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Exploring Pre-Service Teachers' Perceptions of ChatGPT Integration into Physical Sciences Teaching: A Case Study at a Rural South African University

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Abstract. The emergence of artificial intelligence, exemplified by generative chatbots such as ChatGPT, has elicited optimism among some educators regarding enhanced teaching and learning methods. Simultaneously, it has raised concerns among others, who perceive these chatbots as being disruptive to established pedagogical norms developed over centuries. This study investigated pre-service teachers' perceptions regarding integrating ChatGPT into physical sciences teaching at a rural South African university. A case study research design utilizing a qualitative approach was adopted to collect, analyze, and interpret data. This methodology was employed to gain comprehensive insight into the viewpoints held by final year Bachelor of Education Honors physical sciences students serving as pre-service teachers. The study explored the benefits and potential challenges of incorporating emerging technologies such as ChatGPT into physical sciences teaching. The theoretical framework guiding the study was the technological, pedagogical content knowledge (TPACK) framework. Eleven purposively sampled physical sciences pre-service teachers participated in semi-structured interviews. The collected data were analyzed using thematic analysis. The research

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findings indicate that ChatGPT has the potential to contribute to the teaching of physical sciences in the areas of lesson planning, preparation, presentation, and formative assessment. However, the study revealed that ChatGPT is unable to answer certain questions in the physical sciences accurately and this was of great concern. These findings shed light on how artificial intelligence generative chatbots can be incorporated into physical sciences learning. The findings provide insights for policymakers, who can facilitate the use of these tools in lesson preparation; science educators, who should leverage the chatbots to enhance learner engagement; and researchers, to help them deepen their understanding of the role of emerging technologies in science education.

Keywords: artificial intelligence; ChatGPT; physical sciences; technological, pedagogical content knowledge

1. Introduction

Artificial intelligence (AI) chatbots, such as ChatGPT, can potentially transform and enhance physical sciences teaching in rural communities, contributing to the United Nations Sustainable Development Goal of quality education. ChatGPT was developed by OpenAI and released to the public in November 2022 (Baidoo-Anu & Ansah, 2023; Grassini, 2023). It is an artificial language model based on the transformer architecture, which generates human-like text responses to various prompts and questions (Sharma & Yadav, 2022). It has the capacity to engage in conversational interactions with users. The abbreviation ChatGPT stands for chat generative pre-trained transformer. Founders of OpenAI and ChatGPT include Elon Musk, Sam Altman, Ilya Sutskever, and Greg Brockman (Sharma & Yadav, 2022).

The emergence and widespread dissemination of AI tools like chatbots can only be compared to other groundbreaking technologies that have reshaped human existence, such as gunpowder, Guttenberg's press, and electricity (Wark & Ally, 2020). The impact of AI tools on education and many other areas of human life is yet to be fully understood (Grassini, 2023). They can potentially transform education in ways that were almost unimaginable a few decades ago (Cooper, 2023). However, the impact of this technology points to the need for new paradigms, theories, and strategies to cope with the changing educational landscape (Lee, 2023).

AI chatbot tools mimic the intellectual abilities of human beings and can be used in science education as teaching assistants (Gill et al., 2024; Nguyen et al., 2022; Wollny et al., 2021). Thus, teachers can use them to create learning conditions that offer learners guidance, assistance, and feedback (Chiu et al., 2023). They facilitate the creation of learning environments that stimulate critical thinking by providing engaging and interactive activities for learners (Grassini, 2023; Nguyen et al., 2022). Chatbots are learning aids used in education to support the teaching of content and skills, improve efficiency in teaching and learning, and increase learners' motivation to learn (Wollny et al., 2021).

Extant literature is awash with the shortcomings of traditional instruction, such as the assumptions that all learners are identical and that the teacher offers a uniform curriculum to everyone at the same time (Dervić et al., 2018; Yavuz, 2020). AI chatbots can create more differentiated, personalized learning environments (Chiu et al., 2023; Grassini, 2023; Lee, 2023). When incorporating AI chatbots into teaching, the educator motivates learners to create prompts that address their areas of confusion to gain individual clarity. Moreover, learners are guided to use prompts to create individualized formative assessments, and chatbots can use previous prompts to create questions suitable for the individual's level of understanding (Grassini, 2023). In this context, the teacher can facilitate learning as promoted by educational theories of learning, such as constructivist theory, thus bridging the gap between theory and practice (Barak, 2017).

A teacher can use AI chatbots to seek out ideas to create engaging and motivating lessons. These chatbots can be a starting point for finding teaching resources (Deng et al., 2023). The teacher can use AI chatbots to generate resources such as simulations, games, and videos suitable for teaching a particular topic at a given grade level in science education. The teacher can then visit the suggested websites and, as a professional, evaluate these resources and decide whether or not to include them in instruction. The use of chatbots also aids the teacher in content development and lesson planning (Grassini, 2023; Nguyen et al., 2022). Chatbots can offer ideas for producing informative and engaging lesson plans. A teacher can adapt and modify any lesson plan generated by AI in a few moments, thereby significantly reducing their workload (Lee, 2023).

Despite the many potential benefits of AI, these tools have not yet been widely adopted in science education, particularly in rural areas characterized by limited resources (Vandenberg et al., 2023). It remains unclear how teachers use AI technologies pedagogically and what the tools' roles in classroom learning are (Chiu et al., 2023; Lee, 2023). Moreover, some teachers resist adopting these teaching tools, while others are unaware of their potential (Nguyen et al., 2022). Furthermore, little is known about integrating AI and ChatGPT into the process of teaching learners and initial teacher preparation, particularly in rural communities (Baidoo-Anu & Ansah, 2023).

In cognizance of the above gaps in research, this study aimed to determine the extent to which rural physical sciences pre-service teachers understand AI, as exemplified by ChatGPT's potential benefits and limitations in physical sciences teaching in rural communities. The study focused on answering the following research questions (RQs):

RQ1. How do pre-service teachers in the physical sciences perceive the integration of ChatGPT to create effective, innovative, and adaptive teaching methods?

RQ2. In what ways can initial teacher preparation programs be enhanced to better equip future physical sciences teachers to integrate ChatGPT into their teaching practices?

The following section reviews the literature on the current impact of AI chatbots on education and physical sciences teaching.

2. Literature Review

The rapid advancement and development of AI tools in the past few years have led to opportunities and challenges in relation to their integration into physical sciences teaching (West et al., 2023). This study attempted to close the gap in the literature on how AI tools can be integrated into the teaching of physical sciences. By investigating the readiness of pre-service teachers to use ChatGPT in education, the study contributes to a nuanced understanding of the effectiveness of integrating emerging technologies into teaching practices and preparing future teachers for a rapidly changing technological landscape.

ChatGPT is notable for being widely obtainable, offering a free version that makes AI readily available to a wide-ranging audience, especially in resource-constrained rural communities. However, unlike specialized AI tools with intelligent tutoring systems, such as Duolingo, Coursera, Knewton, and Khan Academy (Iqbal, 2023), ChatGPT currently lacks predictive analytics and adaptive sequencing algorithms. These advanced features enable educational platforms to tailor content dynamically based on users' progress and learning needs (Iqbal, 2023). Although ChatGPT does not yet incorporate intelligent tutoring, its sophisticated natural language processing ability enables adaptive engagements, which can still provide meaningful support in physical sciences learning (Virvou & Tsihrintzis, 2023). Real-time query handling by ChatGPT greatly assists in resource-constrained educational settings, even without the adaptive and predictive functionalities found in specialized tools.

Upon its inception, there were attempts to stifle the use of ChatGPT in schools. Since then, the debate has shifted from *whether* to use AI tools to *how* they should be used (Deng et al., 2023). Efforts to ban ChatGPT in some educational institutions in countries such as the USA (Elsen-Rooney, 2023) have been fruitless, as at the time of writing this paper, AI tools were already being incorporated into many websites and social media, such as Meta AI in WhatsApp and traditional search engines such as Copilot in Microsoft Edge and Gemini in Chrome. Banning chatbots is akin to banning the Internet, which is not viable. Moreover, it has now been suggested that using chatbots will be a necessary professional skill in the future (West et al., 2023). Given these shifting trends in science education, it is essential to explore how science teachers should consider integrating these chatbots into their teaching practices.

Researchers have acknowledged that chatbots can be used to improve teachers' pedagogical approaches and the learning experiences they offer (Grassini, 2023; Lee, 2023). These tools can be used to provide personalized tutoring, language translation, and interactive and adaptive learning (Baidoo-Anu & Ansah, 2023). Furthermore, AI chatbots are being used to automate educational tasks such as grading and assessments, content generation, and teaching support (Yan et al., 2024). If grading is automated, it allows more focus to be placed on creating innovative lesson plans and providing individualized learning (Grassini, 2023).

This implies that the integration of AI technologies can enhance the teaching of physical sciences.

The ability of AI tools like ChatGPT to translate educational information from one language to another can also offer inclusive learning opportunities to many learners whose home language differs from the language of instruction (Baidoo-Anu & Ansah, 2023). Learners with limited proficiency in the language of instruction can use AI tools to overcome language barriers in the physical sciences, enhancing their conceptual understanding of the academic content. This can be used to improve the teaching of physical sciences in economically disadvantaged communities, where the language of instruction is often not the same as the learner's home language.

Teachers are encouraged to integrate AI tools into their classroom practices to ensure innovative pedagogical approaches and seek appropriate content materials and interactive learning activities (Grassini, 2023). According to Grassini (2023), "*incorporating these AI tools within teacher training programs can equip the next generation of educators with the knowledge and skills to utilise these technologies optimally in their classrooms*" (p. 9). For example, future teachers should develop the skills to create prompts aligned with their curricula to ask their learners to seek clarity from ChatGPT for the complex concepts they may be learning (Baidoo-Anu & Ansah, 2023). As it is acknowledged that science concepts are abstract, complex, and difficult for learners to understand, integrating ChatGPT during the exploratory phase of instruction can support learning. In this phase, learners can ask ChatGPT questions using appropriate prompts about areas they do not understand to provide extra support in addition to the teaching input they receive (Baidoo-Anu & Ansah, 2023).

Using ChatGPT in initial teacher training can potentially enhance pre-service teachers' creativity. For example, Liu et al. (2023) found that pre-service teachers using ChatGPT exhibited a higher level of creative ability and better performance than those not using the tool. Creativity is a critical skill for pre-service teachers. They should use it to design innovative and inspiring lesson plans, find teaching and learning materials that enhance learning by appealing to the various different learning styles of learners, and design suitable assessment tasks. In all these cases, the integration of ChatGPT can play a pivotal role. However, there are inherent limitations in AI technologies such as ChatGPT, which pre-service and practicing teachers must be aware of and take into consideration.

One of the critical limitations that has been observed is that, in some cases, ChatGPT can provide incorrect or irrelevant information (Lin, 2023). Therefore, learners and teachers must be able to recognize this when integrating ChatGPT into physical sciences teaching. ChatGPT should be used to supplement traditional sources of information such as textbooks or other learning resources rather than to replace these sources of information (Lin, 2023). Teachers should guide learners in creating specific prompts to avoid receiving irrelevant or incorrect responses from ChatGPT. If learners are confused by a response, it is often necessary to rephrase their query, and ChatGPT will clarify its response.

Therefore, when integrating ChatGPT with physical sciences learning, the teacher should teach learners how to create prompts that help them obtain relevant information. Other issues regarding using generative AI tools in education are currently unresolved. These issues concern plagiarism and the ethical use of these tools in academic work.

3. Theoretical Framework

This study was guided by Mishra and Koehler's (2006) technological, pedagogical content knowledge (TPACK) framework. Mishra and Koehler (2006) extended Shulman's (1987) work on pedagogical content knowledge (PCK) to include technological knowledge after observing the rapid acceleration of digital technology and its effects on many aspects of human endeavors, including education. Content knowledge is the knowledge of facts, concepts, and structure of the subject that a teacher is teaching, including its fundamental principles (Shulman, 1987). On the other hand, the term pedagogy refers to the broad principles and strategies of classroom management and organization. While preparing educators, it was observed that subject matter knowledge and teaching strategies were considered to be distinct components. This observation led Shulman to introduce the concept of PCK in 1987.

PCK means that it is important for teachers to know what to teach and how to teach learners. After realizing that the rapid changes in the technological landscape were impacting the learning-teaching process, Mishra and Koehler (2006) asserted that technological knowledge has become critical to teachers' knowledge, and thus the TPACK framework was formulated. They described TPACK as:

> *"… the basis of good teaching with technology and requires an understanding of the representation of concepts using technologies; pedagogical techniques that use technologies in constructive ways to teach content; knowledge of what makes concepts difficult or easy to learn and how technology can help redress some of the problems that students face."* (Mishra & Koehler, 2006, p. 1029)

From the TPACK framework, physical sciences teachers require knowledge of what to teach, how to teach, how the content they teach can be enhanced by using digital technology, and the teaching strategies by which this can be achieved. The following section elaborates on how the TPACK framework can be applied in the physical sciences while integrating ChatGPT.

3.1 Technological Knowledge of ChatGPT

Teachers would be expected to have technological knowledge of AI chatbots. This should involve an awareness of ChatGPT as a reasoning, creative, social, and generative tool that can be integrated into physical sciences education as an expert collaborator (Mishra et al., 2023). In this context, its use can range from generating scientific concepts and assessment tasks to suggesting resources for teaching and learning to data analysis and engaging learners in scientific argumentation. The technological knowledge required to integrate AI chatbots into physical sciences education successfully includes pre-service teachers' knowledge of prompt engineering (Goldman et al., 2024). In prompt engineering, one should be specific,

use the right prompting technique, make the context explicit, and use simple and clear language, avoiding unnecessary jargon (AI for Education, 2023). Such technological knowledge can greatly enhance teachers' ability to integrate ChatGPT into teaching.

3.2 Technological Pedagogical Knowledge of ChatGPT

The effective integration of ChatGPT into physical sciences education is feasible if teachers combine their technological knowledge of ChatGPT with their pedagogical knowledge. A grasp of technological pedagogical knowledge (TPK) in the use of ChatGPT in learning enables teachers to address issues relating to technological limitations, such as the generation of inaccurate responses by the chatbot (Mishra et al., 2023). Furthermore, assessment can no longer focus on lower-order questions, as outlined in Bloom's taxonomy, requiring recall, such as using the chatbot in homework. Teachers and learners would be expected to use the chatbot as a companion, focusing on higher-order questions requiring creativity and analysis, as described in Bloom's taxonomy (Bloom et al., 1956).

3.3 Technological Content Knowledge

In addition to subject matter knowledge (Goldman et al., 2024), pre-service teachers should develop knowledge of when, why, and how ChatGPT can provide inaccurate responses. For example, in chemistry, ChatGPT and other chatbots are known to experience difficulties in providing accurate responses to questions at higher levels of Bloom's taxonomy of educational objectives (Fergus et al., 2023). Teachers should have knowledge of various AI chatbots and their strengths and areas of weakness.

4. Methodology

4.1 Research Context

The participants in this study were part of a final year Bachelor of Education Honors degree class that took the module Methodology of Physical Sciences. One of the topics in the module was integrating digital technology into the teaching of physical sciences, and ChatGPT was used as one of the emerging technologies. The instructor discussed the benefits and limitations of ChatGPT in educational contexts. While the instructor relied on traditional sources of information such as research articles and textbooks to expose the pre-service teachers to the theories underpinning the methodologies of physical sciences teaching, the pre-service teachers were encouraged to use ChatGPT to supplement their understanding.

4.2 Research Design

A qualitative case study research design was utilized in this study to investigate the perceptions of physical sciences pre-service teachers on integrating ChatGPT into physical sciences teaching. A case study design is a blueprint using a qualitative approach to study an issue, culminating in an in-depth understanding of the complexity of the case through themes (Baskarada, 2014; Creswell & Poth, 2016). The case studied was the pre-service teachers' perceptions of integrating ChatGPT into physical sciences education. This research design enabled a comprehensive insight into the pre-service teachers' perceptions of ChatGPT and potential areas for improvement in initial teacher preparation in its integration into physical sciences education.

4.3 Purposive Sampling

Purposive sampling was used to select participants. This is a form of non-random sampling where the researcher first sets out the focus of their study and then selects informants who have knowledge of the phenomenon being studied (Etikan et al., 2016). Participants were recruited based on their interest, willingness, and understanding of the integration of ChatGPT into physical sciences teaching. Eleven participants agreed to take part in the study. The participants' demographics are summarized in Table 1. Most of the participants were less than 30 years old, and both genders were fairly well represented.

Table 1: Participant demographics

Participant code	Gender*	Age
Participant 1	M	26
Participant 2	M	25
Participant 3	F	27
Participant 4	F	25
Participant 5	F	25
Participant 6	F	23
Participant 7	M	26
Participant 8	F	30
Participant 9	M	25
Participant 10	M	24
Participant 11	F	42

*M = male, F = female

4.4 Ethical Considerations

The participants were informed of the purpose of the study, and the researchers sought their informed consent, which was subsequently granted. The participants were also informed that they were free to withdraw from the study at any time without any negative consequences. They were informed that their responses would be used for academic purposes only and remain anonymous and that their identity would not be revealed to anyone. The university research ethics committee provided ethical clearance to conduct the study (ethical clearance certificate number FHSSE/23/PCEM/03/3008).

4.5 Data Collection

Semi-structured interviews were used for data collection. When conducting semi-structured interviews in qualitative research, the researcher uses open-ended questions to construct an interview guide (Magaldi & Berler, 2020). During the interview, the researcher uses probing follow-up questions to understand the phenomenon under discussion from the participant's viewpoint.

A semi-structured interview guide (see Appendix 1) was used to conduct the interviews in a quiet room at the university. An electronic device was used to record the participants' responses to the interview questions after obtaining their permission. Each interview lasted between 30 and 40 minutes. After the

interviews, the participants' responses were transcribed verbatim with the help of software. The participants were allowed to read their transcribed interviews and agreed that the transcribed interviews represented their views. After authentication by member-checking, the interview transcripts were ready for analysis.

Strategies used to ensure rigor and trustworthiness in the study included a thick description of the phenomenon, persistent observation, prolonged engagement for a semester period of four months, peer review, and lastly, member-checking after the interview process (Liamputtong & Rice, 2021). The collected data were analyzed thematically.

4.5 Data Analysis

Data analysis was undertaken using computer-assisted qualitative data analysis software (CAQDAS) ATLAS.ti 8 following Braun and Clarke's (2006) six iterative stages of qualitative thematic analysis. These include familiarization with the data, generating initial codes, identifying themes, reviewing themes, defining and naming themes, and writing the final report. The purpose of the thematic analysis was to identify, analyze, report, and interpret patterns within the data (Braun & Clarke, 2006). The interview transcripts were imported to ATLAS.ti 8 to search for codes within the interview transcripts, grouping similar codes and developing networks.

Inductive and deductive reasoning (Hecker & Kalpokas, 2024) were applied throughout the data analysis process. The initial data reduction stage involved attaching labels to data segments, a process called coding (Hecker & Kalpokas, 2024). Deductive coding implied that the researchers had a list of codes before commencing data analysis, which was derived from theory and the reviewed literature, focusing on the research questions. However, to a lesser extent, other codes were added from the analyzed interview transcripts. Similar codes were then grouped together and thematic labels assigned to each group, in line with established practices in qualitative thematic analysis (Braun & Clarke, 2006).

5. Results and Discussion

In this section, the themes that emerged from the data are used to organize the results of this study. These results are discussed in the context of the literature reviewed. The research questions, themes, examples of codes, and definitions of themes are summarized in Table 2.

Table 2: Research questions, theme definitions, and examples of codes

Research question	Themes and sub-themes	Theme definition and examples of codes
RQ 1: How do pre-service teachers in the physical sciences perceive the integration of ChatGPT to create effective, innovative, and adaptive teaching methods?	Pre-service teachers' understanding of AI and ChatGPT • AI as machines and computers mimicking human intelligence • ChatGPT: AI based on GPT – a language model	AI as technology that simulates human intelligence, and ChatGPT as an AI tool that generates text-based responses. Code examples: • Computers mimicking human intelligence • ChatGPT as a natural language processing model
	Lesson preparation, planning, and presentation	Organizing learning materials, structuring objectives, delivering content, and assessing learners. Code examples: • Objectives • Curriculum documents • Summarizing content
	Prompt engineering	Designing and refining instructions to guide ChatGPT in generating accurate responses. Code examples • Specificity • Clarity • Context
	Limitations of ChatGPT and suggestions for mitigating the limitations	Areas where ChatGPT is constrained and how to overcome the constraints. Code examples • Accuracy • Ethical concerns
RQ 2: In what ways can initial teacher preparation programs be enhanced to better equip future physical sciences teachers to integrate ChatGPT into their teaching practices?	Areas for improvement	Specific aspects of ChatGPT requiring enhancement Code examples: • Auto-marking learners' work • Preventing plagiarism • How teachers can be assisted in dealing with inaccurate responses

5.1 Pre-Service Teachers' Understanding of AI and ChatGPT

Under this theme, two sub-themes represented the participating pre-service teachers' understanding of AI and ChatGPT (see Table 2). They defined AI as machines and computers mimicking human intelligence and ChatGPT as AI based on GPT – a natural language processing model. The participants understood AI technology as machines or computer programs simulating human intelligence. This is what Participant 2 had to say when asked what he understood by AI:

> *"… the theory and development of computer systems capable of performing human tasks or tasks requiring human intelligence."*

Similar sentiments were echoed by Participants 4 and 5, who described AI in the following ways:

> *"…. involves technology that tries to simulate human intelligence by using machines."* (Participant 4).

> *"… the use of machines or computer systems to do what humans can or solve problems that can only be solved by a human."* (Participant 5)

The participants' understanding of ChatGPT as AI based on GPT – a natural language processing model is demonstrated by the following interview excerpts:

> *"Okay, ChatGPT is a chatbot … generative pre-trained transformer. Looking at what it stands for, I'll say people train it; it is trained by humans to converse with the user in a human-like form."* (Participant 6)

> *"I understand that it stands for generative pre-trained transformer, and you give it prompts, and then it responds to you like a human being, but it's a computer program."* (Participant 11)

The above excerpts suggest that the participants understood AI, ChatGPT, and their capabilities. This implies that they had the technological knowledge of AI within the TPACK framework, which could be transformed into making it feasible to integrate AI into physical sciences teaching. According to Reiss (2021), definitions of AI have evolved over time as discoveries were made and AI is an inanimate matter exhibiting some form of intelligence similar to human intelligence, as suggested by the participating pre-service teachers. This includes machines such as robots performing tasks like medical diagnosis, and software programs called bots mimicking human intelligence (Reiss, 2021). The participants' understanding of ChatGPT as a pre-trained transformer, or a natural language processing model trained on a huge number of words to respond to text inputs, is closely aligned with the literature (Sharma & Yadav, 2022).

5.2 Lesson Preparation, Planning, and Presentation

The participants believed that ChatGPT could be helpful in lesson preparation, planning, and presentation. Codes under this theme were lesson objectives; curriculum documents; lesson preparation, planning, and presentation; summarizing content; ChatGPT as a resource for teaching/learning materials; simulations; ChatGPT as a tool for learner engagement; and ChatGPT as a tool for assessment. The network in Figure 1 demonstrates the relationships that emerged between these codes.

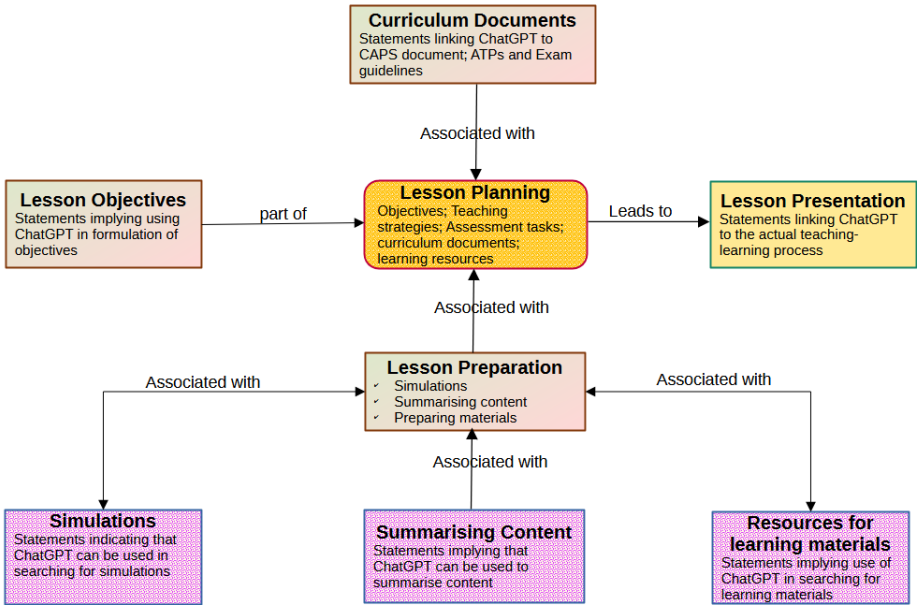

Figure 1: Integrating ChatGPT into lesson preparation, planning, and presentation

In lesson planning, the teacher has to begin by formulating the lesson objectives. Regarding lesson objectives, Participant 6 said:

> *"When ChatGPT gives you the objectives, you, as a teacher, must check them and critically evaluate them. Then, after you evaluate them, you go to a CAPS document or ATP [annual teaching plan], and then you combine them so that you can provide or come up with the proper lesson plan."*

Participants believed it was essential to consult curricular documents in lesson preparation, planning, and presentation. As mentioned by Participant 6, the objectives in any topic that the teacher is teaching while integrating ChatGPT must be verified against curricular documents. In the case of this group of pre-service teachers, the curricular documents were the Curriculum and Assessment Policy Statement (CAPS), the annual teaching plans (ATPs), and examination guidelines. Regarding official curricular documents, Participant 7 had this to say:

> *"As a teacher, I will always use other sources to verify my information, to check if the kind of information I am getting from ChatGPT is appropriate or the kind of information I want. Not just copying everything from ChatGPT. I will use the CAPS document and the different textbooks to check if it's the correct information or if it's wrong."*

In terms of lesson preparation, Participant 11 said:

> *"For lesson preparation, I think mostly to assist me with teaching aids because then it will direct me as to where I can find the simulations for the hands-on experiments and also give me ideas on what type of experiments I can perform with learners for them to understand that particular concept that I want to teach about."*

Other participants, such as Participant 11, mentioned that ChatGPT was useful in searching for resources such as simulations, videos, and websites, and summarizing content. Under *assessment in physical sciences*, Participant 3 said:

> *"It can help teachers who teach physical sciences know how to use ChatGPT to assess learners or create questions they can use in their lessons. In terms of assessment, I can use it to generate questions, maybe, like multiple choice, true or false questions, long and short questions."*

Under the code *ChatGPT as a tool for learner engagement*, Participant 5 mentioned:

> "*ChatGPT can help engage the learners. The students learn better when they're interacting in class. If I can give a question to learners and ask them to check this information from ChatGPT, it will help learners be active and engaged in the classroom.*"

Other participants expressed similar sentiments, indicating that pre-service teachers regarded ChatGPT as a useful tool for enhancing learner engagement and generating assessment tasks and teaching/learning resources. The sentiments expressed by the participants on the potential benefits of integrating ChatGPT into physical sciences teaching align with the findings from previous studies. For example, a study by Jo (2024) revealed that using ChatGPT in learning results in enhanced knowledge acquisition and application, with the novelty associated with personalized learning using ChatGPT stimulating engagement, thus making learning more exciting and motivating.

The participants' perceptions that ChatGPT is a useful tool for generating questions or responding to learners' queries align with the findings from the literature. A study by Lee and Zhai (2024) revealed that pre-service science teachers regarded ChatGPT as a useful tool in the area of learners' formative assessments. This is supported by Rahman and Watanobe (2023), who claimed that physics teachers can use ChatGPT to generate practice questions, quizzes, and explanations for formative assessment. They also argued that ChatGPT can provide step-by-step solutions, helping learners to develop their problem-solving skills. Rahman and Watanobe (2023) also reported that ChatGPT is a useful tool in lesson planning in chemistry and physics, as indicated by the pre-service teachers in this study. This statement corresponds with the research findings indicating that ChatGPT can create effective lesson plans based on the 5E model (Cooper, 2023).

The findings in this study indicate that ChatGPT can be used to plan and execute effective lessons in physical sciences, in line with classroom practices used by teachers. For example, Bitzenbauer (2023) found that implementing activities that promote critical thinking aided by ChatGPT leads to learners having positive perceptions of AI. Similar findings were reported by Makrygiannakis et al. (2024), who found that ChatGPT supports inquiry-based learning in physics, leading to deeper comprehension of concepts.

The perceptions of participants regarding the benefits of ChatGPT in lesson planning, presentation, and assessment provide empirical evidence that they had enhanced TPK, which will be useful in their future careers. By leveraging

ChatGPT, the participants could implement innovative teaching strategies in rural communities, thereby advancing physical sciences education.

5.3 Prompt Engineering

The participants' responses on prompt engineering reflect their appreciable level of understanding, further confirming their TPK. When asked to describe how they could assist their learners to ask prompts in ChatGPT, they responded as follows:

> *"Because, you see, your students are in Grade 10, Grade 11 or 12, and the prompts they give must be specific for that level of education. Because ChatGPT can sometimes provide information that is too advanced for the students. So, on the ChatGPT, you need to ask a specific question related to that grade or that standard so that it can provide you with the correct information. And you need to ask for specific information so that it won't give you the wrong information or the more advanced information to that standard."* (Participant 8)

> *"Let's say we are doing electrical circuits, and they have a question about how resistors in parallel affect the current, they must also be specific that we are doing it for Grade 10. The content needs to be for a Grade 10 learner so that, then, when it gives out the answers, the answers will be in such a way that it's understandable to a learner that is in Grade 10 rather than, maybe, an electrician who then has more knowledge about electricity than a Grade 10 learner."* (Participant 11)

> *"I can ask my learners to ask clear, specific questions. If possible, they must also provide context and follow-up questions."* (Participant 9)

The participants' responses echo some of the features of prompt engineering discussed in Giray (2023), who defined a prompt as a *specific instruction* or a *query* provided to ChatGPT. The four elements of effective prompting identified by Giray (2023) are instruction, context, input data, and output indicator. As noted by participants, the instruction has to be specific to guide the chatbot to an appropriate response. The context is the learner's additional information in the prompt to guide ChatGPT to generate an accurate output (Giray, 2023). Participant 9 stated that learners must be taught to provide context, and other participants, such as Participant 8, stated that learners have to be specific and need responses suitable for their specific grade of education.

Regarding input data, Giray (2023) described this as the core of the prompt and as the specific question that ChatGPT should respond to. This was discussed by Participants 11 and 10:

> *"I think I will have to train or assist my learners in properly putting the prompts so that they give the relevant information. Because if you don't give it the correct prompts, it will just give you any information, seeing that it has access to a lot of information. So, learners need to know that there are certain words that they need to use that will assist them in getting specific answers from ChatGPT."* (Participant 11)

> *"We must be able to teach our learners how to prompt ChatGPT so that they can get problems, explanations, and summaries on topics we've taught them."* (Participant 10)

As for the output indicator, the learner must give ChatGPT directions about the response format required (Giray, 2023). The learner can guide ChatGPT about the length of the response and the details of the response sought. While Participant 10 pointed to the need to specify the type of response, such as problems, summary, or explanation, the participant neglected to state that learners must describe the length of the response. The above perceptions of the participants in prompt engineering suggest that they had sufficient TPACK knowledge to enhance effective physical sciences learning.

5.4 Limitations of ChatGPT and Suggestions for Mitigating the Limitations

The major limitation that ChatGPT currently possesses, which was of great concern to participants, is that it sometimes provides inaccurate information (Elmas et al., 2024). While the participants claimed they could identify inaccurate information, they feared their learners would be unable to differentiate between accurate and inaccurate information. The below excerpts from the participants show their thoughts in this regard:

> *"When I'm teaching my learners when I get the information from ChatGPT, I have to go through it, and I have to consult some sources before I go and teach my learners such information, and I have to use it as an aid."* (Participant 2)

> *"The teacher must emphasize the limitations of using ChatGPT, as many people or learners don't know where to stop. They take all the information, so they must have the knowledge of the limitations. We need to know much about limitations."* (Participant 4)

> *"I can always teach students that they have to learn a good way of putting in the prompt questions and they don't have to rely too much on it. They have to take it as an assistant."* (Participant 1)

The participants believed that using ChatGPT in conjunction with traditional sources of information would mitigate some of its constraints. However, although they claimed this, it was not clear if learners would also manage to utilize ChatGPT in this manner, as reflected by the following excerpts:

> *"As a teacher, on my side, I think I have an advantage because I already have the content knowledge. So, I will be able to identify that this information is incorrect and then use other resources, be it a textbook or other resources, to get the correct information. For me, it starts being dangerous on the part of the learner because the learner is not equipped enough to realize that this information is incorrect. And looking at our children these days, they are over-reliant on digital information. So that's where it will be a challenge as a teacher to encourage my learners to get proper content; they need not rely on ChatGPT only. They also need to refer to the proper textbook we use for physical sciences to get the correct information."* (Participant 11)

> "*A teacher should understand the content so that we can see the flaws in the answers that are out there. Sometimes, it's not just ChatGPT; even the learners' guides sometimes have the wrong information. So, a teacher should be able to understand the content. ChatGPT, though it's worse than the guides that the learners sometimes use, requires a teacher to understand the subject matter and the subject content. A teacher must understand the curriculum document. A teacher must understand the exam guidelines so that we can see the flaws in the answers from ChatGPT or explanations.*" (Participant 10)

The constraints identified by the participants, such as the presence of inaccurate responses, are likely a result of the existing capabilities of chatbots. A study by Fergus et al. (2023) revealed that in chemistry, ChatGPT can satisfactorily provide answers to questions at the remembering and comprehension levels in Bloom's taxonomy but struggles with questions that require application or interpretation. They particularly noted that the chatbot faces difficulties with non-text information, such as questions with graphical or numerical information. Additionally, comparable findings show that ChatGPT could not achieve above 37% accuracy in responses to multiple-choice questions or brief answers at an introductory level for a university chemistry course (Leon & Vidhani, 2023). This means that learners would get incorrect responses most of the time if they attempted to use ChatGPT on its own. Poor performance in responding to biology questions was also observed by Elmas et al. (2024).

Another potential limitation of ChatGPT identified by participants was that learners could develop an over-reliance on it. There was a fear that ChatGPT could assume the role of an epistemic authority for learners despite its limitations in providing accurate information in some chemistry and physics problems. Below are some excerpts illustrating this:

> "*But it's* (ChatGPT) *also not good at all for our learners. As we know, learners are much lazier when searching for information. They will rely much more on ChatGPT as we show them how to use it."* (Participant 8)

> "*The people* (learners) *using it need to use it responsibly. Science is not just about getting a correct answer but how you get to that answer. So, in terms of developing critical skills and problem-solving, that still needs to be done by a human being. So, people need not over-rely on it to provide the correct answer and not understand how to get to that correct answer*." (Participant 11)

These results are aligned with the literature, which suggests that developers of ChatGPT should make an effort to ensure that their algorithms produce more accurate responses for educational settings to prevent harm to learners (Cambra-Fierro et al., 2024). While empirical studies indicate that ChatGPT has many potential benefits at different levels of education, ranging from increasing teachers' well-being and reducing stress to assisting in the achievement of learning objectives and the creation of effective lesson plans (Cambra-Fierro et al., 2024; Wijaya et al., 2024), there is a serious need for teachers to be aware of the limitations discussed by the pre-service teachers in this study. Learners should be

guided in developing critical thinking skills and the ability to evaluate responses from ChatGPT so that this AI tool can be more beneficial. In addition to being critical when using ChatGPT, learners must develop skills to corroborate information and solutions from ChatGPT with trusted educational resources.

5.5 Areas for Improvement

The participants identified auto-marking of learners' works, preventing plagiarism, and how teachers can be assisted in dealing with inaccurate responses as areas that needed improvement with a view to preparing pre-service teachers to integrate ChatGPT into the teaching of physical sciences. The following interview excerpts exemplify their sentiments:

> *"We are not quite sure about using ChatGPT to assess learners' work. … I think it's the same as the limitations. But it has got limitations, such as providing incorrect responses. And I'm unsure how to deal with that in my teaching practice.*" (Participant 3)

> *"The area that must be improved is how learners can avoid plagiarism from ChatGPT. In higher education, most assessments are done online, and learners use ChatGPT as a source of plagiarism. I think they need to come up with solutions. I'm not sure if there can be apps that can be used to help to avoid plagiarism.*" (Participant 9)

> *"The area that I did not find well was that when writing assignments, ChatGPT makes it too easy for a person to write an assignment; you may end up not learning that much because you rely on ChatGPT; you only need a summary, and then you can go to ChatGPT to have an idea after having an idea of what you are searching on ChatGPT can assist you. Therefore, it will limit the critical thinking of students.*" (Participant 5)

The participants' responses imply that pre-service teachers need to be helped during initial teacher preparation to develop skills in the automatic grading of learners' work using chatbots and need to explore how well they can incorporate these techniques into their teaching practices. Issues of plagiarism must also be addressed in initial teacher preparation courses at university. The participants indicated that they were very keen to incorporate ChatGPT into their teaching practices, as expressed by Participant 10 in the following excerpt:

> *"We are in the 4IR at this time, and technology is taking over. So, we cannot be left behind as physical science teachers. Upcoming physical science teachers must be taught how to use AI in their teaching."*

The participants' perceptions regarding the benefits of integrating ChatGPT into learning physical sciences, such as explaining complex science concepts, assisting in problem-solving and conceptual understanding, and increasing learners' motivation, interest, and engagement, are supported by the literature (Iyamuremye & Ndihokubwayo, 2024; Kodkin & Artem'eva, 2024; Taani & Alabidi, 2024). However, it is important that teachers are aware of the limitations of ChatGPT, particularly in responding to questions that require application and solving complex problems in physics and chemistry (Leon & Vidhani, 2023). Areas that need to be improved in teacher preparation programs, as identified by

participants, include using ChatGPT to auto-mark learners' work and dealing with ChatGPT's inaccuracies and plagiarism issues.

6. Implications, Limitations, and Directions for Future Research

This section discusses the implications of the study, its limitations, and directions for future research.

6.1 Implications

The study findings show that pre-service teachers perceive ChatGPT to be beneficial in lesson preparation, planning, and presentation. The study further revealed areas in which they had a limited understanding of the integration of AI. This means that there is a need to develop university modules that incorporate AI literacy and focus on all areas of AI. AI literacy should not focus only on physical sciences teaching; this can also apply to all learning areas. This is particularly critical in rural areas due to constraints in resources and services. AI-driven pedagogic strategies can be enhanced by AI literacy, including strategies such as inquiry-based teaching and problem-based learning.

6.2 Limitations and Directions for Future Research

While this study offers important insights into integrating AI into physical sciences teaching, there are some limitations associated with exploratory studies. For example, while a small sample size was suitable for obtaining an in-depth understanding of pre-service teachers' perceptions, it limits the generalizability of the findings. Suggestions for future research to mitigate these limitations include using a mixed-methods design by collecting both qualitative and quantitative data. Future research should consider longitudinal studies where interviews are conducted at multiple points over time. This could offer a dynamic, in-depth view of participants' beliefs.

7. Conclusion

This study explored physical sciences pre-service teachers' perceptions of integrating ChatGPT into the teaching of physical sciences. It has provided empirical evidence for the potential areas in which ChatGPT can be used to enhance physical sciences instruction. The participating pre-service teachers believed that ChatGPT is a tool that can be used successfully in the areas of lesson preparation and planning for content generation, searching for teaching/learning materials, and generating formative assessment tasks. ChatGPT was also found to have the potential for helping to generate innovative lesson plans. Nevertheless, the investigation revealed that ChatGPT should be used to complement and not lead teachers' efforts. It is advisable to use it to supplement conventional sources of information, such as textbooks and formal curriculum guides. It would be advisable for the developers of ChatGPT to enhance the accuracy of responses generated for questions about the physical sciences. Currently, the application often provides inaccurate answers, which may contribute to misconceptions in subjects such as physics and chemistry. This could adversely affect education in these areas. Policymakers should ensure that they provide professional development to practicing teachers on the potential benefits and constraints of ChatGPT in physical sciences instruction.

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9. Declaration of Interest
The authors declare no conflict of interest.

10. Disclosure
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Appendix 1

Part A: General Questions

- What do you understand by AI, like ChatGPT?
- In your own words, what is ChatGPT?

Part B: Use of ChatGPT in Lesson Preparation and Learning and Teaching

- How can ChatGPT be used in teaching physical sciences?
- How would you use ChatGPT in the following:
    - Lesson planning, preparation and presentation
    - Assessment?
    - Ensuring learners produce prompts suitable to get useful responses from ChatGPT?

Part C: Limitations of ChatGPT

- ChatGPT can produce inaccurate information. How can you, as a teacher, deal with this?
- What are some of the limitations of ChatGPT?

Part D: Preservice Teachers' Perceptions of Integrating ChatGPT in Teaching Physical Sciences

- Based on your understanding of the use of ChatGPT in teaching Physical sciences, how comfortable or prepared are you to integrate it into your teaching?
- What areas in your learning of using ChatGPT in teaching require improvement?
- What can be done to improve preservice teachers' use of ChatGPT in teaching physical sciences?