Teaching English for STEM 1 & 2 courses at Faculty of Education, Assiut University: Investigating the possibilities and challenges

By

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Abstract

This study aims to explore the possibilities and challenges of teaching English for Science, Technology, Engineering and Mathematics (STEM) 1 & 2 courses at the Faculty of Education, Assiut University. The study adopts a mixed-methods approach, combining quantitative data from an online questionnaire administered to 150 STEM students through Google Forms and qualitative data from semi-structured interviews with 15 STEM English language instructors affiliated with many Egyptian universities, including Ain Shams University in Cairo, Zagazig University in Northern Egypt and Minia University (in Upper Egypt). The results reveal that both students and instructors perceive the STEM courses as beneficial for developing students' language skills, content knowledge and critical thinking abilities. However, they also face several challenges, such as insufficient time, resources and support, lack of alignment between the course objectives and the students' needs and expectations, and difficulties in integrating language and content. The study concludes with a suggested framework that includes some implications and recommendations for improving the quality and effectiveness of the STEM courses.

Keywords: STEM; STEM teacher education; English for STEM; language learning problems and challenges.

1. Introduction & Literature Review

STEM (Science, Technology, Engineering, and Mathematics) education plays a crucial role in preparing students for the challenges and opportunities of the 21st century. Effective STEM education relies on well-prepared and knowledgeable teachers who possess the necessary pedagogical content knowledge and instructional strategies specific to STEM disciplines. Research highlights the importance of integrating STEM content, pedagogical knowledge, and practical experiences into pre-service teacher education programs (Schneider et al., 2016). Effective programmes provide hands-on experiences, collaborative learning opportunities, and mentoring to develop STEM-specific teaching skills (Kelley & Knowles, 2016). In addition, many studies emphasize the need for teacher education programmes to integrate the STEM disciplines rather than treating them as separate entities (Bybee, 2013). Integrated approaches help teachers to understand the connections between STEM subjects and promote interdisciplinary teaching and learning (Sanders, 2009).

Ongoing professional development and teacher training programmes focused on specific STEM disciplines and emerging technologies enhance teachers' content knowledge and instructional strategies (Banilower et al., 2018). Such programmes promote inquiry-based learning, hands-on activities, and the use of real-world applications (Jennings & Rentner, 2006). Research suggests the importance of developing teachers' TPACK, which is the integration of technological knowledge, pedagogical knowledge, and content knowledge in STEM instruction (Mishra & Koehler, 2006). Preparing teachers to effectively integrate technology into their STEM teaching enhances student engagement and learning outcomes (Bingimlas, 2009).

Moreover, research emphasizes the significance of collaborative professional development opportunities, such as communities of practice, where teachers can share experiences, resources, and expertise (Shelton, 2021). Collaborative environments foster teacher learning, encourage innovation, and support the implementation of effective instructional strategies (Borko, 2004). Thus, effective STEM teacher education encompasses comprehensive preparation programmes, ongoing professional development, and continuous support systems. Integrating STEM disciplines, developing TPACK, and promoting pedagogical approaches specific to STEM education are essential components. Providing content-specific professional development, fostering collaboration and communities of practice, and offering mentoring and coaching

programs contribute to the continuous growth and effectiveness of STEM teachers. By investing in high-quality STEM teacher education, educators and policymakers can better equip teachers to inspire and prepare students for future STEM-related careers (Borko, 2004; Bingimlas, 2009; Sanders, 2009; Banilower et al., 2018; Shelton, 2021).

The integration of language and content has been widely advocated as an effective way of enhancing students' academic achievement and language proficiency (Coyle et al., 2010; Dalton-Puffer et al., 2014; Llinares et al., 2012). In this regard, Content and Language Integrated Learning (CLIL) has emerged as a popular pedagogical approach that aims to teach both subject matter and a foreign or second language through a dual-focused curriculum (Coyle et al., 2010). CLIL has been implemented in various educational contexts and levels, ranging from primary to tertiary education, and covering different disciplines, such as science, mathematics, history and art (Dalton-Puffer et al., 2014).

Teaching English for STEM 1 & 2 courses is a topic that has gained increasing attention in Egypt in recent years, as STEM subjects (science, technology, engineering and mathematics) are becoming more integrated and interdisciplinary. The aim of these courses is to help English language learners (ELLs) develop both their STEM knowledge and their language proficiency through meaningful interaction in the context of shared experience in the classroom. Thus, teaching English for STEM 1 & 2 courses requires teachers to adopt a creative and adaptable approach to their teaching styles that can leverage the assets that ELLs bring to STEM learning. By using instructional strategies such as PBL, scaffolding and differentiation, teachers can create classroom environments that can foster both STEM learning and language development in ELLs. However, there are also some challenges and opportunities that teachers need to consider when implementing these strategies, such as collaboration with other teachers, professional development, curriculum alignment and assessment practices.

One of the contexts where CLIL has gained considerable attention is Egypt, where the Ministry of Education has launched several initiatives to promote the integration of language and content in the curriculum. One of these initiatives is the introduction of English for Science, Technology, Engineering and Mathematics (STEM) courses in some universities, such as Assiut University. These courses aim to develop students' language skills and content knowledge in relation to

STEM disciplines, as well as their critical thinking and problem-solving abilities (El-Dakhs et al., 2019).

English language proficiency is essential for students pursuing careers in the STEM fields (Cheng, 2017). As English continues to be the lingua franca of scientific communication, it is imperative to incorporate English language instruction into STEM education to enhance students' academic and professional success (Flowerdew, 2016). Hence this research study aims to explore the possibilities and challenges associated with teaching English for STEM 1 & 2 courses at the Faculty of Education, Assiut University.

Teaching STEM English language courses in Egypt is a topic that has gained increasing attention in recent years, as the country seeks to improve its educational quality and competitiveness in STEM fields. This literature review aims to provide an overview of the current state, challenges and opportunities of teaching STEM English language courses in Egypt as part of STEM teacher education. It will also discuss some of the best practices and recommendations for enhancing the effectiveness and sustainability of this approach.

According to the World Bank (2018), Egypt faces a significant gap in STEM skills among its workforce, which hinders its economic growth and innovation potential. To address this gap, the government has launched several initiatives to reform its education system and promote STEM education at all levels, such as the STEM Schools Project, the STEM Teacher Education Project, and the STEM Higher Education Enhancement Project. These initiatives aim to improve the quality of STEM curricula, pedagogy, assessment and teacher training, as well as to increase the enrolment and retention of students in STEM fields, especially girls and underrepresented groups.

One of the key components of these initiatives is the integration of English language instruction into STEM courses, as English is widely recognized as the global language of science and technology. Teaching STEM subjects in English not only exposes students to the latest scientific knowledge and terminology, but also develops their communication, critical thinking and problem-solving skills, which are essential for their future academic and professional success. However, teaching STEM subjects in English also poses significant challenges for both teachers

and students, especially in a context where English is a foreign language and not widely used outside the classroom (Dalton-Puffer et al., 2014; Flowerdew, 2016; Cheng, 2017).

Some of the main challenges include:

- The lack of qualified and trained STEM teachers who are proficient in both English and their subject matter, as well as familiar with the pedagogical principles and methods of teaching STEM subjects in English (El-Deghaidy et al., 2017; El Nagdi et al., 2019).
- The lack of appropriate and adequate resources and materials for teaching STEM subjects in English, such as textbooks, labs, equipment, software and online platforms, which are often outdated, insufficient or inaccessible (El Nagdi et al., 2019; World Bank, 2018).
- The lack of alignment and coherence between the STEM curricula and the English language curricula, which often results in gaps or overlaps in content, skills and assessment (El-Deghaidy et al., 2017; El Nagdi et al., 2019).
- The lack of motivation and confidence among students to learn STEM subjects in English, especially those who have low levels of English proficiency or prior exposure to STEM education (El-Deghaidy et al., 2017; El Nagdi et al., 2019).

In conclusion, teaching STEM subjects in English is a promising approach to enhance the quality and competitiveness of STEM education in Egypt. However, it also requires careful planning, implementation and evaluation to ensure its effectiveness and sustainability. Further research is needed to explore the impact of teaching STEM subjects in English on students' learning outcomes, attitudes and aspirations.

2. Research Problem & Objectives

The STEM programme was launched at Faculty of Education, Assiut University, Egypt in the academic year 2021/2023. Based on the STEM regulations, the English courses taught to STEM students are interdisciplinary in nature, not traditional in the common sense. The first English course delivered to level 1 in the 1st semester is entitled ‘English for STEM 1’ (based on Co-craft

language routine), while the 2nd course which is taught in the 2nd semester is called 'English for STEM 2' (based on Collect & Display language routine). Each of the two courses draws on a STEM philosophy.

The English for STEM 1 course starts the process of STEM teachers learning how to teach the English language in the context of STEM. Teacher trainees experience and learn about models for integrating STEM content and STEM pedagogies with English language learning for themselves and for their future students (which is very challenging and needs much effort and hard work). English for STEM 2 continues this process, but focuses especially on the connections between language forms and functions (particularly in relation to labelling, describing and displaying in oral and written communication. Adapting Stanford's Understanding Language/SCALE (Stanford Center for Assessment, Learning and Equity)'s 2017 Design Principles for promoting mathematical language use for STEM (Zwiers et al., 2017), this course and all English for STEM courses: 1) support sense-making, 2) optimize output, 3) cultivate conversation, and 4) maximize meta-awareness. Each course adapts one math language routine for STEM.

The 2nd semester's focus routine is called "Collect & Display" in which student language used in pair, small group, and whole class discussions and problem-solving sessions (output) is documented and displayed visually as a foundation for developing STEM-specific communication. The purpose of this routine is to capture students' oral words and phrases into a stable, collective reference. Specific content and pedagogies discussed in English for STEM 2 are directly linked to other courses during this semester. The main purpose of this STEM education language routine is: (1) to write down students' oral language so it can be referred to later in class; 2) to use student English output to assist in developing STEM language; 3) the teacher writes down what students say in class using words, diagrams and pictures; 4) the language collected in class can be put into a visual display that is organized and connected to other STEM language; 5) this visual display can be revised and updated throughout the semester as students and teachers engage with other kinds of STEM language; 6) students' own language can be connected to new STEM language being taught in this class and others; and 7) this routine provides feedback for students in a way that increases sense-making while simultaneously supporting meta-awareness of language. The big ideas explored in the course represent a real

challenge for Egyptian STEM student teachers because students are meant to use oral and written language (e.g. descriptive and analytical language, appropriate STEM terminology, English affixes, address common mistakes for Arabic speakers) and visual communication to collect, analyse and display data (about language, science, math, etc.) and not just read other people's data and their analyses.

Besides, learning how to use English to discuss patterns found in data, categorize the data, articulate predictions in English, and communicate about/display findings (about English language use, about STEM disciplines, and about Egyptian Grand Challenges) is an important part of becoming a STEM teacher in English. In addition, the course seeks to explore strategies for understanding STEM content (e.g. using semantic webs/concept maps), different approaches to data collection and the display of information across types of STEM inquiry -- in relation to Egypt's Grand Challenges tackled during this semester (Food & Nutrition and Climate Change & Sustainability in Egypt).

Thus, teaching English for STEM (1 & 2) is quite demanding and challenging for both instructors and students for many reasons:

1. There is no clear linguistic content like in all the other language courses taught at the university level. Besides, there is no direct language practice; without sufficient time for practice, students struggle to improve their reading, writing, speaking, and listening abilities, which are crucial for effective communication and instruction in the classroom.
2. The specific nature of the STEM philosophy which requires connecting the language course with the other STEM courses.
3. Limited focus on language skills: STEM education programmes primarily prioritize technical knowledge and skills, often neglecting the development of language skills. As a result, language courses are often considered secondary or less important, leading to a reduced emphasis on language proficiency among STEM teacher candidates. This limited focus hampers their ability to effectively communicate and explain complex scientific concepts to their students.

4. Inadequate pedagogical approaches used by instructors: although there are many modern pedagogical approaches suggested in STEM guidelines, many STEM teacher educators often rely on traditional teaching methods that are not tailored to the specific needs and interests of STEM teacher candidates. The lack of innovative pedagogical approaches, such as task-based learning or project-based instruction, can hinder engagement and fail to address the unique language challenges faced by STEM teachers in the classroom.
5. It is the first time for students to study a language course in this indirect, interdisciplinary fashion.
6. There is no sufficient training for teachers to enable them to teach this language course adequately and effectively.
7. The STEM goals are too ambitious to cope with the Egyptian environment and the educational background of both students and instructors.
8. The main focus of English for STEM 2 is to help students with acquiring knowledge and concepts for labelling, describing, and displaying data and graphs used in oral and written communication in STEM courses by noting various graphs they observe in their daily lives, including in brochures, commercials, social media, etc. and in subject courses.

Teaching English for STEM 1 & 2 courses at the Faculty of Education, Assiut University presents both possibilities and challenges. Incorporating English language instruction into STEM education can enhance students' communication skills, provide access to international research, and create global opportunities. However, challenges such as content-integrated language instruction, specialized vocabulary, and discipline-specific language skills need to be addressed to ensure effective language instruction in STEM courses.

However, despite the potential benefits of CLIL and STEM education, there is a scarcity of empirical research on how these courses are implemented and perceived by the stakeholders involved, especially in the Egyptian context. Therefore, this study seeks to fill this gap by investigating the possibilities and challenges of teaching English for STEM 1 & 2 courses at the Faculty of Education, Assiut University.

Therefore, the research problem can be stated as follows: *There is a need to investigate the challenges and effectiveness of teaching English for STEM courses at the Faculty of Education,*

Assiut University, Egypt. The interdisciplinary nature of these courses, combined with the need to integrate language learning with STEM content, poses several difficulties for both instructors and students. The problem encompasses the lack of clear linguistic content, limited focus on language skills development, inadequate pedagogical approaches, insufficient teacher training, and ambitious STEM goals within the Egyptian educational context. Understanding and addressing these challenges is crucial for improving the effectiveness of English language instruction in STEM courses and enhancing students' communication skills in the context of STEM education.

The study addresses the following research questions:

1. What are the students' perceptions of the benefits and challenges of learning English for STEM 1 & 2 courses?

2. What are the instructors' perceptions of the benefits and challenges of teaching English for STEM 1 & 2 courses?

3. What is a suggested framework that includes some implications and recommendations for improving the quality and effectiveness of English for STEM 1 & 2 courses?

The main intention of the study is to accomplish the following objectives:

1. Identifying the present problems and challenges associated with teaching English for STEM 1 & 2 courses at Faculty of Education, Assiut University.
2. Exploring students' perceptions of the benefits and challenges of learning English for STEM 1 & 2 courses.
3. Examining instructors' perceptions of the benefits and challenges of teaching English for STEM 1 & 2 courses.
4. Providing a working framework that includes some implications and recommendations for improving the quality and effectiveness of English for STEM 1 & 2 courses.

3. Method

The study adopts a mixed-methods approach, combining quantitative data from a questionnaire administered to 120 STEM students and qualitative data from semi-structured interviews with 15 STEM instructors. All participating STEM student teachers (n = 120) were in the 1st level, but their minor majors were represented in three specialisations: (1) Math (n = 50), (2) Chemistry (n = 45), and Biology (n = 25). The questionnaire administered to students consists of two sections: the first section contains 20 Likert-scale items that measure the participants' perceptions of the benefits and challenges of learning English for STEM 1 & 2 courses. The items were adapted from previous studies on CLIL (e.g., Lasagabaster & Sierra, 2009; Lorenzo et al., 2010; Pérez-Cañado, 2012). The questionnaire was validated by five experts in the field of English language instruction and applied linguistics and piloted with a sample of 20 students. The reliability coefficient (Cronbach's alpha) was calculated as 0.87. Along with the quantitative part of the questionnaire (see Table 1 below), it also included an open-ended part (the 2nd section) in which students were prompted to answer online the following questions as a type of feedback given by students after studying each of the two courses:

Table 1

The questionnaire administered online to STEM student teachers

Section 1: the quantitative part

Please read the statements below to indicate to what extent you **agree** or **disagree** with each by ticking ONE of the 5 boxes that best expresses your real attitude (Please tick **Undecided** if you cannot decide):

	Strongly Agree	**Agree**	**Undecided**	**Disagree**	**Strongly Disagree**
1. The STEM courses help me improve my English language skills.	❒	❒	❒	❒	❒
2. The STEM courses help me acquire new knowledge and concepts in STEM disciplines.	❒	❒	❒	❒	❒

	Strongly Agree	Agree	Undecided	Disagree	Strongly Disagree
3. The STEM courses help me develop my critical thinking and problem-solving skills.	❒	❒	❒	❒	❒
4. The STEM courses motivate me to learn more about STEM topics.	❒	❒	❒	❒	❒
5. The STEM courses increase my confidence and interest in using English.	❒	❒	❒	❒	❒
6. The STEM courses are relevant to my academic and professional goals.	❒	❒	❒	❒	❒
7. The STEM courses are well-organized and structured.	❒	❒	❒	❒	❒
8. The STEM courses provide sufficient time and opportunities for practice and feedback.	❒	❒	❒	❒	❒
9. The STEM courses use appropriate and varied materials and activities.	❒	❒	❒	❒	❒
10. The STEM courses are enjoyable and fun to learn.	❒	❒	❒	❒	❒
11. The STEM courses are too difficult and demanding for me.	❒	❒	❒	❒	❒
12. The STEM courses are too fast-paced and intensive for me.	❒	❒	❒	❒	❒
13. The STEM courses require too much homework and self-study from me.	❒	❒	❒	❒	❒

Section 2: the open-ended (qualitative) part

1- What are the main topics and sub-topics of the course?

2- What did the course add to your knowledge base in the area?

3-What are the things that you liked about this course?

4- What are the things that you disliked about this course?

5- In your opinion, how can you connect the knowledge/ideas you have got from the course to real teaching at STEM schools?

6- Please write here any comments or personal impressions about this course:

Moreover, some semi-structured interviews were conducted with 15 STEM instructors who had recently taught English for STEM 1 & 2 courses at some Egyptian universities. The interviews included a set of open-ended questions that elicited the instructors' views on the benefits and challenges of teaching English for STEM 1 & 2 courses, as well as their suggestions for improvement. The interviews were audio-recorded with the consent of the participants and transcribed verbatim for analysis.

Sample interview questions

Interviewer: Thank you for participating in this interview. We appreciate your time and expertise. We would like to gather your insights on teaching English for STEM 1 & 2 courses. Please feel free to share your thoughts openly. Let's begin:

1. *Can you briefly describe your experience teaching English for STEM 1 & 2 courses? How long have you been teaching these courses, and at what level (e.g., high school, university)?*
2. *In your opinion, what are the key benefits of integrating English language instruction with STEM subjects (Science, Technology, Engineering, and Mathematics)? How do these courses contribute to students' overall learning experience?*
3. *Are there any specific challenges or obstacles you have encountered when teaching English for STEM 1 & 2 courses? If so, could you please elaborate on them?*
4. *Do you believe that teaching English for STEM courses requires a different approach compared to teaching general English courses? If yes, how is it different? And what teaching strategies or methodologies have you found effective in this context?*
5. *How do you assess the progress and performance of students in English for STEM 1 & 2 courses? Are there any unique assessment methods or tools you find particularly useful in evaluating their language skills in STEM contexts?*
6. *In your experience, do you think students perceive the value of English language instruction in STEM courses? How do you encourage students to see the importance of language skills in their STEM education and future careers?*
7. *Have you observed any positive outcomes or achievements resulting from teaching English for STEM 1 & 2 courses? It could be related to student engagement, language proficiency, or any other aspect.*
8. *Are there any specific improvements or changes you would like to see in the curriculum or teaching materials for English for STEM courses? What suggestions do you have to enhance the effectiveness of these courses?*
9. *Are there any professional development opportunities or resources that you have found beneficial for enhancing your own teaching skills in the context of English for STEM education?*
10. *Finally, based on your experience, what advice or recommendations would you give to other instructors who are starting to teach English for STEM 1 & 2 courses? What key factors should they consider to ensure success in their teaching?*

Thank you again for your valuable insights. Your feedback will contribute to our understanding of the benefits, challenges, and potential improvements in teaching English for STEM 1 & 2 courses.

The quantitative data are analysed using descriptive statistics (mean and standard deviation) to identify the participants' level of agreement or disagreement with each item. The qualitative data are analysed using thematic analysis (Braun & Clarke, 2006) to identify the main themes and patterns that emerge from the interview transcripts. These main themes are reported in Table 3 below.

4. Results & Discussion

The results and discussion section of this research study presents the findings and analysis of the data collected from the students and instructors of English for STEM 1 & 2 courses. The data were obtained through online surveys and semi-structured interviews. The main research questions that guided this study are:

1. What are the students' perceptions of the benefits and challenges of learning English for STEM 1 & 2 courses?

2. What are the instructors' perceptions of the benefits and challenges of teaching English for STEM 1 & 2 courses?

3. What is a suggested framework for improving the quality and effectiveness of English for STEM 1 & 2 courses?

The first research question aimed to explore the students' views on how English for STEM 1 & 2 courses helped them develop their language skills and content knowledge in science, technology, engineering, and mathematics (STEM) fields. The second research question focused on the instructors' perspectives on how English for STEM 1 & 2 courses supported them in delivering the curriculum and facilitating the students' learning. The third research question sought to identify the strengths and weaknesses of English for STEM 1 & 2 courses and provide suggestions for improvement.

The results showed that both students and instructors perceived several benefits and challenges of learning and teaching English for STEM 1 & 2 courses. The benefits included enhancing the students' academic vocabulary, reading comprehension, critical thinking, and communication skills in STEM disciplines; increasing the students' motivation, interest, and confidence in learning English and STEM subjects; providing the instructors with a clear framework,

objectives, and materials for teaching English and STEM content; and fostering a collaborative, interactive, and learner-centred environment in the classroom. The challenges included coping with the high level of difficulty, complexity, and workload of English for STEM 1 & 2 courses; addressing the diverse needs, levels, and backgrounds of the students; balancing the integration of language and content; and overcoming the lack of resources, support, and training for teaching English for STEM 1 & 2 courses.

4.1 Students' Perceptions of the Benefits and Challenges of Learning English for STEM 1 & 2 Courses:

To explore students' perceptions, a survey was conducted among a sample of students enrolled in English for STEM 1 & 2 courses at the Faculty of Education, Assiut University. The survey questionnaire included questions related to the benefits and challenges of learning English for STEM courses.

4.1.1 Quantitative data results:

Here are the results of the first section of the questionnaire: i.e. quantitative data analysis of students' impressions about the courses (see Table 2 below).

Table 2

Mean scores and standard deviations of the questionnaire items

Item	Mean	Standard Deviation (SD)
1. The STEM courses help me improve my English language skills.	4.23	0.82
2. The STEM courses help me acquire new knowledge and concepts in STEM disciplines.	4.17	0.86
3. The STEM courses help me develop my critical thinking and problem-solving skills.	4.12	0.91
4. The STEM courses motivate me to learn more about STEM topics.	4.08	0.93

5. The STEM courses increase my confidence and interest in using English.	3.97	0.95
6. The STEM courses are relevant to my academic and professional goals.	3.92	0.98
7. The STEM courses are well-organized and structured.	3.85	1.01
8. The STEM courses provide sufficient time and opportunities for practice and feedback.	3.79	1.03
9. The STEM courses use appropriate and varied materials and activities.	3.76	1.05
10. The STEM courses are enjoyable and fun to learn.	3.72	1.07
11. The STEM courses are too difficult and demanding for me.	2.81	1.12
12. The STEM courses are too fast-paced and intensive for me.	2.76	1.14
13. The STEM courses require too much homework and self-study from me.	3.72	1.07

Perceived Benefits:

Items 1 to 4 (mean scores ranging from 4.08 to 4.23): STEM student teachers generally perceive positive benefits in terms of improving their English language skills, acquiring new knowledge and concepts in STEM disciplines, and developing critical thinking and problem-solving skills. These high mean scores suggest that the participants agree that the STEM courses are beneficial in these areas.

Items 5 to 9 (mean scores ranging from 3.76 to 3.97): The scores are still above the midpoint of the scale (3), indicating that the STEM courses are perceived to some extent as increasing confidence and interest in using English, being relevant to academic and professional goals, and providing sufficient time, opportunities for practice, and appropriate materials and activities.

However, the scores are slightly lower, suggesting that while these aspects are generally positive, there may be some room for improvement or variations in opinions among participants.

Item 10 (mean score of 3.72): STEM student teachers find the courses enjoyable and fun to learn, but the mean score is below 4, indicating that opinions on this aspect are somewhat mixed. Some participants might have found the courses enjoyable, while others may have had a different experience.

Perceived Challenges:

Items 11 to 13 (mean scores ranging from 2.76 to 3.72): These items represent the challenges perceived by the STEM student teachers in learning English for STEM courses. The scores are below the midpoint of the scale, indicating that the participants generally find the courses less demanding, fast-paced, and homework-intensive. However, the scores are still somewhat close to the neutral point, suggesting that there might be some differing opinions among participants regarding the level of difficulty and intensity of the courses.

Overall, the quantitative data from the questionnaire provides valuable insights into the perceptions of STEM student teachers regarding the benefits and challenges of learning English for STEM courses. The generally high mean scores for the perceived benefits indicate that the courses are positively received by the participants in terms of improving language skills, acquiring knowledge, and developing critical thinking. However, there are areas for improvement, as indicated by the slightly lower mean scores in some aspects and the mixed opinions on the courses' enjoyment.

In addition to the quantitative data stated above, the data collected through the open-ended section of the questionnaire revealed the following key findings:

4.1.2 Qualitative analysis: Benefits of Learning English for STEM Courses:

The qualitative results of the open-ended section of the questionnaire indicate the following benefits:

a) *Enhanced Communication and Collaboration Skills*: The majority of students recognized the importance of English language proficiency in improving their communication, collaboration and study skills. They acknowledged that learning English enabled them to effectively express their ideas and thoughts, both orally and in writing, thereby facilitating their ability to communicate complex scientific concepts to diverse audiences.

b) *Access to International Resources*: Students expressed that learning English provided them with the opportunity to access a wide range of international resources, including research papers, publications, and online platforms. This access to global knowledge enhanced their understanding of current advancements in their respective STEM fields.

c) *Academic and Career Advancement*: Students acknowledged that proficiency in English opened up academic and career opportunities for them. They recognized that English proficiency was necessary for participation in international conferences, research collaborations, and scholarship programs, ultimately contributing to their personal and professional growth. Teaching English for STEM courses can facilitate academic mobility for students, allowing them to participate in exchange programs and collaborate with international institutions. Proficiency in English enhances their chances of obtaining scholarships, internships, and research opportunities abroad. Furthermore, it prepares students for future careers in multinational corporations or organizations, providing them with a competitive edge in the global job market. Here are some excerpts copied from students' responses on the online questionnaire (open-ended section) via Google Forms that support the reached results:

> *1-In this course, I loved connecting language learning to global challenges such as climate change. I also liked the application of modern learning theories such as 1-flipped learning, which makes the student understand the title of the lesson in depth before studying it. 2- The theory of collection and display, which is very important to me because through it I acquired the skill of collecting intelligent information and how to display it in the best possible way.*
>
> *2-I liked the collaborative work, teamwork, participation, communication, knowledge of active learning strategies, and knowledge of graph types, and this helped me in knowing the use of technology and participation.*
>
> *3- This course added many things to my knowledge, such as (1) how to make a graph and how to name this graph through some keywords; (2) knowing the types of graphs and each type of them used for what purpose; (3) the difference between good and bad graphs; (4) new English words and linguistic notes that I did not know before,*

such as the difference between 'especially' and 'specially'. I also learned the answers to some questions related to climate change, such as how climate affects nutrition, what are the causes of climate change, why is it a serious problem, and how can we deal with these changes, etc. And I learned the strategy of think, pair, share and teamwork to produce a good product like what was done during the lecture to answer these aforementioned questions The above is the beginning of the individual thinking of each of us, leading to the sharing of what we have reached among all groups. I also learned the flipped classroom strategy and some information on how we can reduce our carbon footprint.

4.1.3 Challenges of Learning English for STEM Courses:

The qualitative results of the open-ended section of the questionnaire indicate the following challenges:

a) *Technical Vocabulary*: Many students reported facing challenges in acquiring and using specialized technical vocabulary relevant to their specific STEM disciplines. They expressed difficulties in understanding and using discipline-specific terminology, which affected their ability to comprehend scientific literature and effectively communicate scientific ideas.

b) *Language Demands*: Students highlighted the high language demands of STEM courses, including complex sentence structures, academic writing conventions, and scientific reasoning. They found it challenging to comprehend and produce advanced English language skills required for reading and writing scientific texts, in addition, some students expressed concerns about their fluency and pronunciation in English. They felt that their language skills might not meet the desired standards for effective communication, leading to self-doubt and potential barriers in expressing their ideas clearly.

c) *Time Constraints*: All students (n = 150) who did the online questionnaire (through Google Forms) reported that the duration of the lecture was short. The time constraints within the curriculum posed challenges in providing sufficient language instruction and practice opportunities. They emphasized the need for curriculum restructuring and increased contact hours to allocate dedicated time for language instruction without compromising the STEM content coverage. In addition, most of them (n = 120) reported that the language course was not direct like all the language courses they used to study. They expected more direct instruction that deals with vocabulary and grammar, for instance, rather than the STEM content-based language

currently delivered to them. Many students (n = 90) did not like the noise resulting from group interactions due to the nature of the STEM activities, which were mostly based on active learning and cooperative learning strategies. Furthermore, many students were not mature enough to do the activities without side talks and private conversations that were irrelevant with STEM work. Here are some excerpts copied from students' responses on the online questionnaire (open-ended section) via Google Forms that support the reached results:

> *1-I liked the collaborative spirit that was present inside the lecture and also thought of the display wall on which the interactive activities were presented I did not like the duration of the lecture because it would not allow me to practice the activities in sufficient time.*
>
> *2- I hope that the course will help me learn more things that make me a good STEM teacher who has a lot of useful information and strategies that are followed with the students in order to make them useful.*
>
> *3- The lecture is very interesting and we learn new things from it, but the problem is that the lecture time is short and the content is so large that we will not be able to take the full information at the time of the lecture.*
>
> *4- I feel like the course wasn't helpful enough for me as a teacher of STEM as I want to learn more about the English language that will benefit me in teaching math in the future or the language in general that will benefit me in teaching.*

4.2 Instructors' Perceptions of the Benefits and Challenges of Teaching English for STEM 1 & 2 Courses:

To gain insights into instructors' perceptions, in-depth interviews were conducted with experienced instructors (n = 15) who taught English for STEM 1 & 2 courses, and who were affiliated with many Egyptian universities. The interviews explored the benefits and challenges they encountered in their teaching experiences. The analysis of the interview data revealed the following findings (see Table 3 below):

Table 3

Illustration of interview results based on recurring themes

Theme	Frequency	Percentage (%)	Additional Information
Benefits:			
Enhanced Content Understanding	11	73.3	Instructors noted that integrating language instruction with STEM subjects helps students grasp complex concepts more effectively.
Interdisciplinary Collaboration	7	46.7	STEM English courses promote collaboration among students from different disciplines, fostering a holistic understanding of real-world problem-solving.
Professional Development	9	60.0	Instructors mentioned that teaching English for STEM courses improved their own language and STEM subject knowledge.
Problems & Challenges:			
Expertise in STEM and Language Instruction	14	93.3	Most instructors expressed challenges in balancing language and STEM content expertise while delivering effective instruction.

Theme	Frequency	Percentage (%)	Additional Information
Limited Resources and Materials	6	40.0	Some instructors cited a lack of suitable resources and materials tailored specifically for English language instruction in STEM fields.
Advanced Knowledge	8	53.3	Students with higher STEM knowledge often struggle to express complex ideas in English, requiring targeted language support.
New Instructional Strategies	5	33.3	Adopting innovative teaching strategies to engage students and facilitate language development posed difficulties for some instructors.
Collaborative and Teamwork	3	20.0	Encouraging effective teamwork among students from diverse linguistic backgrounds presented challenges for a few instructors.
Time Management Constraints	10	66.7	Limited lecture time in STEM courses made it challenging to cover both language and STEM content adequately.
Assessment Methods and Tools	10	66.7	Assessment methods and tools were new and challenging to students as they did not get used to them.

Theme	Frequency	Percentage (%)	Additional Information
Unique Assessment Methods	9	60.0	Instructors used various innovative assessment methods, such as project-based evaluations, to gauge students' language skills in STEM contexts.
Student Awareness of Language Importance	12	80.0	Instructors emphasized the significance of language skills for future STEM careers, motivating students to value English language instruction.
Positive Outcomes and Achievements			
Improved Student Engagement	6	40.0	STEM English courses were associated with increased student engagement, fostering active participation and discussion.
Enhanced Language Proficiency	10	66.7	Several instructors observed notable improvements in students' language proficiency as a result of English for STEM courses.
Curriculum and Teaching Materials	7	46.7	Instructors suggested developing more tailored curriculum and materials to cater to the unique needs of English for STEM education.
Beneficial Resources	8	53.3	Instructors found workshops and online resources valuable for enhancing their teaching skills in the

Theme	Frequency	Percentage (%)	Additional Information
			context of English for STEM education.
Key Success Factors	13	86.7	Experienced instructors emphasized the importance of balancing language and STEM knowledge, fostering student engagement, and using innovative teaching methods.

4.2.1 Benefits of Teaching English for STEM Courses:

a) *Enhanced Content Understanding*: Instructors acknowledged that teaching English for STEM courses helped them deepen their understanding of the STEM content. They highlighted how the process of explaining scientific concepts in English enhanced their own knowledge and allowed them to develop a more comprehensive understanding of the subject matter.

b) *Interdisciplinary Collaboration*: Instructors recognized the opportunities for collaboration and interdisciplinary interaction that teaching English for STEM courses provided. They reported engaging in collaborations with STEM faculty members to develop content-integrated language instruction, fostering a more holistic educational experience for students.

C) *Professional Development*: Teaching English for STEM courses offered instructors the opportunity for professional growth and development. They mentioned that integrating language instruction into STEM courses required them to continually update their teaching approaches and resources, enhancing their pedagogical skills.

4.2.2 Challenges of Teaching English for STEM Courses:

a) *Expertise in STEM and Language Instruction*: Instructors acknowledged the challenge of balancing their expertise in both STEM content and English language instruction. They

highlighted the need for on-going professional development to bridge the gap between the two domains and effectively integrate language instruction into STEM courses.

b) *Limited Resources and Materials*: Instructors expressed the lack of specialized resources and materials tailored to teaching English for STEM courses. They felt the need for more comprehensive textbooks, authentic scientific texts, and multimedia resources that catered specifically to the language needs of STEM students.

The results are presented according to the research questions. The mean scores and standard deviations of the questionnaire items are shown in Table 2.

Based on the results, several implications and recommendations were derived for improving the quality and effectiveness of English for STEM 1 & 2 courses. The implications included recognizing the importance and relevance of English for STEM 1 & 2 courses for preparing the students for their future academic and professional endeavours in STEM fields; acknowledging the challenges and difficulties faced by both students and instructors in learning and teaching English for STEM 1 & 2 courses; and providing adequate resources, support, and training for both students and instructors to enhance their language skills and content knowledge in STEM disciplines.

The recommendations included revising the curriculum, objectives, and assessment of English for STEM 1 & 2 courses to align with the student's needs, levels, and goals; providing more scaffolding, feedback, and differentiation for the students to cope with the high level of difficulty, complexity, and workload of English for STEM 1 & 2 courses; offering more professional development opportunities, guidance, and collaboration for the instructors to improve their pedagogical knowledge and skills in teaching English for STEM 1 & 2 courses; and increasing the availability, accessibility, and quality of resources, materials, and technology for teaching and learning English for STEM 1 & 2 courses.

The results and discussion section of this research study presents the main findings and implications of teaching English for STEM 1 & 2 courses at Faculty of Education, Assiut University. The study aimed to investigate the possibilities and challenges of integrating STEM content and language learning in these courses, which are designed to prepare pre-service teachers for teaching STEM subjects in English. The study employed a mixed-methods

approach, using questionnaires, interviews, classroom observations, and document analysis as data collection tools.

The results showed that both teachers and students had positive attitudes towards teaching and learning English for STEM, and perceived it as beneficial for their academic and professional development. However, they also faced several challenges, such as lack of adequate resources, time constraints, curriculum alignment, assessment issues, and language proficiency gaps. The study also revealed some best practices and suggestions for improving the quality and effectiveness of teaching and learning English for STEM, such as using authentic materials, collaborative activities, project-based learning, differentiated instruction, and formative feedback.

4.3 Suggested Framework

STEM subjects in English present unique challenges that require innovative solutions to ensure effective learning outcomes for students with diverse linguistic backgrounds. To address these challenges and elevate the quality of English-based STEM education, a comprehensive framework has been developed based on research findings and best practices. This framework outlines the fundamental requirements for successful implementation, explores effective instructional strategies, identifies areas for improvement, and offers practical recommendations for policymakers, educators, and researchers. By integrating language proficiency and subject matter knowledge, fostering collaboration, and tailoring language instruction to specific STEM disciplines, this framework paves the way for a transformative and inclusive approach to teaching English for STEM courses.

4.3.1 Basic requirements

To overcome these challenges and enhance the quality and effectiveness of teaching STEM subjects in English, several research results suggest some best practices and recommendations for policymakers, educators and researchers. Some of these include (see also Figure 1 below):

Figure 1

Basic requirements

1. Developing a clear vision and framework for teaching STEM subjects in English that is aligned with the national goals and standards of education, as well as the needs and expectations of stakeholders (see also El-Deghaidy et al., 2017; World Bank, 2018).
2. Providing adequate and continuous professional development opportunities for STEM teachers to improve their English language proficiency, subject matter knowledge and pedagogical skills for teaching STEM subjects in English (see also El-Deghaidy et al., 2017; El Nagdi et al., 2019; World Bank, 2018).
3. Developing and adopting appropriate and relevant resources and materials for teaching STEM subjects in English that are based on sound pedagogical principles and methods, such as inquiry-based learning, project-based learning, cooperative learning and differentiated instruction (see also El-Deghaidy et al., 2017; El Nagdi et al., 2019; World Bank, 2018).
4. Establishing a coherent and integrated curriculum for teaching STEM subjects in English that covers both content and language objectives, skills and assessment criteria (see also El-Deghaidy et al., 2017; El Nagdi et al., 2019).

5. Creating a supportive and engaging learning environment for students to learn STEM subjects in English that fosters their motivation, confidence and interest, as well as provides them with feedback, guidance and scaffolding (see also El-Deghaidy et al., 2017; El Nagdi et al., 2019).

4.3.2 Possibilities for English for STEM Courses Instruction:

One of the main instructional strategies for ELLs in STEM learning is *project-based learning* (PBL), which involves engaging students in authentic, real-world problems that require them to apply their STEM skills and language skills to find solutions. PBL can foster collaboration, creativity, critical thinking and communication among ELs, as well as enhance their motivation and interest in STEM subjects. PBL can also provide opportunities for ELs to use different modes of expression, such as oral, written, visual and digital, to demonstrate their understanding and share their findings. Some examples of PBL projects for ELs in STEM learning are designing a sustainable city, creating a video game or app, or investigating a local environmental issue.

Another instructional strategy for ELLs in STEM learning is *scaffolding*, which refers to providing temporary support and guidance to help students achieve a learning goal that they could not reach independently. Scaffolding can take various forms, such as modelling, questioning, feedback, graphic organizers, sentence starters or word banks. Scaffolding can help ELs access grade-level, content-rich, language-rich STEM learning opportunities by bridging the gap between their prior knowledge and the new information. Scaffolding can also help ELs develop their academic language skills, such as vocabulary, grammar, discourse and register that are essential for communicating effectively in STEM disciplines.

A third instructional strategy for ELLs in STEM learning is *differentiation*, which means adapting the curriculum, instruction and assessment to meet the diverse needs and abilities of individual students. Differentiation can help ELLs in STEM learning by providing them with multiple entry points, multiple ways of engagement and multiple ways of expression. Differentiation can also help teachers address the heterogeneity of ELs in terms of their language proficiency levels, cultural backgrounds, learning styles and preferences. Some examples of

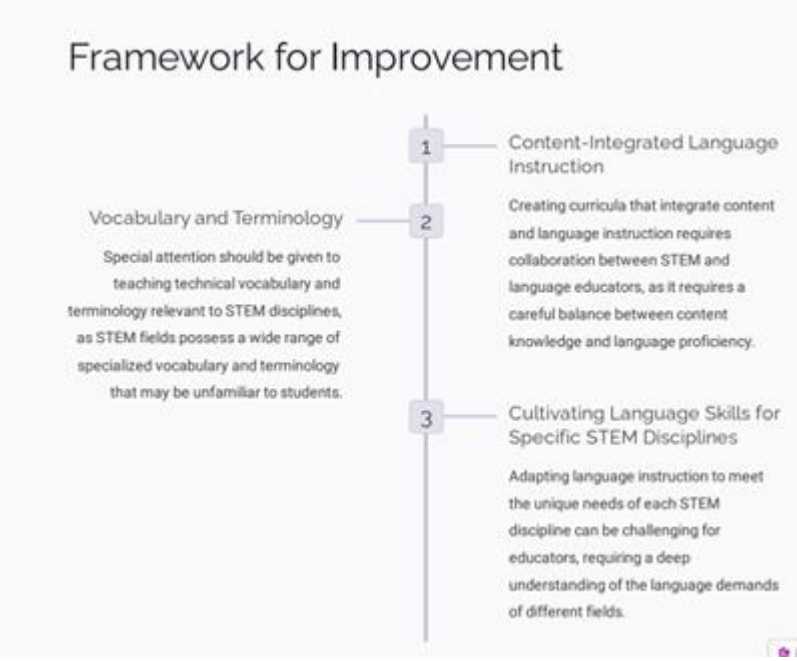
differentiation techniques for ELLs in STEM learning are tiered assignments, flexible grouping, choice boards or menus.

4.3.3 Framework for Improvement

The framework for improvement includes some suggested procedures that can be employed for enhancing the status quo of teaching English for STEM courses (see also Figure 2 below)

Figure 2

Framework for improvement



1. Content-Integrated Language Instruction:

Teaching English for STEM courses requires a careful balance between content knowledge and language proficiency. Educators must possess expertise in both the subject matter and English language instruction to effectively teach scientific concepts in English. Developing curricula that integrate content and language instruction can be challenging, as it requires collaboration between STEM and language educators.

2. Vocabulary and Terminology:

STEM fields possess a wide range of specialized vocabulary and terminology that may be unfamiliar to students. Teaching English for STEM courses requires explicit instruction and practice in technical vocabulary, ensuring students understand and can use subject-specific terminology accurately. Identifying and prioritizing key vocabulary items relevant to each STEM discipline is essential for effective language instruction.

3. Cultivating Language Skills for Specific STEM Disciplines:

Different STEM disciplines may require specific language skills. For example, while engineering students may focus on technical writing and presentations, biology students may require proficiency in scientific reading and data analysis. Adapting language instruction to meet the unique needs of each STEM discipline can be challenging for educators, requiring a deep understanding of the language demands of different fields.

4.3.4 Implications and Recommendations for Improving the Quality and Effectiveness of English for STEM 1 & 2 Courses:

Based on the findings, several implications and recommendations can be made to improve the quality and effectiveness of English for STEM 1 & 2 courses:

a. *Curriculum Design and Integration*: There is a need to develop well-designed curricula that integrate English language instruction with the STEM content. Collaboration between STEM and language educators is crucial to ensure the seamless integration of language learning within the STEM curriculum.

b. *Vocabulary Instruction*: Special attention should be given to teaching technical vocabulary and terminology relevant to STEM disciplines. Providing explicit instruction, practice, and resources can support students' comprehension and usage of subject-specific terms.

c. *Language Support*: Students' language fluency and pronunciation can be addressed through targeted language support initiatives such as pronunciation clinics, language labs, and conversation practice sessions. Providing opportunities for students to practice speaking and listening skills in a supportive environment can boost their confidence in using English.

d. *Professional Development*: Continuous professional development programs should be provided for instructors to enhance their language proficiency and pedagogical skills. Workshops, seminars, and online resources can assist instructors in integrating language instruction effectively and staying updated with the latest research in English for STEM education.

e. *Collaboration and Communication*: Enhancing collaboration between English language and STEM educators is essential. Regular meetings and workshops can facilitate the exchange of ideas, strategies, and resources, promoting a cohesive and integrated approach to teaching English for STEM courses.

F. *Resources and Materials Development*: Efforts should be made to develop and provide specialized resources and materials specifically designed for English for STEM courses. This includes textbooks, scientific articles, multimedia materials, and online resources that cater to the language needs of STEM students.

g. *Increased Contact Hours*: Allocating dedicated time for language instruction within the curriculum is essential to address the time constraints faced by both students and instructors. Increasing contact hours for English language instruction in STEM courses can provide more opportunities for language learning and practice.

5. Conclusion

In conclusion, the study revealed students' perceptions of the benefits and challenges of learning English for STEM 1 & 2 courses, as well as instructors' perceptions of the benefits and challenges of teaching these courses. The implications and recommendations emphasize the importance of curriculum design, vocabulary instruction, professional development, resources development, and increased contact hours to enhance the quality and effectiveness of English for STEM courses. By addressing these factors, institutions can better prepare students to excel in STEM fields by improving their English language proficiency and facilitating their academic and professional success.

Addressing these problems requires a holistic approach that recognizes the importance of language skills in STEM education. It is essential to provide dedicated time and resources for

language instruction, integrate language learning with STEM content, enhance the language proficiency of STEM teacher educators, employ innovative pedagogical approaches, and develop comprehensive language assessment strategies. By addressing these challenges, STEM teacher education programs in Egypt can better equip future STEM teachers with the necessary language skills to excel in their profession.

The research study highlighted the challenges and opportunities in teaching STEM subjects in English and provided a comprehensive framework for enhancing the quality and effectiveness of English for STEM courses. To overcome these challenges, policymakers, educators, and researchers are recommended to adopt specific strategies and practices.

Thus, a clear vision and framework for teaching STEM subjects in English was developed, aligning with national goals and educational standards. Adequate and continuous professional development opportunities for STEM teachers are essential to improve their English language proficiency, subject matter knowledge, and pedagogical skills. Additionally, appropriate and relevant resources and materials should be adopted, incorporating sound pedagogical principles such as inquiry-based learning and differentiated instruction.

Furthermore, a coherent and integrated curriculum covering content and language objectives, skills, and assessment criteria should be established. Creating a supportive and engaging learning environment for students fosters motivation, confidence, and interest in STEM subjects.

The study also identifies instructional strategies for English Language Learners (ELLs) in STEM learning, including project-based learning (PBL), scaffolding, and differentiation. These strategies can enhance collaboration, critical thinking, communication, and motivation among ELLs, promoting their interest in STEM subjects and language skills development.

The research study provides a comprehensive framework for improvement, emphasizing content-integrated language instruction, vocabulary and terminology instruction, and cultivating language skills specific to STEM disciplines. Recommendations for curriculum design, vocabulary instruction, language support, professional development, collaboration, resources

development, and increased contact hours are offered to improve the quality and effectiveness of English for STEM courses.

Overall, the research study offers valuable insights and practical recommendations that can guide policymakers, educators, and researchers in optimizing the teaching and learning of STEM subjects in English, ultimately contributing to better educational outcomes for students.

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