ChatGPT for STEM Education: A Working Framework

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Abstract—This paper sheds light on the possible use of most recent technology, ChatGPT in STEM (Science, Technology, Engineering, and Mathematics) education. Here we used the ChatGPT tool and explored how it can help teachers in STEM class. Our work first presented a literature work related to Chat GPT in terms of its use in education, explained generative AI (Artificial Intelligence) and ChatGPT. ChatGPT tool is used to generate responses to prompts given. We ask ChatGPT that how it can be used in class for teaching science, mathematics, and coding. After detailed analysis of the responses by ChatGPT we presented a theoretical framework for guiding the use of ChatGPT in STEM educational settings. Next, we presented limitations of using ChatGPT in educational context and highlighted the bottlenecks and ethical issues in using technologies like ChatGPT. Finally, we presented our future research directions and concluded that ChatGPT has a great potential in STEM education and can be used as an effective tool for STEM teachers. We also emphasized on the concerning ethical issues related to the technology.

Keywords—ChatGPT, STEM education, skill development, artificial intelligence, science education, active learning

I. INTRODUCTION

New trends and technologies are opening new doors for educational reforms and support. On the other hand, the newfangled technologies offer big challenges too both for the teachers and students. A neutral take on the new technology adaptation should be to see both sides of the technology use to anticipate its pros and cons realistically. The last decade has shown a tremendous progress in the technology development and its adaptation in general and specifically in the field of education. Digital transformation of education has seen new heights during and post covid 19 eras.

Online learning tools, mobiles, digital learning applications, IoT, and AI tools are already in daily practice in educational systems. The most recent technology in market for education is AI chatbot ChatGPT. AI in general is making its place in every field of life and has become an important part of daily life in many ways from searching suitable routs on google maps to watching movies on Netflix.

A. What Is Generative AI (Gen AI)?

Generative AI can be defined as a technology that (i) leverages deep learning models to (ii) generate human-like content (e.g., images, words) in response to (iii) complex and varied prompts (e.g., languages, instructions, questions).

The last decade has shown enormous progress towards AI development and release of AI tools such as ChatGPT, GitHub Copilot, and DALL-E which have attracted widespread attention, optimism, and skepticism [1]. These technologies are all examples of "generative AI", a class of machine learning technologies that can generate new content—such as text, images, music, video, poems, interesting phrases, or idea creation by analyzing patterns in existing data. Generative AI uses large language models to generate content. In 2017, the Transformer network made progress in generative models, leading to the first Generative Pre-trained Transformer (GPT), known as GPT-1 in 2018, this progress was followed in 2019 by GPT-2 which demonstrated the ability to generalize many different tasks as a Foundation model. In 2021, the release of DALL-E, a transformer-based pixel generative model, marked the emergence of practical high-quality artificial intelligence art from natural language prompts. GPT-4 was released in March 2023 [2].

Our conceptual paper has the following objectives: (1) to propose a theoretical framework for guiding the use of ChatGPT in STEM education (or "educative AI", which refers to the use of AI in educational settings to enhance teaching and learning outcomes) and (2) to illustrate ChatGPT's potential benefits and challenges for use in the field of education. This study also provides recommendations for future research, policy, and practice in educative AI [3].

B. What Is ChatGPT?

Open AI developed a natural language processing model to generate human conversation like texts called ChatGPT, stands for Chat Generative Pre-Trained Transformer, launched on 30 November 2022. ChatGPT is versatile in its functionality as compared to a normal chatbot. From writing poetry and essays, composing music, teleplays, generating business ideas, translating, and explaining texts to writing and debugging the computer programs ChatGPT is proving to be a master of all trades [4, 5].

Ability to understand the context, generating coherent responses and adapting its language style based on the input it receives are some of the key features of Chat GPT. Therefore, Chat GPT can be used for answering questions, writing content, creating ideas, having conversations, planning discussions and many more.

Chat GPT is undoubtedly a versatile AI tool, but it is important for users to keep in mind that its responses are based on patterns learned during training and may not always be contextually accurate and perfect. Therefore, for users, it's important to verify information gathered from Chat GPT. It is important for STEM (Science, Technology, Engineering, and Mathematics) educators to understand the implications of this technology and to study how to adapt this technology in STEM ecosystem. This would ensure that the next generation of STEM professionals can take optimal advantages as offered by generative AI while minimizing any negative consequences.

II. CHATGPT FOR STEM EDUCATION

A. How Can a Science Teacher Use ChatGPT?

A science teacher can use ChatGPT in many ways to support, enhance and effectively deliver the learning tasks to the learners. From the last decade we have observed that artificial intelligence is playing a vital role in teaching and learning [6, 7]. Following are some suggestions for the science teachers that how they can use Chat GPT to support their teaching process.

Teachers can brainstorm ideas, can answer student`s questions, can create interactive learning environment and interactive lessons where students are engaged in a conversation with ChatGPT to reinforce concepts. For instance, a teacher can set up a scenario where students must solve a scientific problem by asking ChatGPT for hints and guidance. ChatGPT can be used as a personal teacher assistant to look for references and data for the topics and can provide research material to investigate for the preparation of teaching materials. ChatGPT can be used by teachers for idea creation as how to plan a class lesson.

Teachers can use ChatGPT to stimulate debates or discussions in the classroom. Students can ask ChatGPT for arguments related to a scientific topic and then use this information in a structured debate.

At this point of discussion, we are interested to know that what Chat GPT itself says about its usage in STEM classes both by students and teachers. So, we gave a prompt to Chat GPT as follows:

Response of Chat GPT was as follows:

A science teacher can integrate ChatGPT into the classroom in various ways to enhance science teaching and engage students. Here are some ideas:

- **Answering Questions**: Use ChatGPT to quickly answer students' questions related to science topics. This can be particularly helpful for clarifying doubts, providing additional information, or exploring related concepts beyond the textbook.

- **Virtual Science Assistant**: Treat ChatGPT as a virtual science assistant. Students can interact with it to get explanations, summaries, or elaborations on science concepts. This can be especially useful for students who may need extra help or clarification.

- **Discussion Starter**: Use ChatGPT-generated prompts to initiate class discussions. Ask the model to generate questions or statements related to the current science topic, and then discuss the responses as a class. This can encourage critical thinking and diverse perspectives.

- **Writing Prompts**: Ask ChatGPT to generate writing prompts related to science topics. Students can use these prompts for essays, research papers, or creative writing exercises. It encourages students to think deeply about the subject matter.

- **Interactive Learning**: Integrate ChatGPT into interactive learning activities. For example, create a scenario where students have to ask the model questions to solve a science-related problem or simulate a scientific inquiry.

- **Homework Assistance**: Students can use ChatGPT as a resource for homework help. They can ask for explanations, examples, or additional resources related to the topics covered in class.

- **Concept Reinforcement:** After teaching a concept, the students would be able to summarize what they've learnt by interacting with ChatGPT? This can help reinforce the understanding of the material and identify any misconceptions.

- **Science Project Ideas:** Ask ChatGPT for creative and innovative science project ideas. This can inspire students and provide a starting point for them to explore their scientific interests further.

- **Language Skill Development:** Incorporate ChatGPT to help students develop their **language skills:** They can ask the model to explain scientific concepts in their own words, improving both their understanding of the material and their ability to communicate effectively.

- **Ethical Discussions:** Utilize ChatGPT to explore ethical considerations in science. Generate questions or scenarios related to the ethical implications of scientific advancements and engage students in thoughtful discussions.

It's important to note that while ChatGPT can be a valuable tool, it's not a replacement for the teacher's expertise. Teachers should guide the use of ChatGPT, ensuring that it complements their teaching methods and enhances the learning experience for students. Additionally, it's crucial to critically evaluate the information generated by ChatGPT, as it may not always be entirely accurate or up to date.

B. How Can a Math's Teacher Use ChatGPT in Class?

Response of Chat GPT was as follows:

While ChatGPT is primarily a text-based model and may not have specific knowledge about being a "math

teacher", you can still integrate it into your science or math class in various ways. Here are some ideas on how a math teacher can use ChatGPT in the classroom:

- **Answering Math Questions:** Use ChatGPT to answer students' math questions. It can help provide additional explanations, step-by-step solutions, or alternative approaches to solving problems.
- **Problem-Solving Practice**: Create math problems or equations and ask students to solve them. Students can then use ChatGPT to check their answers, get hints, or explore different methods of solving the problems.
- **Math Concepts Explained:** Have ChatGPT explain specific math concepts. This can be especially useful for students who may need extra support or for introducing advanced topics beyond the curriculum.
- **Math Puzzles and Challenges:** Generate math puzzles or challenges using ChatGPT and use them as engaging activities in the classroom. Students can work individually or in groups to solve these puzzles, promoting critical thinking and problem-solving skills.
- **Interactive Quizzes:** Use ChatGPT to create interactive quizzes where students can ask questions related to the quiz content. This can be a fun and interactive way for students to review and reinforce their understanding of math concepts.
- **Math Project Ideas:** Ask ChatGPT for creative math project ideas. Students can use these ideas as a starting point for independent or group projects, fostering creativity and exploration in mathematics.
- **Historical Math Context:** Explore the historical context of mathematical concepts. Ask ChatGPT to provide information on the historical development of specific mathematical ideas, helping students understand the evolution of mathematical thought.
- **Math Vocabulary and Definitions**: Use ChatGPT to reinforce math vocabulary and provide clear definitions of mathematical terms. This can be particularly helpful for students who may struggle with the language of mathematics.
- **Coding and Mathematics Integration**: If applicable, explore the intersection of mathematics and coding. Ask ChatGPT to provide coding examples related to mathematical concepts, promoting interdisciplinary learning.
- **Real-World Applications**: Discuss real-world applications of mathematical concepts with the help of ChatGPT. This can make math more relevant and interesting to students by showing how it is used in various fields.

We should always remember to guide students on how to use ChatGPT effectively and to emphasize that it's a supplementary tool rather than a replacement for the teacher's guidance. Additionally, it is to be ensured that the information provided by ChatGPT is not only aligned with the curriculum but also is accurately delivered and applied in the said educational context.

C. How ChatGPT Can Help in Teaching Coding to Kids?

Response of Chat GPT was as follows:

ChatGPT can be a valuable tool in teaching coding to kids in various ways. Here are some ways you can leverage ChatGPT to enhance the coding learning experience:

- **Coding Assistance:** Kids can use ChatGPT to seek help with coding problems. They can ask questions about syntax, logic errors, or general programming concepts. ChatGPT can provide explanations and solutions, acting as a virtual coding tutor [8].
- **Code Writing Assistance**: Encourage kids to write code snippets or even full programs with ChatGPT's assistance. The model can help them with code structure, suggest improvements, and provide examples to illustrate coding principles.
- **Concept Explanation**: Use ChatGPT to explain coding concepts in a kid-friendly manner. It can break down complex ideas into simpler terms, making it easier for children to understand fundamental programming concepts.
- **Creative Coding Ideas**: Ask ChatGPT for creative coding project ideas that align with the kids' interests. This can inspire them to work on projects that are not only educational but also personally engaging and enjoyable.
- **Debugging Practice**: Kids can use ChatGPT to practice debugging. They can share their code with the model, describe the issue they are facing, and receive suggestions on how to identify and fix bugs.
- **Coding Challenges**: Generate coding challenges or puzzles using ChatGPT. Kids can then attempt to solve these challenges, promoting problem-solving skills and critical thinking in a fun and interactive way.
- **Learning Resources**: Ask ChatGPT to recommend age-appropriate coding resources, tutorials, or games. This can supplement the formal learning process and expose kids to a variety of coding tools and languages.
- **Storytelling with Code**: Kids can use ChatGPT to explore coding in a creative context. Encourage them to tell stories using code, where they create interactive narratives or games by applying coding concepts they've learned.
- **Coding Language Exploration**: If your curriculum includes multiple coding languages, kids can use ChatGPT to explore the differences between them. They can ask for comparisons, advantages, and use cases for various programming languages.
- **Coding History Exploration:** ChatGPT can provide information about the history and evolution of coding languages. This historical

context can make coding more interesting and help kids appreciate the development of the tools they are using.

It's important to note that while ChatGPT as an AI chat bot [8] can offer valuable assistance, hands-on coding practice, real-world projects, and interactive activities should remain central to the learning experience. Additionally, ensure that the coding concepts introduced align with the age and skill level of the students. Always encourage kids to think creatively, employ problem-solving techniques independently, and enjoy the process of learning to code. ChatGPT has a greater capability to provide personalized and efficient learning experiences [9].

The above prompt questions and the responses of the ChatGPT, explain a vast application of Chat GPT in STEM education. STEM education focusses on phenomenon or project-based learning and development of critical thinking [10]. Following features are the main ingredients of STEM education:

Asking questions, thinking, understanding problem, creating ideas, interaction, communication, collaboration, taking challenges and solving problems, language exploration, looking for authentic resources, debugging and recreating solutions, validating, testing and researching [11].

Research conducted [3] in pharmacy education concluded that ChatGPT has a great potential of enhancing process driven phenomenon or project-based learning [7]. As, we can clearly see from the above Chat GPT responses that it justifies its usage in STEM education.

D. Framework for Using ChatGPT in STEM Education

With an immense progress in technology and with growing number of tools and applications which can assist teachers and students digitally, there is a dire need of a working framework, which adheres to the needs and provides a clear instruction on the application of AI assisted tools in education. In our case here we propose a working framework for using ChatGPT in STEM education.

The application of AI technologies in STEM education is a burgeoning trend, capable of providing personalized and efficient learning experience with the challenge of integrating AI techniques in the complex STEM educational system.

1) Technology knowhow and ethical awareness

A very first step in implementing ChatGPT in enhancement of STEM education is to get awareness of the technology and after training teachers, the students should be provided with the complete awareness of the technology. Technology awareness includes:

- What is this technology?
- How technology works?
- What are the ethical issues?
- What are the benefits and limitations of this technology?
- To what extent this technology can be used in STEM education scenario?

2) Lesson explanation and reinforcement

- ChatGPT integration into learning platforms or websites to provide instant explanations and clarification of STEM concepts.
- Students can ask real time questions during or after lessons, receiving immediate responses to get better understanding of a certain topic.

3) Experimentations and simulations

- Students can use virtual lab assistance to design experiments or simulations, offering guidance and explanations throughout the process.
- ChatGPT can be used for interactive demonstrations to trigger scientific processes and visualize the concepts that are otherwise hard to grasp.

4) Project assistance and idea creation

- Equip students in brainstorming and creating ideas for STEM projects or assignments.
- Assist students and help them in rethinking and interacting in projects.

5) Collaborative and interactive learning

- ChatGPT facilitates group discussions by providing explanations, resources, and guidance during collaborative projects and produces an interactive learning environment.

6) Problem solving techniques

- A step-by-step guidance to the problem and finding its solution by breaking problem into pieces. Problem solving skill is an important part of STEM education [11].

7) Personalized teaching

- ChatGPT can offer personalized tutoring sessions where students can ask specific questions or can receive additional support in understanding challenging topics. Personalized learning is an important part of STEM teaching as not all students are at the same pace and in that case personalized tutoring helps in understanding complex STEM concepts.

8) Adaptive Learning Methods

- Adaptive learning Paths can be tailored based on students' individual strengths and weaknesses by providing targeted explanations and resources. In this way a student gets flexible and adaptive learning assistance according to his/her needs.

9) Assessments and feedback

- Continuous assessments and feedback are necessary for improved learning. ChatGPT help students prepare for exams by offering practice questions, explanations, and clarifications.
- Provides students with detailed feedback so that they can learn from it and improve their shortcomings in future.
- Also helps teacher to generate personalized feedback for students from their tasks and write assessments on individual student performances.

10) Accuracy, authenticity, and safety

- Ensures that the information generated from the ChatGPT, must be reliable. Students should check

the authenticity of the information from other sources as well. In the learning process students must take safety, accuracy, and authenticity into consideration.

11) Ethics and privacy

- Teachers and students must maintain privacy standards and ethical considerations when interacting with students, especially considering the age group and educational setting.

III. LIMITATIONS

Integration of AI tools in STEM education is a new trend in educational research [7]. Educational institutions can mitigate the disruptive effects of this technology and can promote academic integrity by developing clear policies and guidelines. Designing assessments that include limited AI-generated text would also prove beneficial. The main shortcomings faced on different levels of use of ChatGPT in different scenarios are lack of reliability that is the information generated can be biased or false or not updated. Limited knowledge is another important limitation. ChatGPT can give biased responses [5]. There can be accuracy problems and grammatical issues. Computational cost and power, academic integrity and safety issues are also some of the bottlenecks [12]. Language limitation is another drawback of ChatGPT. For example, ChatGPT3 is trained on English language. Therefore, there is language constraints which should be overcome [13].

IV. FUTURE WORK AND CONCLUSION

In future we will collect data from teachers in the form of interviews to find that how teachers are using ChatGPT for the benefit of teaching and learning in classrooms and what are the problems they are facing. We asked ChatGPT that how a science teacher can use ChatGPT and included the responses of Chat GPT, which are interesting to know. We presented a detailed framework for use of ChatGPT in STEM education. The ChatGPT as objects-to-think-with offer promising avenues to revolutionize STEM education through a fostering engagement in inclusive and accessible learning environments. Chat GPT is a new technology and making its place in everyday life. It is concluded from the above explanations and research that ChatGPT had a great potential in STEM education. 21st century skill development through STEM education enhanced with Artificial intelligence technologies is a new focus area. Therefore, we need to explore the AI technologies like ChatGPT. We should consider its limitations and see how we can minimize the challenges and maximize the usefulness of the technology.

CONFLICT OF INTEREST

The authors declare that they have no known competing interests or personal relationships that influence the work reported in this paper. Therefore, there is no conflict of interest.

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