provide hands-on experiences in areas like AI, data science, and cybersecurity. Simulations allow students to experiment with complex concepts and scenarios, fostering a deeper understanding of theoretical concepts and practical applications. Through generative AI, educators can create realistic and immersive simulation environments that enable students to engage in data analysis, machine learning, cybersecurity threats, and network simulations.

3) Case Studies and Real-World Scenarios

Generative AI can contribute to developing case studies and real-world scenarios that bridge the gap between theoretical concepts and their practical implementations. By analyzing real-world data and industry trends, generative AI algorithms can generate case studies that simulate authentic challenges computer engineers and computer scientists face. These case studies expose students to real-world problem-solving,

decision-making, and critical thinking, preparing them for the demands of the industry.

4) Integration of Generative AI in Active Learning

Educators can integrate Generative AI in the course work through active learning tasks to increase student engagement (Ouatu, et. al., 2021). For instance, students can evaluate the Generative AI responses for the topics discussed during the lecture. The educator can use active learning activities such as, think – pair – share in the classroom to increase the student engagement, and teamwork. The think – pair – share activity also helps students better understand the lecture topics covered in the course. This can help reduce the risk of students misuse the technology in the coursework.

C. Implications for Student Learning and Industry Relevance

Integrating generative AI in computer engineering and computer science education offers several implications for student learning and industry relevance. Firstly, it ensures that educational content remains up-to-date, relevant, and aligned with industry demands. By utilizing generative AI, educators can provide students with the latest knowledge and skills required to excel in their careers. Secondly, generative AI enables personalized learning experiences by tailoring content to individual student needs, fostering greater engagement and mastery of concepts. Finally, using generative AI tools in content development minimizes faculty time commitments, allowing educators to allocate more time towards student mentorship, guidance, and facilitating collaborative projects.

IV. GENERATIVE AI IN MECHANICAL ENGINEERING EDUCATION

A. Dynamic Nature of Mechanical Engineering

Mechanical engineering (ME) has evolved over the years to keep up with advancements in technology and industry demands. The ME professional organizations across the world continuously update the discipline specific body of knowledge to provide students with a comprehensive understanding of the discipline. ASME Vision 2030 (ASME, 2011) recognized that it is crucial to incorporate the emerging developments and practical applications into their education. Generative AI offers a transformative approach to addressing the dynamic nature of ME education. Some of the notable improvements to address changing landscape of ME education are theory to practical application; technological advancements such as programming, computing, CAD, modeling and simulation tools, CFD (computational fluid dynamics), and finite element analysis (FEA); interdisciplinary focus such as mechatronics, robotics, and materials science, manufacturing, and automation; emphasis on design with problem, project, outcome based with real world examples; sustainability, circular economy, product/system lifecycle and environmental concerns; increased business/communication; and global context of engineering education.

B. *Virtual Simulations and Design Scenarios*

Generative AI can revolutionize mechanical engineering education by enabling the creation of virtual simulations and design scenarios that emulate real-world conditions. These simulations can encompass various aspects of mechanical engineering including the analysis, modeling, design and optimization of mechanical, thermal and acoustic systems. Some notable examples such as simulation of complex fluid dynamics patterns, and structural analysis of nonlinear systems can be explored with ease. By utilizing generative AI algorithms, educators can develop virtual environments that allow students to explore and analyze complex flows, evaluate structural integrity, and optimize designs for different engineering challenges and manufacturing processes. For example, AI can be used to generate 3D models of products, optimize the design of products for performance and manufacturability, and simulate the behavior of products in real-world conditions.

1) *Fluid Dynamics: Simulating Complex Flows*

Fluid dynamics plays a vital role in mechanical engineering, and generative AI can enhance students' understanding of this complex field. Through generative AI, educators can create virtual simulations that accurately represent fluid flow phenomena, such as turbulent flows or multiphase flows in air and spacecrafts, turbines and other systems. These simulations allow students to explore different scenarios, visualize flow patterns, and analyze the impact of design changes. Students can develop a deeper understanding of fluid dynamics concepts by engaging with generative AI-powered simulations and improving their problem-solving skills. For example, the University of California, Berkeley, is using AI to create a virtual lab for students to learn about fluid mechanics. The lab uses real-world data and simulations to help students understand how fluids flow.

2) *Structural Analysis and Optimization Techniques*

Generative AI can also facilitate structural analysis and optimization techniques in mechanical engineering design. Educators can generate virtual scenarios through generative AI algorithms where students can analyze and optimize structures for various load conditions. These simulations enable students to evaluate the performance of different materials, geometries, and configurations, fostering critical thinking and design optimization skills. By incorporating generative AI tools, mechanical engineering students gain practical experience in structural analysis and optimization, preparing them for real-world engineering challenges. Several universities including MIT are using AI to create an interactive simulation for students to learn about the design of complex trusses in bridges and machine structures. These simulations allow students to experiment with different design parameters and see how they affect the performance of the structure.

3) *Integration of Generative AI in Laboratories and Hands-on Activities*

Generative AI can significantly impact mechanical engineering education by enhancing laboratory experiences and hands-on learning. Students can access virtual equipment and conduct experiments in a simulated environment by integrating generative AI in laboratory settings. This expands the scope of laboratory activities and enables students to engage in experiments that may not be feasible in a traditional setup due to cost, safety, or logistical constraints. Generative AI-based laboratories provide students with realistic and immersive experiences, fostering their practical skills development and reinforcing theoretical concepts.

4) *Impact on Student Learning and Practical Skills Development*

The integration of generative AI in mechanical engineering education profoundly impacts student learning outcomes and practical skills development. Students can bridge the gap between theory and practice by incorporating virtual simulations, design scenarios, and hands-on laboratory experiences powered by generative AI. AI can be used to create personalized learning experiences for each student, based on their individual strengths, weaknesses, and interests. This can help students learn more effectively and efficiently. These interactive learning opportunities enable students to gain hands-on experience, develop critical thinking skills, and enhance their problem-solving abilities. Additionally, generative AI in mechanical engineering education enhances student engagement, promotes active learning, and encourages student collaboration.

V. BENEFITS OF GENERATIVE AI IN ACCREDITATION EFFORTS

Accreditation is a vital aspect of engineering education, ensuring that programs meet specific quality standards and produce competent and well-prepared graduates for professional practice. However, accreditation processes can be complex and time-consuming for institutions. Generative AI offers several benefits in addressing accreditation requirements and challenges, facilitating the efficient and effective fulfillment of accreditation criteria including assessment and continuous improvement.

A. *Ensuring Standardization and Consistency*

Generative AI tools can ensure standardization and consistency in engineering education. Accreditation bodies often emphasize the need for standardized curriculum and learning outcomes across different programs. Generative AI algorithms can assist in developing and maintaining consistent course materials, assessments including rubrics , and learning resources. By utilizing generative AI, institutions can create standardized content that aligns with accreditation criteria, promoting uniformity in curriculum delivery and student learning experiences.

B. *Evidence-Based Curriculum Design and Documentation*

Generative AI can aid in evidence-based curriculum design and documentation, a key component of accreditation processes. Generative AI algorithms can identify trends, patterns, and best practices in engineering education by analyzing vast amounts of data. This information can inform curriculum development, ensuring programs align with industry demands and emerging

trends. Generative AI tools can also assist in documenting program outcomes, student learning assessments, and continuous improvement efforts, providing comprehensive evidence for accreditation purposes.

C. Streamlining the Accreditation Process

Generative AI has the potential to streamline the accreditation process, reducing administrative burden and optimizing resource allocation. Generative AI tools enable institutions to gather and present evidence more efficiently by automating data collection, analysis, and reporting tasks. GAI will help in comparing and providing insights on the functionality and user interface in integrating several assessment tools to track and improve student learning in courses using Learning Management Systems such as Blackboard and Canvas. This streamlining of the accreditation process of assessment data collection, evaluation of data, and use of evaluation results for continuous improvement allows faculty and administrators to focus their time and energy on strategic initiatives, such as curriculum enhancement and student support, rather than being consumed by administrative tasks.

D. Demonstrating Continuous Improvement

Generative AI tools can support institutions in demonstrating continuous improvement, a critical aspect of accreditation. Through data analytics and predictive modeling, generative AI algorithms can identify areas for improvement and suggest interventions to enhance program outcomes. This enables institutions to implement evidence-based strategies for continuous improvement and monitor their effectiveness over time. Generative AI-generated insights and recommendations can inform decision-making processes, enabling institutions to proactively address accreditation standards and ensure ongoing enhancement of educational quality.

In essence, the utilization of generative AI in accreditation efforts offers significant benefits to engineering education programs. From ensuring standardization and consistency in the curriculum to facilitating evidence-based curriculum design and documentation, generative AI tools support institutions in meeting accreditation requirements. Moreover, generative AI streamlines the accreditation process, freeing up faculty and administrators' time and resources for more strategic initiatives. By leveraging generative AI, institutions can demonstrate continuous improvement and align their programs with industry demands, ultimately enhancing the quality and relevance of engineering education. Overall, the use of AI for ABET accreditation has the potential to improve the efficiency, consistency, and accuracy of the assessment process. However, there are also some potential challenges that need to be considered.

VI. MINIMIZING FACULTY TIME COMMITMENTS

Faculty members in engineering education face numerous challenges regarding content creation and updates. Developing up-to-date and engaging course materials, assignments, and assessments can be time-consuming, especially considering the rapid advancements in engineering fields. Additionally, faculty members often have other responsibilities, such as research, advising, and service, which limit their time and energy for content development.

Generative AI offers a promising solution to minimize faculty time commitments in content generation and updates. Institutions can automate creating and updating of educational content by leveraging generative AI algorithms. For example, generative AI can generate lecture slides, practice problems, interactive simulations, and assessment rubrics (Teachermatic, 2023) based on the latest research findings and industry trends. This automation reduces the burden on faculty members and ensures that course materials remain current and aligned with the latest advancements in the field.

By utilizing generative AI tools for content generation, faculty members can free up valuable time that can be allocated to student mentorship and personalized instruction. Instead of spending hours creating and updating content, faculty members can focus on interacting with students, providing guidance, and fostering deeper learning experiences. This shift in faculty priorities enhances student engagement, facilitates meaningful discussions, and promotes individualized support, ultimately improving student outcomes and satisfaction.

Some specific examples of generative AI is being used in engineering education include: The University of California, Berkeley, is using generative AI to create personalized learning modules for its engineering students. These modules are tailored to each student's individual needs and interests, and they are based on the latest research in cognitive science. The Massachusetts Institute of Technology (MIT) is using generative AI to develop a new virtual reality (VR) engineering lab. This lab will allow students to interact with virtual simulations of engineering problems, and it will be used to teach students about the design and analysis of complex systems. The University of Michigan is using generative AI to assess student learning in its engineering courses. The university is developing a new AI-powered assessment tool that will be used to automatically grade student homework assignments and exams.

VII. CHALLENGES AND CONSIDERATIONS

A. Ethical Implications and Bias in Generative AI

While generative AI offers numerous benefits in engineering education, it is important to acknowledge and address the ethical implications and potential biases associated with its use. Generative AI algorithms learn from existing data, which may contain biases or reflect existing inequalities. This raises concerns about the perpetuation of biases and the potential impact on underrepresented groups in engineering. It is crucial for educators to actively monitor and evaluate the generated content to ensure fairness, inclusivity, and accuracy.

Institutions should establish clear guidelines and ethical frameworks for generative AI in content generation to mitigate these challenges. Faculty members should be trained to critically evaluate the output of generative AI algorithms and make necessary adjustments to ensure unbiased and inclusive

content. Additionally, involving diverse voices in developing and overseeing generative AI systems can help minimize biases and promote equitable educational experiences.

Additional challenges of generative AI include Accuracy, bias, and interpretability. Generative AI models are only as good as the data they are trained on. If the data is not accurate or representative, the generated content may be inaccurate or misleading. These generative AI models can be biased, reflecting the biases that are present in the data they are trained on. This can be a problem if the goal is to generate content that is fair and unbiased. It can be difficult to understand how generative AI models work. This can make it difficult to debug and improve the models.

B. Technical Requirements and Infrastructure

Implementing generative AI tools in engineering education requires appropriate technical infrastructure and resources. Generative AI algorithms often require significant computational power and storage capabilities to process large datasets and generate complex content. Institutions must invest in robust hardware and software infrastructure to support the deployment and operation of generative AI systems. Furthermore, data security and privacy considerations must be addressed to protect sensitive student information and intellectual property.

C. Faculty Training and Professional Development

To fully leverage the potential of generative AI in engineering education, faculty members need comprehensive training and professional development opportunities. Faculty should have the knowledge and skills to effectively integrate generative AI tools into their teaching practices, critically evaluate the generated content, and make informed decisions about its use. Training programs should focus on ethical considerations, data handling practices, algorithm evaluation, and pedagogical strategies for incorporating generative AI-generated materials in the classroom.

Institutions should establish communities of practice or collaborative spaces where faculty members can share their experiences, exchange best practices, and collaborate on effectively integrating generative AI in engineering education. Ongoing professional development initiatives should be offered to keep faculty members updated on the latest advancements in generative AI and its applications in the engineering field.

D. Adapting to Evolving Industry Needs

The engineering field constantly evolves, with emerging technologies and industry demands shaping the skills and knowledge required by engineering graduates. Generative AI can play a vital role in helping engineering education institutions adapt to these changing industry needs. By utilizing generative AI tools, institutions can quickly update their curriculum and offer courses that align with the latest industry trends and emerging technologies.

Designing and aligning an engineering education on the principles of Lemelson Foundation, Lumina Foundation, ABET, World Economic Forum, NSPE (National Society of Professional Engineers- Model Curriculum for Engineers), ASEE (American Society for Engineering Education), NEP 2020 (National Education Policy -India), and NAE (National Academy of Engineering) involves incorporating innovation, workforce readiness, quality standards, and global perspectives. The engineering educators need to leverage emerging educational models in enriching teaching and learning to prepare a globally industry ready workforce. Each of these organizations plays a distinct role in contributing to the development of up-to-date content in engineering education, but their approaches and focuses vary. Lemelson and Lumina indirectly influence content through innovation and workforce readiness initiatives, while ABET's accreditation process directly ensures content quality.

However, balancing incorporating generative AI-generated content and maintaining a strong foundation in fundamental engineering principles is essential. Engineering education should not solely rely on generative AI-generated materials but should also prioritize critical thinking, problem-solving skills, and hands-on experiences. The integration of generative AI should supplement, rather than replace, traditional teaching approaches to ensure a holistic and comprehensive education.

VIII. CONCLUSION

In this paper, we have explored the potential of generative AI in engineering education. We discussed the understanding of generative AI, its role in engineering education, and its advantages in content generation. We then examined specific applications of generative AI in electrical engineering, computer engineering and computer science, and mechanical engineering education. Furthermore, we discussed the benefits of generative AI in accreditation efforts and the minimization of faculty time commitments. Finally, we addressed the challenges and considerations of using generative AI in engineering education.

Generative AI can revolutionize engineering education by providing up-to-date, relevant, and interactive content. By leveraging generative AI tools, educators can offer engaging learning experiences that align with industry demands and technological advancements. Creating dynamic simulations, design scenarios, and coding exercises tailored to specific engineering disciplines enables students to develop practical skills and apply theoretical knowledge in a realistic setting. Moreover, generative AI can assist in accreditation efforts by streamlining curriculum design, assessment, continuous improvement and ensuring standardization, and facilitating evidence-based documentation.

As generative AI continues to advance, several future directions and recommendations exist for its effective implementation in engineering education. Firstly, ongoing research is needed to address the ethical implications and potential biases and misinformation associated with generative AI algorithms. Efforts should be made to ensure fairness, inclusivity, and accuracy in the generated content.

Additionally, institutions should invest in developing user-friendly generative AI tools specifically tailored for engineering education including distance and on-line learning. These tools should provide intuitive interfaces, comprehensive documentation, and customizable options to cater to diverse learning needs and preferences. Collaboration between academia and industry can further enhance the development and adoption of custom generative AI tools that align with the evolving demands of the engineering profession.

Furthermore, continuous faculty training and professional development programs should be established to equip educators with the necessary knowledge and skills to integrate generative AI in their teaching practices effectively. These programs should focus on technical aspects and pedagogical strategies for incorporating generative AI-generated content in the classroom. Faculty should be encouraged to experiment, share best practices, and engage in research on the use of generative AI in engineering education. In summary, when using AI to generate content, it is important to keep in mind that the AI tool is only a starting point. One still needs to review and edit the information generated to ensure that it is accurate and aligned with the learning objectives.

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