

An Artificial Intelligence-Powered Program for Fostering STEM College Students' Cognitive Academic English Language Proficiency (CALP)

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Abstract :

*This study explored the effectiveness of an Artificial Intelligence (AI)-powered program for fostering Cognitive Academic English Language Proficiency (CALP) among STEM (Science, Technology, Engineering, and Mathematics) college students. The study utilized quasi-experimental research method (pretest-posttest control group design). Sixty participants enrolled in STEM program at the Faculty of Education, **Minia** University were randomly assigned to two intact groups: a treatment group (n=30) and a non-treatment group (n=30). Both groups participated in pre- and post-tests to gauge their CALP levels. The participants in the treatment group were trained and instructed using an AI-powered program designed by the researchers whereas their counterparts in the non-treatment group did not receive such intervention as they received regular instruction. Instruments of the study included a test of English academic language proficiency and wh-communication prompts in interviews, a test of English formal academic learning, and a test of English-speaking skills with a scoring checklist of specific speaking subskills. The findings revealed that the participants in the treatment group significantly surpassed their counterparts in the non-treatment group in the post-performance of the test of English formal academic learning, and the test of English-speaking skills. Valuable insights into the potential of AI-powered interventions were contributed. Additionally, the development of effective and innovative language learning tools tailored to the specific needs of STEM college students for promoting their academic English language proficiency were introduced. Suggestions for further research and recommendations were also presented.*

Keywords: *Artificial Intelligence, Cognitive Academic English Language Proficiency (CALP), STEM students*

Introduction

Our world is increasingly becoming more interconnected with the growing importance of English language proficiency. As the world's lingua franca, English creates a vast array of opportunities from accessing educational resources and the latest scientific research online to collaborating with colleagues and clients across the globe. Thus, fluency in English empowers individuals to participate actively on the international stage. Furthermore, English proficiency is a major asset in today's job market. Many multinational corporations use English as their primary language, and mastering English not only expands job prospects but also allows professionals to network and collaborate with a wider range of colleagues.

However, the benefits of English extend far beyond the professional realm. Learning English opens doors to cultural exchange and fosters a deeper understanding of diverse perspectives. By bridging communication gaps, English paves the way for international networks and enriches personal growth. While English may not be everyone's native language, mastering it equips individuals with the tools they need to navigate the complexities of our interconnected world. Investing time and effort into learning English is an investment in a brighter future with opportunities for personal and professional development.

Cognitive Academic Language Proficiency (CALP)

The capacity to comprehend and use language required for academic success is known as Cognitive Academic English Language Proficiency, or CALP. This competency requires students to understand difficult academic concepts and use

higher order thinking techniques, going beyond simple interpersonal communication abilities. CALP addresses the oral and written language needed to succeed in academic subjects (Cummins, 2008). For students to succeed in STEM education, where complicated concepts and technical jargon are common, CALP is essential (García & Kleifgen, 2018).

CALP is particularly required due to the increasingly transnational nature of different future professions. CALP gives students the tools they need to understand and articulate difficult scientific ideas and concepts. Developing globally competitive graduates is a top objective in Egyptian universities, therefore fostering all students' CALP abilities is essential.

Addressing CALP to STEM college students is particularly difficult because of the specialized and technical vocabulary that is inherent to STEM professions. Proficiency in both basic academic language and specialist phrases and concepts specific to their field of study is required for students studying STEM disciplines. The technical nature of STEM jargon can make it challenging for students who are still developing their academic language skills to comprehend and interact with one another (Snow and Uccelli, 2009).

Targeting CALP to STEM students, especially those who do not speak English as their first language can be challenging. Since they might not offer the individualized and flexible learning experiences necessary to acquire academic English, traditional techniques frequently fall short in meeting the unique demands of these students (Kelley & Knowles, 2016). There may be a gap in

language competency if manual grading and standardized tests fail to appropriately represent each student's progress or pinpoint areas that require development.

STEM Educational Context

STEM discipline has become an essential part of the current educational systems all over the world. The rapidly evolving fields of science, technology, engineering, and mathematics (STEM) have emphasized the need for those students to acquire not only scientific subjects but also strong English proficiency. English language is considered the key to open the doors for deep involvement in such scientific subjects. These skills are essential and independent to effectively incorporate, analyze, and communicate findings on complex academic topics (Cummins, 1999 and 2023).

However, for many STEM students, especially those for whom English is not a first language, acquiring the necessary academic language skills is a significant challenge (García & Kleifgen, 2023). STEM students experience considerable language difficulties in their academic classes. In this regard, CALP is critical, which entails comprehension as well as utilization of academic English in various tasks including reading, writing, and speaking.

AI and English Language Learning

Language educators usually face greater challenges when trying to bridge the gap between students' technical skills and their ability to understand and articulate complex academic concepts in English. These challenges are often more psychological and academic, which require a thorough understanding of language and its content (Cummins, 2008). The struggle to enhance English

language proficiency among students is an important issue that affects their academic achievement and educational experience.

Artificial intelligence (AI) has the potential to significantly improve a lot of learning domains, including STEM education and language competency, when it is integrated into the educational system. AI-enabled solutions are useful in contemporary educational environments because they can deliver tailored learning experiences, adjust to each student's needs, and provide real-time feedback (Chen et al., 2019). Particularly when it comes to language competency, these resources can help bridge the gap between conventional teaching approaches and the needs of modern students.

Additionally, the use of AI in CALP development offers several advantages. For teachers, it provides a valuable tool that can help students identify and address specific language challenges, enabling them to develop more targeted and effective instructional strategies. AI-powered tools could completely transform CALP instruction by providing a customized, effective, and engaging method that meets the requirements of different students in different contexts.

Furthermore, the use of AI in language teaching can significantly reduce the teaching load on teachers, allowing them to focus on imparting content knowledge rather than resolving language teaching issues. Such technologies, when integrated into the STEM curriculum, would create a scalable sustainable model that can be adopted by educational institutions facing similar challenges. By improving students' English language proficiency, their overall academic achievement will be promoted; thereby

contributing to the development of highly skilled and competent STEM professionals (Bybee, 2023).

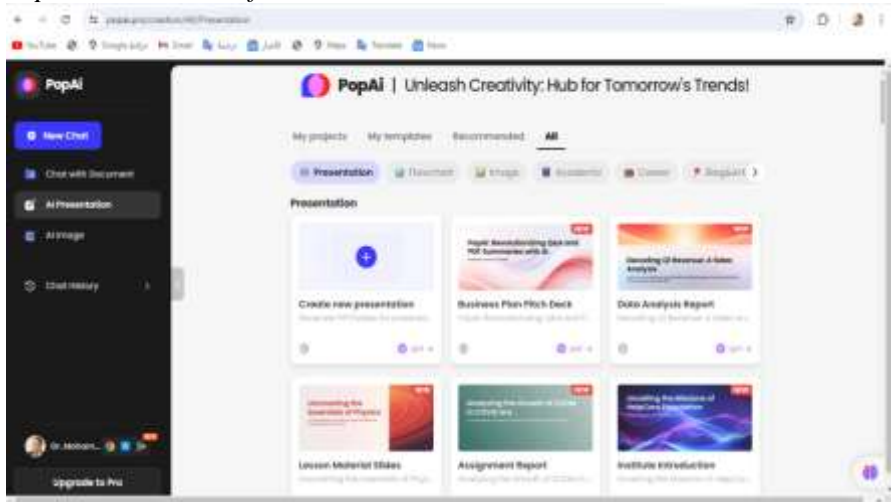
It is common to find English learning activities where the teachers must spend hours grading the answer scripts and often make mistakes in the process. Also, these methods do not cater for the complexity of learning needs of STEM students. AI seems to be a possible solution to this problem since it provides individualized and self-accelerating learning processes. Students' performance data can be processed using AI tools; its potential weak points can be determined, and valuable feedback can be provided to the students leading to improved total academic achievement. This approach not only meets STEM students' immediate language needs but also prepares them for future academic and career endeavors in an increasingly globalized and technology-driven world (Russell & Norvig, 2023).

The advantages of using AI in Building Instructional Programs

By integrating AI multimedia components like sounds, pictures, graphics, and infographics, AI is completely changing the way the instructional programs are made and presented. AI may enhance instructional programs or presentations made by PowerPoint in several ways:

- 1- Automated design suggestions: PowerPoint Designer is one of the AI-powered applications that may automatically recommend design layouts and templates based on the text used. With text and picture analysis, this function provides coherent and visually appealing designs. AI may reorganize components on slides to guarantee a polished and well-balanced appearance while accounting for the significance and information hierarchy. This is shown in figure (1).

Figure 1
Pop Ai Site Sub Interface



Source: Link:(<https://www.popai.pro/creation/All/Presentation>)

- 2- **Image Recognition and Optimization:** AI can examine text on a slide and suggest pertinent images to improve the message. Tools that recommend relevant, high-quality photos from internet sources include Microsoft's AI-driven design tools.
- 3- **Image enhancement:** AI algorithms can automatically alter brightness, contrast, and resolution to produce clear and powerful images.
- 4- **Speech and sound integration:** Voice-over narration, without the requirement for human voice recording, AI algorithms may provide natural-sounding voice-overs for slides. Artificial voices can be produced with tools like Google's Wave Net. AI can also recommend suitable sound effects or background music that fit the presentation's theme and tone. These audio components can improve information retention and involvement in the audience.

- 5- Illustration and infographic creation: AI can convert unprocessed data into visually striking charts and infographics, which simplify and make complicated material easier to understand. AI is used by programs like Tableau and Power BI to provide dynamic and interactive visuals.
- 6- Custom images: AI tools can produce icons and images that are in line with the presentation's theme. Simple line art to intricate pictures pertinent to the subject under discussion might all be included.
- 7- Content improvement and grammar checking: By looking for grammar, spelling, and style mistakes, AI-powered programs like Grammarly and Microsoft Editor may improve the text content of presentations and guarantee professional and understandable communication. Moreover, AI can examine the substance of the presentation and recommend other details, websites, or subjects that will improve the presentation and give a deeper grasp of the subject.
- 8- Real-Time audience interaction: AI can help with interactive Q&A sessions in real time throughout presentations. Tools like Slido link with PowerPoint to let viewers ask questions and get answers from AI. Through analyzing audience comments and engagement measures during the presentation, AI can reveal which parts worked best and which would need work.
- 9- Adaptive content: AI can customize presentations for various students by determining their interests and degree of expertise. AI, for example, can modify the information's intricacy according to how well the student is familiar with the subject.

Ultimately, through automation of design procedures, optimization of multimedia components, and real-time interaction and feedback, the incorporation of AI into PowerPoint presentations greatly improves their quality, engagement, and efficacy. AI can produce visually stunning, expertly narrated, and very interactive presentations that appeal to a variety of audiences and enhance general communication and information retention by using AI.

Review of Literature and related studies

Connectivism Theory

In his (2005) Learning Theory, connectivism, George Siemens highlights the importance of social and cultural settings in the learning process. Connectivism, in contrast to other theories, admits the influence of technology on education and the sharing of knowledge. It holds that knowledge is contained in systems and is obtained by connecting to specific information sources and individuals (Siemens, 2005). Relevance of this idea is seen in educational technology and the application of AI in teaching and learning.

Central ideas in Connectivism

1. Learning and knowledge rest in diversity of opinions

Diverse opinions support learning and knowledge. According to connectivism, learning depends critically on a range of viewpoints. This idea might be put into practice in an AI-powered program that promotes CALP by giving students access to a variety of viewpoints and information sources. Because AI can curate a variety of material, it can show students many points of view and improve their critical thinking and grasp of academic English in different settings (Siemens, 2005).

2. Learning is a process of connecting specialized nodes or information sources

Connecting information sources or specialized nodes is learning.

Connectivism is essentially the idea that learning is interacting with information sources or specialized nodes. Through its mediation role, AI can help students connect with pertinent academic materials, professionals, and peer networks. Students that use this method develop a strong network of knowledge that bolsters their academic language ability (Downes, 2010).

3. Ability to see connections between fields, ideas, and concepts is a core skill

Fundamental to connectivism is seeing and comprehending the relationships between many disciplines, thoughts, and ideas. STEM college students can benefit from these links made by AI-powered educational programs that combine language learning with scientific studies, therefore promoting a more in-depth comprehension of both disciplines (Siemens, 2006). AI can show, for example, how academic English linguistic systems resemble the logical structures of scientific thinking.

4. Accurate, up-to-date knowledge is the intent of all connectivism learning activities

The goal of every connectivism learning activity is receiving accurate and current knowledge. Connectivism requires one to keep up with current information. Students can guarantee access to the most recent studies, advancements, and best practices in their STEM disciplines as well as language acquisition thanks to AI technologies. Their knowledge is kept accurate and relevant by this ongoing information updating (Anderson & Dron, 2011).

5. Decision-making is itself a learning process

Making decisions in the context of learning refers to selecting what and how to learn something. AI can help with this by offering customized suggestions and flexible learning routes that lead pupils through their educational process. By empowering students to make knowledgeable choices about their learning processes, customization raises both their engagement and results (Siemens & Tittenberger, 2009).

Application of Connectivism in AI-Powered CALP Programs

1. Networked learning and AI integration

Integrating AI and networked learning using networked learning environments where students engage with classmates, teachers, and AI tutors, an AI-powered application can promote CALP. These networks offer students a rich, cooperative environment in which to exchange information and resources and absorb ideas from many angles (Garrison, 2011). AI-driven systems, for instance, can support discussion boards and forums where students engage in real-time academic English conversation.

2. Personalized and adaptive learning

The capacity of AI to examine student data and modify training to suit specific requirements fits in perfectly with the connectivism focus on individualized learning routes. Through tracking student progress and offering customized feedback, AI can assist students in overcoming obstacles in learning academic English, so improving their general competency (Dede, 2008).

3. Real-time feedback and continuous improvement

Real-time input and ongoing development improvement and feedback should never stop, according to connectivism. Real-time performance feedback from AI can enable students to spot and fix mistakes fast. For language acquisition, where prompt corrections can have a big impact on learning outcomes, this quick response loop is essential (Luckin et al., 2016).

4. Integration of Multimedia Resources

Multimedia includes different materials as videos, infographics, interactive simulations, AI generated images, sounds, and illustrations. These materials are just a few of the multimedia tools that AI may select and provide to suit various learning styles. These tools not only improve learning but also, by providing several representations, assist students in comprehending difficult academic ideas (Mayer, 2009). This multimedia method offers many linked knowledge sources, so supporting connectivism ideas.

5. Facilitating autonomous learning

Supporting independent study, Connectivism helps students become self-sufficient and skilled users of enormous information networks. Programs driven by AI can enable STEM students to take care of their learning by offering instruments and materials that promote independent study. Students can do self-evaluation exercises, look for further materials, and investigate interesting subjects all of which advance their academic language skills (Siemens, 2008).

Commentary

Academic English training can be made far more effective by instructors using AI to build Connectivism learning

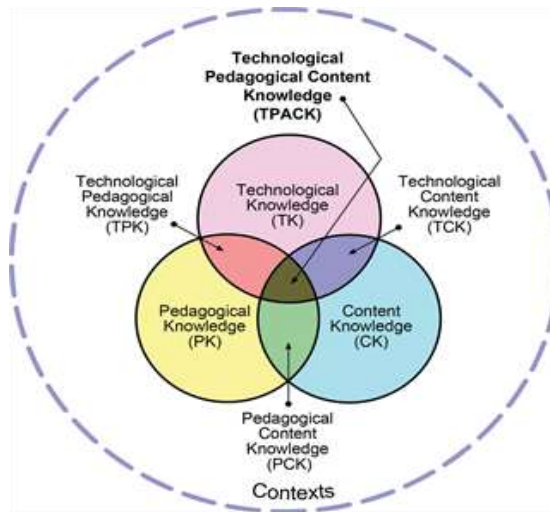
environments, customize instruction, offer real-time feedback, integrate multimedia resources, and enable autonomous learning. Thus, connectivism can be embodied in the use of AI to promote CALP among STEM college students.

TPACK Model

Developed by Mishra and Koehler (2006), the Technological Pedagogical Content Knowledge (TPACK) model is a framework that highlights the information instructors' need to successfully include technology into their instruction. By including a technological component and highlighting the interdependence of technology, pedagogy, and content, the TPACK model builds on Shulman's (1986) idea of Pedagogical Content Knowledge (PCK). Figure (2) below presents the elements of the model.

Figure 2

Technological pedagogical content knowledge.



Source: <http://tpack.org/>

Major Elements of TPACK

1. Content Knowledge (CK): information about the subject matter to be taught (Cognitive Academic English Language Proficiency).
2. Pedagogical knowledge (PK) : knowledge regarding the procedures and methods used in learning.
3. Technological knowledge (TK): information regarding the application of different technologies in education.
4. Pedagogical Content Knowledge (PCK): understanding how to teach specific content.
5. Technological Content Knowledge (TCK): understanding how technology and content influence each other.
6. Technological Pedagogical Knowledge (TPK): understanding how teaching and learning can change when technologies are used.
7. Technological Pedagogical Content Knowledge (TPACK): an extensive knowledge resulting from the combination of content, pedagogy, and technology expertise.

TPACK Model and its relation to AI-powered CALP programs

1. Content Knowledge (CK)

Using artificial intelligence applications created for STEM college students aims to improve their grasp of academic English within their STEM fields. This calls for a strong foundation in the STEM subject matter as well as the linguistic requirements of academic English (Mishra & Koehler, 2006). Customized content that is in line with the curriculum can be produced by AI technologies, guaranteeing that language education is pertinent to the academic requirements of the students (Liu et al., 2021).

2. Pedagogical Knowledge (PK)

CALP cannot be promoted without effective teaching techniques. Pedagogical strategies that support language learning, such as scaffolding, interactive exercises, and formative evaluation, must be mastered by teachers. By delivering individualized feedback, collaborative learning possibilities, and adaptive learning environments that react to student input, AI can enhance various pedagogical approaches (Luckin et al., 2016).

3. Technological Knowledge (TK)

Applying an AI-powered CALP program requires understanding how to use AI and other digital tools. AI programs that can generate instructional content, assess language usage, and offer pronunciation advice must be known to teachers. With this level of technological expertise, teachers can easily include AI technologies into their lessons, improving the learning process for the students (Russell & Norvig, 2023).

4. Pedagogical Content Knowledge (PCK)

Understanding how to teach academic English within the context of STEM demands a specific pedagogical skill. Instructors must know how to address the unique challenges STEM college students face when learning academic English, such as the complexity of scientific vocabulary and the structure of technical writing. AI can aid in this process by identifying common linguistic challenges and providing targeted practice and feedback (Cummins, 2008).

5. Technological Content Knowledge (TCK)

An AI-powered CALP program depends critically on the way content and technology interact. Because AI offers interactive simulations, visuals, and practical applications, it can help students master difficult STEM ideas. Students

can better understand the meaning and use of prefixes and suffixes in scientific language, for instance, by using infographics produced by AI (García & Kleifgen, 2018).

6. Technological Pedagogical Knowledge (TPK)

By allowing new kinds of interaction and involvement, AI technologies have the potential to revolutionize conventional pedagogy. Via virtual reality or gamified learning modules, AI-powered language learning platforms, for example, can provide immersive experiences. The more interactive and interesting learning is made possible by these tools, the more motivated and retained pupils are (Anderson & Dron, 2011).

7. Technological Pedagogical Content Knowledge (TPACK)

One example of how technology, pedagogy, and topic knowledge are integrated is a CALP program driven by AI. This all-inclusive strategy guarantees that technology is applied to improve academic English teaching and learning in a STEM setting. An AI-powered application might, for instance, have modules that teach scientific adages and wise sayings using AI-generated graphics and sounds, therefore bridging the gap between language and scientific knowledge through creative pedagogy (Dede, 2008).

Related Studies

AI-Powered Language Proficiency Solutions

The usefulness of AI in enhancing academic achievement and linguistic proficiency has been shown by earlier studies. Li and Lalani (2020), for example, examined recent research on AI's application in English language instruction and discovered notable gains in language proficiency among students. A different study conducted by Liu et al. (2021) demonstrated how AI-powered

learning platforms improved STEM students' academic English ability. These studies highlight how AI has the power to revolutionize language instruction and meet the requirements of STEM students.

AI technology also presents encouraging answers to these problems. Learning platforms with AI capabilities may evaluate student performance data, spot trends, and offer individualized feedback based on each student's requirements (Liu et al., 2021). These platforms provide focused interventions to enhance CALP by accommodating varying learning velocities and styles. Additionally, AI can automate monotonous jobs like grading, freeing up teachers to concentrate on more important facets of instruction (Luckin et al., 2016).

CALP and STEM Education

The conventional emphasis on material understanding in STEM education means that academic language skills development frequently receives less attention. Studies suggest that STEM educators may not possess the necessary resources to address the language demands of their students (Lee & Buxton, 2013). With no instructional help, students might struggle to achieve the CALP needed to succeed in their classes.

To effectively teach CALP in STEM subjects, pedagogical methodologies that blend language and topic education are required. It's probable that many STEM educators lack the resources or knowledge required to implement these tactics. According to Valdés, Kibler, and Walqui (2014), professional development is crucial for giving STEM instructors the resources they need to support language development in addition to content acquisition. Without

this training, it might be challenging for educators to provide the linguistic scaffolding that kids require.

Teaching CALP to students from a variety of linguistic and cultural backgrounds may provide challenges. García and Kleifgen's (2018) research indicates that culturally responsive teaching practices are essential for fulfilling the different language needs of students. However, implementing these tactics effectively necessitates a deep understanding of students' backgrounds as well as the ability to create an inclusive learning environment.

AI, CALP and STEM Education

AI has significantly improved learning results and student engagement in STEM education. AI-powered technologies can help simplify difficult ideas so that students can understand them better by breaking them down into smaller, more digestible chunks. Additionally, by offering dynamic and captivating educational opportunities, these tools can promote a deeper comprehension of STEM disciplines (Russell & Norvig, 2023). STEM college students can better understand course content and contribute to academic discourse by using AI to improve their language abilities.

Incorporating technology into STEM education to foster CALP has demonstrated promise in mitigating certain concerns. AI-driven language learning systems, for instance, can offer individualized support and adaptable learning opportunities that fit the needs of every single learner (Liu, Wang, & Fang, 2021). By providing additional practice and feedback, these resources can help students improve their academic language skills outside of the traditional classroom setting.

Commentary

Teaching CALP to STEM college students presents several challenges, such as specialized vocabulary, abstract concepts, a dearth of instructional support, and a diversity of student backgrounds. Specialized teaching techniques, professional development for teachers, and the use of technology to speed up language learning are required to address these issues. AI-powered solutions can greatly enhance learning outcomes and academic success by addressing the unique difficulties STEM college students encounter in studying academic content. The purpose of this study is to add to the increasing body of knowledge by assessing how an AI-powered program affects CALP development among Minia University STEM students.

Context of the problem

It has been noticed that STEM college students need to recognize the morphological structure of scientific terminology since it facilitates the comprehension of difficult texts and the development of vocabulary unique to their field. Moreover, college students need to adjust to the linguistic requirements of their disciplines. Abstract concepts sometimes need physical representation for better learning. Conventional approaches may fail to promote these students' needs of deep academic learning and comprehension. Learners need engaging and interactive learning experience. Thus, using AI-powered PowerPoint presentations which blend audio and visual information can greatly enhance students' cognitive academic language proficiency. Quality, contextually relevant photos and infographics created by AI technology can enhance textual material and increase learning effectiveness (Mayer, 2009 and Luckin, et al., 2016).

To validate the problem of the study, insufficient English language proficiency among STEM students, the researchers designed and administered a test of English academic language proficiency to 30 first-semester STEM program students enrolled in the 2022/2023 academic year. This test aimed to shed light on potential gaps in their English language learning, specifically focusing on cognitive academic language skills like grammar, reading comprehension, and vocabulary in specific disciplines. The results revealed a critical weakness in students' English formal academic vocabulary. Notably, they lacked the academic language needed to effectively communicate scientific ideas within their specific contexts.

Further exploration of the students' language proficiency level was conducted through structured interviews utilizing four "Wh-communication prompts." These prompts provided valuable insights into the students' strengths and weaknesses. While the students generally understood presentations on recent scientific breakthroughs, they struggled to comprehend the scientific jargon used. Responses to another prompt demonstrated their ability to explain a scientific phenomenon (e.g., bioplastics vs. traditional plastics) to other mates out of their field of study, but with some difficulty using appropriate scientific vocabulary. This common pattern, evident in both the test and interview responses, highlights the need for alternative teaching strategies to enhance their overall cognitive academic language proficiency. These strategies should specifically target their formal language skills and speaking abilities.

AI is becoming more and more a game-changing instrument in education, improving different teaching strategies and resources. AI applications offer creative answers to persistent problems in education. AI sound generating is one important use; it provides interactive

language lessons and precise pronunciation models. Speaking and listening abilities of language learners are greatly enhanced by AI-powered language learning systems, notably those that combine speech recognition and generation (Li & Lalani, 2020). Personalized feedback made possible by these technologies is essential for academic English proficiency, especially for non-native speakers in STEM disciplines.

Statement of the Problem

English language is the medium of instruction in all STEM disciplines. Though STEM college students are well-trained in the use of technology, their English language skills are not up to the required level. AI has shown great promise in educational settings, providing customized instruction that can meet the specific needs of each student, thus addressing individual language deficits. Hence, the current study proposes an alternative solution: an artificial intelligence-powered program specifically designed to enhance STEM college students' English cognitive academic language proficiency.

Questions of the Study

The present study attempted to answer the following question: How can an AI-powered program be designed to foster STEM college students' cognitive academic English language proficiency (CALP)?

More specifically, the following questions can be branched out:

- 1- What is the effect of using an AI-powered program on fostering STEM college students' English formal academic learning?
- 2- What is the effect of using an AI-powered program on fostering STEM college students' English-speaking skills?

Aim of the Study

The aim of this quantitative study was to explore the impact of using AI to foster STEM college students' cognitive academic English language proficiency.

Hypotheses of the Study

The present study attempted to test the following hypotheses:

- 1- There would be a statistically significant difference between mean scores obtained by the participants of the treatment and the non-treatment groups in the post-performance of the test of English formal academic learning (favoring the treatment group) with a p-value of 0.01 or lower.
- 2- There would be a statistically significant difference between mean scores obtained by the participants of the treatment and the non-treatment groups in the post-performance of the test of English-speaking skills (favoring the treatment group) with a p-value of 0.01 or lower.

Significance of the Study

The use of AI for fostering academic English skills within the field of STEM higher education is hopefully expected to:

- enable STEM college students to understand the complex scientific and technical concepts presented in English leading to better academic performance and increased success in STEM fields.
- enable individual STEM college students to target the areas of their weaknesses to be able to learn at their own pace through tailored support for more efficient learning and better outcomes.
- enhance STEM college students' engagement in classrooms discussions, collaborative projects, and all

other learning activities, thus enriching their educational experience and professional development due to overcoming communication barriers.

- prepare STEM college students for effective communication in their future workplaces, enhancing their employability and career prospects.
- provide English educators with valuable tools for improving students' English language skills to the optimal level required for success in STEM education and thus, increase access to STEM programs.
- reduce English educators' workload to address other aspects of teaching, such as providing more in-depth instruction on scientific concepts and developing students' critical thinking and problem-solving skills.
- promote interdisciplinary collaboration among experts in AI, language education, and STEM fields to offer new insights and innovative solutions to educational challenges.
- provide different educational institutions with a cost-effective solution through AI-programs that can provide high-quality language support without the need for extensive physical resources.
- enable educational institutions to scale AI-powered programs through an online version to ensure its accessibility for students regardless of their geographical location, thus promoting educational equity.

Delimitations of the study

The present study was delimited to the following elements:

1. The participants in this study were 60 second-semester STEM program students at Minia University's Faculty of Education for the 2022/2023 academic year.

2. All participants in English for STEM Course 4 were entirely new to the material due to the Faculty of Education at Minia University's credit-hour program policy. This policy requires students who drop or repeat the course to retake it entirely the following year.
3. There is no balance between male and female STEM students at the Faculty of Education in both the treatment and the non-treatment groups. This is due to the sex ratio of this population.
4. The focus of cognitive academic English language proficiency (CALP) was restricted to formal academic learning and speaking skills.
5. The instructional content is specifically tailored to STEM subjects, with a focus on the usage of prefixes and suffixes in science, and the comprehension of old adages and wise sayings in teaching. Other academic disciplines and content areas are not covered in this study.
6. AI was used in generating sounds, images, illustrations, infographics, and PowerPoint presentations, e.g. DALL-E or Midjourney, TTS. These AI-generated elements were integral parts of the instructional program, and their quality and effectiveness are contingent on the capabilities of the AI technologies employed. This delimitation acknowledges that the study's outcomes are influenced by the specific AI tools used and may vary with different AI applications or traditional methods.

By defining these delimitations, the study acknowledges the specific parameters within which the research is conducted, thereby providing a clear context for interpreting the findings and understanding the scope of its applicability.

Definitions of Terms

Artificial Intelligence (AI):

- It focuses on creating systems capable of performing tasks that typically require human intelligence. These tasks include problem-solving, learning, reasoning, and understanding natural language (Russell & Norvig, 2023).
- Wei (2023:3) defines AI as a branch of computer science that enables machines to simulate human intelligence, learn from experiences, and perform tasks that typically require human cognitive abilities.
- In the educational contexts, Wei (2023:4) defines AI as technologies that hold immense potential to transform traditional instructional methods, providing personalized learning experiences tailored to individual needs and preferences.
- The definition of AI in educational context by Wei (2023) is adopted in this study.

STEM (Science, Technology, Engineering, and Mathematics)

- STEM education is designed to develop students' skills in critical thinking, problem-solving, and the ability to integrate knowledge across disciplines in science, technology, engineering, and mathematics (Kelley & Knowles, 2016).
- STEM is an interdisciplinary approach to learning where academic concepts are coupled with real-world lessons. Students are then asked to apply science, technology, engineering, and mathematics in contexts that make connections between school, community, work, and the global enterprise, enabling the development of STEM literacy with it the ability to compete in the new economy (National Science

Foundation, 2023 and Bybee, 2023).

- The researchers defined the STEM term procedurally as an interdisciplinary approach that integrates four specific disciplines (Science, Technology, Engineering, and Technology), emphasizing real-world applications and problem-solving skills to develop critical thinking, creativity, and innovation to prepare STEM program graduates for careers in a rapidly evolving technological landscape.

Cognitive Academic English Language Proficiency (CALP):

- CALP refers to the level of language proficiency required to understand and discuss academic content in a classroom setting. It involves the use of language in decontextualized academic situations and is essential for students to succeed in a school environment (Cummins, 2023 and García & Kleifgen, 2023).
- The researchers defined the CALP term procedurally as the level of language proficiency required for the STEM college students to understand and express orally complex ideas and concepts in an academic setting to be able to engage in higher-order thinking tasks such as analysis, synthesis, and evaluation, which are critical for success in academic and professional contexts.

Method

Research Design

The present study utilized quasi-experimental research design. The pre-post control group design (Hatch and Farhady, 1982) was used in designing and conducting the study. A treatment group and a non-treatment group were exposed to pre and post means of getting data. The treatment group was only instructed and trained using an AI-powered program while the non-treatment group did not receive such training.

Participants of the Study

Sixty (60) STEM college students enrolled in STEM program in Minia University's Faculty of Education in the academic year 2022-2023 were recruited for this study. The participants were randomly divided into two equal intact groups, treatment, and non-treatment. Homogeneity was established between participants in both groups at the entry level before the intervention as follows:

Age.

All the participants recruited in both groups were aged between 19 and 21 at the beginning of the study.

Linguistic background.

This study involves two groups of participants who share a similar educational background. All participants completed 12 years of English language education, from primary school through secondary school, in Minia Governorate, Egypt. In addition to that they all enrolled in the second level of STEM program in Minia University's Faculty of Education.

Pedagogical background

All the participants in both groups are STEM students at the Faculty of Education.

Instructor

The researchers taught only the treatment group by themselves while the non-treatment group was taught by another instructor. This was done to avoid contamination of the procedures of teaching the non-treatment group and to keep the two groups intact.

Variables of the Study

The independent variable.

The use of an AI-powered program.

The dependent variables.

The level of English formal academic learning and the level of English-speaking skills.

Piloting Study Instruments

The sample group participated in piloting study instruments was thirty (30) male and female STEM college students enrolled in the STEM program in Minia University's Faculty of Education in the second semester of the academic year 2022/2023. Piloting study instruments lasted for fifteen days and helped in determining the validity and reliability of the study tools.

Instruments of the study

To fulfill the study aims, a test of English academic language proficiency, wh- communication prompts through structured interviews, a test of English formal academic learning, and a test of English-speaking skills were utilized.

A- Exploratory study instruments

1- A test of English academic language proficiency

Purposes of the test. Determining the current level of English academic proficiency and consequently, the appropriate instructional methods for STEM college students enrolled at Minia University's Faculty of Education.

Construction of the test. (a) A thorough review of existing literature was conducted to identify established methods for assessing academic language proficiency, (b) Stating the objectives of the test, (c) An initial version of the test was created, containing 30 multiple-choice questions, (d) Evaluating the preliMiniary form of the test by a jury of 5 TEFL experts. Their feedback ensured the test's alignment with the stated objectives and its appropriateness for the target population, (e) the test was revised and finalized. The final version consisted of 20 multiple-choice questions with clearly defined answer options.

Validity of the test. A jury of 5 TEFL experts was asked to approve the validity of the test. They approved its face validity, suitability and appropriacy for the study participants.

Administration of the test. The test was administered to STEM college students enrolled in the STEM program of Minia University's Faculty of Education to determine their needs and challenges in relation to English cognitive academic language proficiency.

Results. Analyzing the results obtained from the students on the test of English academic language proficiency showed that the average scores for the students was (6.36). The difference between the overall mean and the student mean was (13.64), and the percentage of correct student responses is (31.8%). This is shown in table (1).

Table (1)
Means, standard Deviations for the test of English Academic Language Proficiency N-30

Total score	Means	Standard Deviation	Means dif.	Percent of correct responses
20	6.36	1.65	13.64	31.8%

Additionally, the percentage of correct answers ranged from 10% to 50%, while the percentage of incorrect answers ranged from 50% to 90%, highlighting the prevalence of incorrect responses. This overall low percentage of correct answers signifies a substantial weakness in the academic terminology aspect of learning for STEM college students. This necessitates a considerable evaluation of the current teaching methods and the exploration of innovative approaches to enhance their English cognitive academic language proficiency.

2- Wh- communication prompts in interviews

Purposes of the interview. Determining the current level of English language proficiency for STEM college students enrolled at Minia University's Faculty of Education.

Construction of the interview. (a) Reviewing the literature related to the different language communication skills (b) Stating the objectives of the interview, (c) Designing a preliminary 6 wh-communication prompts (d) Evaluating the preliminary form of the interview by a jury of 5 TEFL experts, (e) The final version of the interview after modification consists of 4 wh-communication prompts.

Validity of the interview. A jury of 5 TEFL experts was asked to approve the validity of the interview. They approved its face validity, suitability and appropriacy for the study participants.

Administration of the interview. The wh-communication prompts were introduced to STEM college students enrolled in the STEM program of Minia University's Faculty of Education. The students' responses were recorded for later analysis to determine their needs and challenges in relation to English cognitive academic language proficiency.

Analyzing students' responses on the 4-wh-communication prompts through the interviews revealed their clear understanding of the related scientific concepts, as reflected in their explanations of photosynthesis process, solar cells, stem cells, etc. However, a gap in their academic vocabulary and overall speaking proficiency emerged as a prominent area for development. This was evident in unclear use of stress patterns and limited use of cohesive devices in spoken discourse. The organization in presenting information was also not manifested.

These common problems in their communication may potentially affect their ability to effectively collaborate with peers, present research findings to a broader audience, make job applications and other attempts towards other goals in the future.

Prior related studies emphasized that interventions focused on formal academic learning can support STEM college students in a great way. Applying interventions on scientific language and speaking skills, utilizing recent technological applications, or providing opportunities to practice oral presentation could be valuable strategies to consider. Additionally, advancements in AI applications offer brilliant solutions to bridge this gap. AI-powered tools can be integrated into the learning process to enhance their academic vocabulary and foster their speaking skills leading to overall enhancement of their language communication skills.

B- Measuring Instruments

1. A Test of English Formal Academic Learning

Purpose of the test. A test of English Formal Academic Learning was designed by the researchers for STEM students enrolled in the STEM Program of Minia University's Faculty of Education to assess their English formal academic learning, to ensure equality of the participants in the treatment and non-treatment groups through piloting, and to measure the degree of improvement of the participants in both groups on their knowledge of the targeted aspects of cognitive academic language proficiency after finishing the intervention.

Construction of the test. It is a test of formal academic knowledge. It consists of two sections: a) academic prefixes and suffixes in STEM contexts (32 item) and b) old adages and wise sayings in education (28 item) totaling 60 items. Both sections of the test use multiple choice questions with one point awarded per each correct multiple-choice answer.

Instructions for the test. This test is intended to be administered online, hosted on Google Forms, through the following link: <https://n9.cl/g8a4rl>. The instructions of the test are written in English. They are brief and easy to understand. They include information about the purpose of the test, the way of recording the answers and the time allowed to complete the test.

Piloting the test. A pilot run was conducted with a mixed-gender group of 30 STEM students enrolled in the STEM Program of Minia University's Faculty of Education during the first semester of the 2022-2023 academic year. The pilot test determined an average completion time of 50 minutes, based on the total time taken by all participants divided by the number of participants (30).

Validity of the test.

1. The face validity of the test.

It was determined by submitting it to a panel of five experts who evaluated it based on three key criteria: clarity and conciseness of test items, alignment in accordance with the program's learning objectives, and the appropriateness for the target student group. The experts' input and proposed changes were then integrated to develop the test in its final form.

2. The internal consistency of the test.

The same piloting sample took the test. The internal consistency of the individual items of both section one (academic prefixes and suffixes in STEM contexts) and section two (old adages and wise sayings in education) was calculated as shown in table (2). The values of the correlation coefficient, ranged from (0.682:0.875), are considered acceptable.

Table (2)
Establishing the internal consistency of the test
The correlation of the items of each section with the total of that section

Sections	Internal consistency
The total of section one	0.875**
The total of section two	0.682**

Note. **. Correlation is significant at the level (0.01).

Reliability of the test.

Establishing the reliability of the test was done during piloting. The same piloting sample took the test. The reliability coefficient of the test was determined using Alpha Cronbach coefficient. It ranged from (0.752) to (0.778) for each of the sections of the test and for the total of the sections. The alpha coefficient of the whole test is (0.793) which is considered acceptable as shown in table (3).

Table (3)
The Cronbach Alpha's Reliability Coefficient of the test

The test sections	Means	Variance	Standard Deviation	Alpha
Section one	26.93	4.06	4.58	0.752
Section two	17.60	8.97	2.01	0.778
Total	52.06	21.06	2.99	0.793

Note. *. Alpha is significant at the level (0.01).

Cohen et al. (2007:506) point out that the alpha coefficient is considered reliable if they range from 0.70 to 0.90. Thus, the reliability coefficient of the test is considered within the acceptable range.

Item analysis. It evaluates the effectiveness of the items and of the test.

Index of difficulty. Analysis of the responses to individual items was calculated to determine item difficulty for the test. The difficulty of the items is understood as the proportion of the persons who answer a test item correctly. The index of difficulty of this test ranged from 0.45 to 0.71, which is considered acceptable.

Item discrimination. It is the ability of the item to differentiate more knowledgeable students from the less ones. To calculate knowledge, the top scoring students are separated from the bottom scoring students and then their response patterns would be compared. It was found that the items had a positive discriminating power. None of the items had a zero- discriminating power. This means that all questions somewhat distinguished between high and low-performing students. Thus, the power of discrimination of this test is considered acceptable.

Test time Allocation. Time taken by each student was recorded, divided by the whole number of the participants (30) who took the test, which was found to be 50 minutes. Thus, the testing time was 50 minutes.

2. A test of English-speaking skills

Purposes of the test. A test of English-speaking skills was designed by the researchers for STEM students enrolled in STEM program in Minia University's Faculty of Education to assess their English-speaking skills, to ensure equality of the participants in the treatment and non-treatment groups through piloting and to measure the degree of improvement of the participants in both groups on their speaking skills as an aspect of their cognitive academic language proficiency after finishing the intervention.

Construction of the test. It consists of two sections: a) knowledge and (12 item) and b) application (15 item) totaling 27 items. Section one of the test has pre-defined answers with one point awarded per each correct answer. Section two of the test has scenarios for the students to respond orally. These responses are graded against a detailed scoring checklist linked to specific speaking sub-

skills (10 in total). The scoring checklist employs 3-point Likert scale, ranging from developing (1), competent (2), and mastery (3) with the maximum of 450 score for this section.

Instructions for the test. The instructions of the test are written in English. They are brief and easy to understand. They include information about the purpose of the test, the way of recording the answers and the time allowed to complete the test. The following google drive link: <https://drive.google.com/drive/folders/1xWSw2Vxee20L04drtpoYxFSHWyeTGv?usp=sharing> was established to record and upload students' oral responses.

Piloting the test. A pilot run was conducted with a mixed-gender group of 30 STEM students enrolled in the STEM Program of Minia University's Faculty of Education during the first semester of the 2022-2023 academic year. The pilot test determined an average completion time of 60 minutes, based on the total time taken by all participants divided by the number of participants (30).

Validity of the test.

1. The face validity of the test with its scoring checklist

This was determined by submitting both the test and its scoring checklist to a panel of five TEFL experts who evaluated them based on three key criteria: clarity of language in the test items, alignment with the program's learning objectives, and appropriateness for the target student population (STEM students). The experts feedback and recommendations were incorporated to refine them into their final form.

2. The internal consistency of the test.

The same piloting sample (30 STEM students enrolled in STEM Program in Minia University's Faculty of

Education) took the test. The internal consistency of the individual items of both section one (knowledge) and two (application) was calculated as shown in table (4). The values of the correlation coefficient, ranged from (0.963: 0.967), are considered acceptable.

Table (4)

Establishing the internal consistency of the test
The correlation of the items of each section with the total of the two sections of the test

Sections	Internal consistency
The total of section one (knowledge)	0.967**
The total of section two (application)	0.963**

Note. **. Correlation is significant at the 0.01 level (two-tailed).

2. The internal consistency of the scoring checklist.

The internal consistency of the individual criteria of the three dimensions; delivery, language use, and content were calculated as shown in table (5). The values of the correlation coefficient ranged from (0.996: 0.998) are considered acceptable.

Table (5)

Establishing the internal consistency of the scoring checklist/ The Correlation Between Each dimension and the total scoring checklist with the total of the two sections of the test

The Dimensions	Internal consistency
Section1	0.967**
Delivery	0.998**
Language Use	0.996**
Content	0.997**
Section2	0.963**

Note. **. significant at the 0.01 level (2-tailed)

Reliability of the test.

Establishing the reliability of the test was done during piloting. The same piloting sample took the test. The reliability coefficient of the test was determined using Alpha Cronbach coefficient. It ranged from (0.792) to (0.911) for each of the sections of the test and for the total

of the sections. The alpha coefficient of the whole test is (0.923) which is considered acceptable as shown in table (6).

Table (6)
The Cronbach Alpha's Reliability Coefficient of the test

Dimensions	Means	Standard Deviation	Variance	No. of items	of Alpha
Section1	2.35	2.01	4.037	12	0.842
Delivery	67.09	22.10	488.56	4	0.792
Language Use	50.16	16.93	286.47	3	0.855
Content	48.45	16.21	262.79	3	0.911
Section2	165.71	53.62	2875.28	10	0.852
Total Sections	168.06	55.27	3054.59	22	0.923

Note. *. Alpha is significant at the level 0.01 (2-tailed).

Item analysis. It evaluates the effectiveness of the items and of the test.

Index of difficulty. Analysis of the responses to individual items was calculated to determine item difficulty for the test. The index of difficulty of this test ranged from 0.49 to 0.73, which is considered acceptable.

Item discrimination. It is the ability of the item to differentiate more knowledgeable students from the less ones. It was found that the items had a positive discriminating power. None of the items had a zero-discriminating power. This means that all questions somewhat distinguished between high and low-performing students. Thus, the power of discrimination of this test is considered acceptable.

Test time Allocation. Time taken by each student was recorded, divided by the whole number of the participants (30) who took the test, which was found to be 60 minutes. Thus, the testing time was 60 minutes.

The AI-powered program

An AI-powered program was designed by the researchers through leveraging AI multimedia components like sounds,

pictures, graphics, and infographics in PowerPoint presentations that give the program its distinguished feature of instructional design.

Its aim:

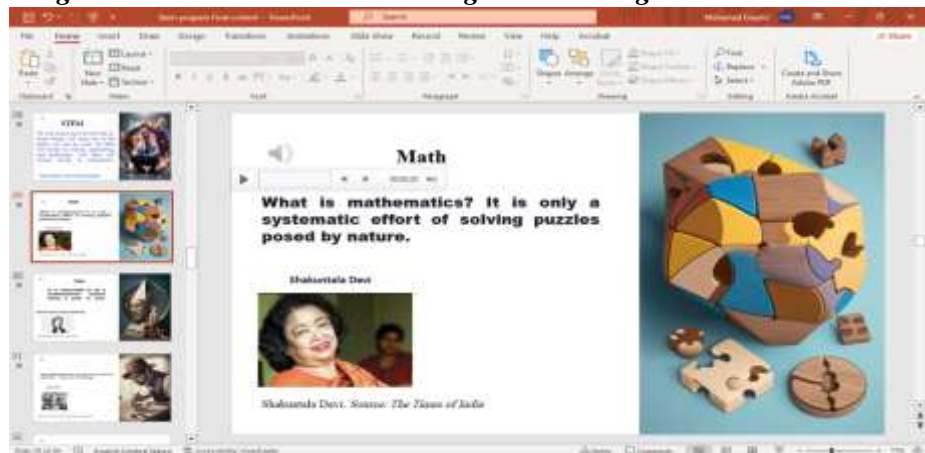
The aim of this program is to transform the way STEM college students learn academic English language using AI-powered applications (e.g. AI-generated audios for pronunciation and explanation). More specifically the program aims at enhancing the English formal academic learning and English-speaking skills of STEM students. This is ultimately will enhance their overall English cognitive academic learning.

Its structure:

The AI-powered program comprises a five-module structure. The first two modules introduce academic prefixes and suffixes in STEM contexts. The remaining modules tackle old adages and wise sayings in education. For each module, interactive AI-generated audios, illustrations and images were employed to foster students' ability to acquire academic formal vocabulary and practice speaking skills. This is shown in figure (3).

Figure 3

Adage slide screenshot that shows AI generated image and sound.



Source: (AI-powered program)

Its components

The AI-powered program utilizes a well-structured, two-hour study session format to ensure a consistent and effective learning experience. Each session follows a standardized template, allowing participants to become familiar with the flow and maximize their learning.

Instructional Activities.

The AI-powered program employs a set of instructional activities to maximize the students' opportunities for practice. These activities include: (a) interactive quizzes with both objective -testing items and open-ended questions with scenarios, (b) pair and group discussions for interpretations and insights from different cultural perspectives, (c) pronunciation practice employing peer and instructor feedback, and (d) description, translation and paraphrasing activities to promote their speaking skills.

Description of Designing AI-Generated Images and Illustrations for Old Adages and Wise Sayings in Education

1. Selecting Adages:

- Choose adages that are widely recognized and applicable to teaching.
- Ensure they have clear and relevant meanings.

2. Creating Illustrations:

- Use AI tools like DALL-E or Midjourney to generate relevant images.
- Put specific prompts that capture the essence of each adage (e.g., "a teacher lighting a fire in a student's mind").

3. Editing and Refining:

- Use graphic design software to refine and enhance AI-generated images.

- Ensure clarity and visual appeal for educational purposes.

Description of Designing AI English Sounds for Old Adages and Wise Sayings in Education

1. Recording Adages:

- Use text-to-speech (TTS) AI tools to generate audio of the adages.
- Ensure the TTS tool supports natural and clear pronunciation (e.g., Google Cloud TTS, Amazon Polly).

2. Customizing Audio:

- Adjust the speed, tone, and pitch of the AI-generated audio to match educational needs.
- Include pauses and emphasis on key words for better comprehension.

3. Integrating into Slides:

- Embed the AI-generated audio into the PowerPoint slides.
- Provide controls for students to replay and practice along with the audio.

Evaluation of the program

The AI-powered program used the following evaluation procedures:

- Formative evaluation. Throughout each session, researchers used a variety of formative assessments like interactive quizzes, discussion questions, reflections, scenarios, pronunciation and speaking tasks. These activities allowed for continuous feedback and adjustments to teaching based on student understanding. This ensured students' continuous improvement.
- Additionally, summative quizzes were given at the end

of each unit. These quizzes measured how well students learned the key concepts covered in that unit. This approach provided a step-by-step evaluation of student progress, ultimately contributing to assessing the entire program's effectiveness.

The construction of the training program. It has gone through the following steps: reviewing the literature related to the use of AI-applications to enhance students' academic language learning, stating the general and the specific objectives of all modules and their sessions, preparing the content, submitting the program to 5 TEFL jury members to be evaluated according to the following criteria; statement of items, academic verification of the content, appropriateness of the methods and the techniques used for the content and the target audience of the study and applicability of the program.

The Experimental Procedures

1. A test of English academic language proficiency and wh-communication prompts in interviews were developed and conducted by the researchers to identify the challenges faced by STEM college students in their English formal academic leaning. These exploratory instruments aimed to gather information that would help students actively participate in the intervention and strengthen their English cognitive academic learning proficiency.
2. ***Pre-testing procedures***
Pre-testing the participants of both the treatment and non-treatment groups, (N=60), using the test of English formal academic leaning and the test of English-speaking skills before the intervention to ensure their homogeneity at the entry level. According to Table (7) and (8), the average scores (means) and spread of scores (standard deviations) on both the test of English formal

academic learning and the test of English-speaking skills were close for both the treatment and non-treatment groups. This is statistically confirmed by a nonsignificant t-value, indicating no difference between the groups at the commonly used confidence levels of 95% (0.05) and 99.9% (0.001). This finding supports the homogeneity of the two groups in terms of their English formal academic learning and English-speaking skills before the intervention began.

Table (7)

Means, standard deviation, mean difference, t-value, η^2 and effect size on the pre-performance of the treatment and non-treatment groups of the test of English Formal Academic Learning ($N=60$)

Aspects of comparison	Group	Mean	Std. Deviation	t-value	df	Sig(2-tailed).
Section1	pre-non-treatment	11.43	7.37	0.685	58	0.378
	pre – treatment	11.89	6.61			
Section2	pre-non-treatment	10.43	7.62	0.480	58	0.158
	pre – treatment	8.75	3.61			
Total of Dimensions	pre-non-treatment	20.14	4.75	0.152	58	0.241
	pre – treatment	18.58	7.22			

Note. **. significant at the 0.01 level (2-tailed)

Note. *. significant at the 0.05 level (2-tailed)

Table (8)

Means, standard deviation, mean difference, t-value, η^2 and effect size on the pre-performance of the treatment and non-treatment groups of the test of English -Speaking Skills ($N=60$)

Aspects of comparison	Group	Mean	Std. Deviation	t-value	df	Sig.
Section1	pre-non-treatment	1.97	1.189	0.342	58	0.734
	pre – treatment	1.87	1.074			
Delivery	pre-non-treatment	62.80	3.34	0.038	58	0.970
	pre – treatment	62.77	3.50			
Language use	pre-non-treatment	46.30	1.12	0.191	58	0.849
	pre – treatment	46.23	1.55			
Content	pre-non-treatment	46.00	1.11	1.484	58	0.143
	pre – treatment	46.80	2.73			
Section2	pre-non-treatment	155.10	3.57	0.658	58	0.513
	pre – treatment	155.80	4.61			
Total of Dimensions	pre-non-treatment	157.07	4.01	0.530	58	0.598
	pre – treatment	157.67	4.74			

Note. **. significant at the 0.01 level (2-tailed)

Note. *. significant at the 0.05 level (2-tailed)

- 3- **The intervention.** Participants at the treatment group were trained using the AI-powered program passing through all the previously mentioned steps, activities, and tasks.
- 4- **Post-testing** the participants of both the treatment and nontreatment groups, (N=60), using the test of English formal academic learning and the test of English-speaking skills after the intervention to compare the results with the pre-testing results.
- 5- **The non-treatment group.** Participants in the non-treatment group received instruction on English for STEM 6 course using the regular way with no AI-powered program intervention.

Results and Discussion

Verifying study hypotheses

Hypothesis 1

The first hypothesis of the study predicted that there was a statistically significant difference (favoring the treatment group) between mean scores obtained by the participants of the treatment and the non-treatment groups on the post-performance on the test of English formal academic learning. Statistical analysis of the obtained data showed that the treatment group achieved a higher degree of improvement than the non-treatment group on this test as t-value (14.59) is significant at (0.01) level and beyond. Thus, the first hypothesis is confirmed. Table (9) below shows the data obtained to test this hypothesis.

To assess the effectiveness of the AI-powered program in fostering STEM college students' English formal academic learning, statistical analysis utilizing the eta-squared formula (η^2) was employed. Cohen et al. (2007:522) have indicated that an eta-squared value of 0.01 signifies a weak effect, 0.06 represents a medium effect, and 0.14 indicates a large effect. The results, presented in Table (9), revealed

a remarkably high eta-squared value of 0.866. This falls well within the category of a large effect, suggesting the AI-powered program has a substantial and positive impact on improving English Formal Academic Learning among STEM college students.

Table (9)

Statistical analysis of data obtained by the participants of the treatment and the non-treatment groups on the post- performance on the test of English formal academic learning $N=60$

Aspects of comparison	Group	Mean	Std. Deviation	t-value	df	Sig. (2-tailed)	η^2	Effect size
Section1	Post-non-treatment	28.36	2.35	**8.84	58	0.000	0.775	High
	Post – treatment	19.96	4.63					
Section2	Post-non-treatment	20.90	5.24	**5.16	58	0.000	0.645	High
	Post – treatment	13.40	5.97					
Total of Dimensions	Post-non-treatment	49.26	4.14	**14.59	58	0.000	0.866	High
	Post – treatment	33.36	4.29					

Note. **. significant at the 0.01 level (2-tailed)

Note. *. significant at the 0.05 level (2-tailed)

The positive impact of the AI powered program was not limited to just comparing the treatment and non-treatment groups. Analyzing the treatment group's performance itself revealed a significant improvement in their English formal academic language Table (10) illustrates a substantial difference between their scores on the pre- and post-assessment of English formal academic learning (t-value = 35.62, significant at 0.01 level and beyond). This statistically significant difference indicates a great improvement within the treatment group. Further strengthening this finding, the eta-squared value (η^2) for this comparison is exceptionally high at 0.978, which again falls under the category of a large effect. This reinforces the conclusion that AI-powered program has a powerful influence on fostering STEM students' English formal academic learning within the treatment group.

Table (10)
Comparison of pre- and post-test scores within the treatment group for the test of English formal academic learning ($N=30$)

Aspects of comparison	Group	Mean	Std. Deviation	t-value	df	Sig.	η^2	Effect size
Section1	Pre- treatment.	11.43	7.37	**_-24.87	29	0.000	0.956	High
	Post-treatment.	28.36	2.33					
Section2	Pre- treatment.	10.43	7.62	**_-18.36	29	0.000	0.921	High
	Post-treatment.	22.60	5.26					
Total of Dimensions	Pre-treatment.	20.14	4.75	**_-35.62	29	0.000	0.978	High
	Post-treatment.	49.26	4.14					

Note. **, significant at the 0.01 level (2-tailed)

Note. *, significant at the 0.05 level (2-tailed)

Hypothesis 2

The second hypothesis of the study predicted that there was a statistically significant difference (favoring the treatment group) between mean scores obtained by the participants of the treatment and the non-treatment groups on the post-performance on the test of English-speaking skills. Statistical analysis of the obtained data showed that the treatment group achieved a higher degree of improvement than the non-treatment group on this test as t-value (98.571) is significant at (0.01) level and beyond. Thus, the second hypothesis is confirmed. Table (11) below shows the data obtained to test this hypothesis.

To assess the effectiveness of the AI-powered program in fostering STEM college students' English-speaking skills, statistical analysis utilizing the eta-squared formula (η^2) was employed. The results, presented in Table (11), revealed a remarkably high eta-squared value of 0.994. This falls well within the category of a large effect, suggesting the AI-powered program has a substantial and positive impact on improving English-speaking skills among STEM college students.

Table (11)

Statistical analysis of data obtained by the participants of the treatment and the non-treatment groups on the post- performance on the English-speaking skills test with its scoring checklist $N=30$

Aspects of comparison	Group	Mean	Std. Deviation	t- value	df	Sig.	η^2	Effect size
Section1	Post-non-treatment	2.33	1.348	**29.338	58	0.000	0.937	High
	Post – treatment	11.20	0.961					
Delivery	Post-non-treatment	63.30	3.10	**69.858	58	0.000	0.988	High
	Post – treatment	176.00	8.28					
Language use	Post-non-treatment	47.03	1.43	**85.790	58	0.000	0.992	High
	Post – treatment	133.23	5.32					
Content	Post-non-treatment	47.30	1.99	**61.822	58	0.000	0.985	High
	Post – treatment	130.60	7.11					
Section2	Post-non-treatment	157.63	3.76	**97.056	58	0.000	0.994	High
	Post – treatment	439.83	15.48					
Total of Dimensions	Post-non-treatment	159.97	4.16	**98.571	58	0.000	0.994	High
	Post – treatment	451.03	15.63					

Note. **, significant at the 0.01 level (2-tailed)

Note. *, significant at the 0.05 level (2-tailed)

The positive impact of the AI powered program was not limited to just comparing the treatment and non-treatment groups. Analyzing the treatment group's performance itself revealed a significant improvement in their English -speaking skills Table (12) illustrates a substantial difference between their scores on the pre- and post-assessment of English-speaking skills (t-value = 102.730, significant at 0.01 level and beyond). This statistically significant difference indicates a great improvement within the treatment group. Further strengthening this finding, the eta-squared value (η^2) for this comparison is exceptionally

high at 0.994, which again falls under the category of a large effect. This reinforces the conclusion that AI-powered program has a powerful influence on fostering STEM students' English -speaking skills within the treatment group.

Table (12)

Comparison of pre- and post-test scores within the treatment group for the test of English -speaking skills with its scoring checklist ($N=30$)

$N=30$

Aspects of comparison	Group	Mean	Std. Deviation	t-value	df	Sig.	η^2	Effect size
Section1	Pre-treatment.	1.87	1.07	**36.571	29	0.000	0.956	High
	Post-treatment.	11.20	0.961					
Delivery	Pre-treatment.	62.77	3.50	**69.531	29	0.000	0.988	High
	Post-treatment.	176	8.28					
Language use	Pre-treatment.	46.80	2.73	**85.728	29	0.000	0.992	High
	Post-treatment.	130.60	7.11					
Content	Pre-treatment.	46.23	1.55	**63.676	29	0.000	0.984	High
	Post-treatment.	133.23	5.32					
Section2	Pre-treatment.	155.80	4.61	**98.413	29	0.000	0.994	High
	Post-treatment.	439.8333	15.47653					
Total of Dimensions	Pre-treatment.	157.67	4.74	**102.730	29	0.000	0.994	High
	Post-treatment.	451.03	15.63					

Note. **. significant at the 0.01 level (2-tailed)

Note. *. significant at the 0.05 level (2-tailed)

Discussion

The following discussion will compare the present study outcomes with what other literature has found, illuminating consistencies, and disparities, and outlining the broader implications of our study.

The study's design forms the basis for interpreting the findings.

The Technological Pedagogical Content Knowledge (TPACK) framework, Artificial Intelligence (AI), and Connectivism integrated in STEM programs at Minia University's Faculty of Education yielded significant advantages for enhancing students' Cognitive Academic Language Proficiency (CALP). The interdisciplinary and cooperative character of STEM education was well matched with connectivism, which stressed learning as a process of building networks and connections. Through making a wide variety of materials, knowledgeable communities, and peer networks more accessible, connectivism promoted the growth of a strong academic language and content comprehension. Students were especially well served by this networked learning strategy in keeping current with the most recent developments and many viewpoints in their disciplines (Siemens, 2005 and Downes, 2012).

Because it cohesively combined technology, pedagogy, and content understanding, the TPACK framework improved STEM education even more.

This strategy made sure that technology was not employed alone but rather smoothly included into the teaching and learning process, which improved the interest and comprehension of difficult ideas among the students. TPACK supported the use of technology to give students contextualized and relevant language learning experiences in the context of developing CALP, hence increasing student access to abstract scientific terminology and concepts (Mishra & Koehler, 2006).

A more dynamic and interesting learning environment was created by the combination of AI, TPACK, and connectivism. Using these cutting-edge teaching techniques, this study gave students the abilities and information required to succeed in both their academic and professional lives. Together with improving CALP, this integrated strategy also equipped students for the language and cognitive demands of the contemporary STEM workforce. Furthermore, the application of AI and technology in education promoted the acquisition of 21st-century abilities including critical thinking, problem-solving, and teamwork, which were crucial for success in the quickly developing sciences and technology (Chen et al., 2019).

Ultimately, the integration of AI, TPACK, and connectivism into this study provided STEM college students a thorough and innovative approach to advancing CALP. This strategy made sure that students got a comprehensive education that combined pedagogy and technology to improve learning results. Using these creative approaches, the AI powered program offered a unique educational program that satisfied the demands of contemporary students and equipped them for the prospects and problems of the future (Siemens, 2005; Mishra & Koehler, 2006 and Liu, Wang & Fang, 2021).

Post-intervention reflections and observations of participants' reactions provided valuable insights.

- These reflections highlighted several key themes that are crucial for understanding the impact of the intervention on STEM college students' Cognitive Academic English Language Proficiency (CALP):
- The increased level of engagement and motivation

among the participants. Students were notably more enthusiastic about the learning process, often expressing excitement about the interactive and dynamic nature of the AI-powered program.

- Participants reported a better understanding of complex scientific terms and concepts, attributing this improvement to the use of AI-generated images and infographics in the first part of the intervention. Most students expressed positive attitudes towards the use of AI in their learning process.
- Additionally, some participants expressed a desire for more diverse examples in the infographics and illustrations to cover a broader range of scientific terms and concepts. This feedback aligns with Luckin et al. (2016), who emphasized the importance of continuous improvement and customization in AI educational tools.

The interpretation of the findings with reference to the related literature (for and against)

This study provides insightful outcomes on the integration of AI in enhancing CALP among STEM students. The study's findings can be interpreted by comparing them with existing literature, highlighting consistencies and disparities, and outlining the broader implications.

Consistencies with Existing Literature

1. **Enhancement of Language Proficiency through AI:** The findings align with Liu, Wang, and Fang (2021), who demonstrated that AI-powered learning platforms significantly enhance academic English proficiency in STEM contexts. The use of AI in the present study facilitated personalized learning and immediate feedback, which are critical in language acquisition.

2. **AI and Personalized Learning:** Luckin et al. (2016) argued that AI can create highly personalized learning environments by adapting to individual student needs and learning styles. The AI-powered program in this study offered tailored instructional materials, which aligns with Luckin's findings on the effectiveness of AI in personalizing education.
3. **Engagement and Motivation:** The study's positive impact on student engagement and motivation corroborates with findings from Chen, Zou, Cheng, and Xie (2019), who noted that AI and interactive technologies increase student engagement through interactive and adaptive learning environments.
4. **Support for Non-native English Speakers:** García and Kleifgen (2018) emphasized the importance of tailored language support for emergent bilinguals. The AI program in the current study provided scaffolding and contextual learning, echoing García and Kleifgen's recommendation for context-specific language support.

Disparities with Existing Literature

1. **Technical Challenges and Accessibility:** Some studies, such as Li and Lalani (2020), highlight the technical challenges and accessibility issues related to AI implementation in educational settings. However, the current study did not report significant technical difficulties, possibly due to the targeted support and infrastructure available at Minia University.
2. **Teacher's Role and AI Integration:** Valdés, Kibler, and Walqui (2014) stressed the essential role of teachers in facilitating AI integration. The present

study found that while AI was effective, the teacher's role remained crucial for contextualizing and reinforcing learning, suggesting a more balanced view compared to the sometimes-overestimated autonomy of AI in the literature.

3. **Cultural Relevance of Content:** Some research, such as Cummins (2023), indicates that AI-generated content may lack cultural relevance. The present study addressed this by customizing AI-generated materials to fit the local cultural and educational context, resulting in a more effective learning experience.

Broader Implications

1. **Curriculum Design:** The study suggests that integrating AI into curriculum design can significantly enhance CALP among STEM students by providing personalized and context-specific learning experiences.
2. **Professional Development:** The findings highlight the need for professional development programs to train educators in effectively integrating AI tools into their teaching practices, as supported by Bybee (2023).
3. **Policy and Infrastructure:** There is a need for educational policy makers to invest in AI infrastructure and support systems to facilitate the integration of AI in education, aligning with the recommendations of the National Science Foundation (2023).
4. **Future Research:** Further research should explore long-term impacts of AI-powered learning on language proficiency and STEM education, considering diverse educational contexts and student populations.

In conclusion, the study provides valuable evidence on the effectiveness of AI in fostering CALP among STEM students, aligning with and extending existing literature. While demonstrating significant benefits, it also underscores the importance of addressing technical, cultural, and pedagogical challenges to fully harness the potential of AI in education.

Challenges

Though the AI-powered program used for fostering STEM college students' English cognitive academic proficiency introduces creative solutions, applying it presents some challenges

- AI programs usually focus on mechanics over content as they might prioritize grammar and vocabulary over understanding the scientific concepts and expressing them effectively. This was overcome through the researchers themselves as instructors of the program. They carefully provided continuous feedback on content, style, and level of thinking.
- Overreliance on AI programs can decrease students' motivation and engagement and a lack of the development of critical thinking skills. This was solved through incorporating interactive exercises, simulations, and discussions to enhance student engagement and critical thinking.

Limitations

The present study was limited to the following elements:

1. One college (Faculty of Education), recommending replicating it at other faculties that include the STEM program
2. One program (STEM program) at the Faculty of Education, Minia University.

Conclusions

A strong foundation is offered by the TPACK model for comprehending how to include AI into STEM student learning programs. Through addressing the points where content, pedagogy, and technology converge, instructors may design efficient, interesting, and customized learning environments that improve students' academic language ability. Because it cohesively combined technology, pedagogy, and content understanding, the TPACK framework improved STEM education even more. TPACK underlined the requirement of teachers possessing a thorough knowledge of how technology may be applied to improve instruction in particular subject areas. This strategy made sure that technology was not employed alone but rather smoothly included into the teaching and learning process, which improved the interest and comprehension of difficult ideas among the students. TPACK supported the use of technology to give students contextualized and relevant language learning experiences in the context of developing CALP, hence increasing student access to abstract scientific terminology and concepts (Mishra & Koehler, 2006).

Recommendations

- Educational institutions should think about including AI-powered programs, with the help of AI specialists, within their curricula to improve STEM college students' language skills and overall learning experiences.
- Teachers should receive adequate training to be able to fully use AI technologies in the creation of interesting and dynamic learning materials.
- Curriculum planners should include AI-driven resources and activities that concentrate on scientific terminology and contextual learning to promote students' academic language skills,

- AI programs should undergo ongoing evaluation to guarantee their efficacy and to make required changes depending on student performance and input.
- AI-powered interactive tests should be added to provide students with immediate feedback, point up areas for development and strengthen what they have learned.
- Blended learning models should be integrated with AI-powered tools with conventional classroom education to improve overall learning and offer a well-rounded approach
- Teachers should be provided with continuous chances for professional development so they can keep up with the recent advances in AI and their classroom applications.
- Rules and ethical issues for the application of AI in education should be provided to guarantee student data privacy and responsible technology use.
- Using AI to design gamified learning experiences that boost student motivation and engagement and make learning more fun and efficient.

Suggestions for further research

- A remedial program based on artificial intelligence and its impact on overcoming difficulties and common errors in academic language and the attitude towards it among STEM college students.
- AI as a catalyst for advancing academic English proficiency in STEM fields.
- Comparative analysis of traditional vs. AI-based methods in enhancing CALP for STEM students.
- The effectiveness of AI-powered language programs in supporting STEM students' academic success.
- AI Integration in STEM Curricula: Impact on Students'

cognitive academic English proficiency.

- Using AI to overcome language barriers in STEM education.
- Optimizing STEM education through AI-driven language proficiency programs.
- This study may be replicated with a larger and more diverse sample of STEM college students from different governates in Egypt.

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