The Impact of Interactive Google Classroom on EFL Reading Comprehension and Visual Literacy Skills among STEM Freshman Students at Faculties of Education

A Research Paper

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ABSTRACT:

This study aimed at investigating the effect of utilizing interactive Google Classroom (IGC) on developing EFL reading comprehension and visual literacy skills of STEM freshman students at the Faculty of Education, Mansoura University. A purposive sample of first year STEM students (n= 21) were the target participants. The quasi-experimental approach using a pre- post administration to one treatment group design was adopted for achieving the purpose of the current study. Instruments designed and used were a checklist for identifying the target EFL reading comprehension skills, a checklist for determining the necessary visual literacy skills for STEM students, an EFL reading comprehension skills test, and a visual literacy inventory. Non-parametric Wilcoxon signed-rank test for dependent samples was used for data analysis. Results proved that the treatment group's post levels in reading comprehension and visual literacy skills were significantly higher than their pre-levels. These results demonstrated that the use of IGC had considerable potential in enhancing both EFL reading comprehension and visual literacy skills among STEM students.

Keywords: Google classroom, EFL, Reading comprehension, Visual literacy, STEM, Freshman students

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أثر فصل جوجل التفاعلي على مهارات الفهم القرائي باللغة الإنجليزية والتنور البصري لدى طلاب برامج تعليم العلوم والتكنولوجيا والهندسة والرياضيات (STEM) بكليات التربية

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ملخص الدراسة:

هدفت الدراسة الحالية إلى قياس أثر فصل جوجل التفاعلي على تنمية مهارات الفهم القرائي باللغة الإنجليزية والتنور البصري لدى طلاب برامج تعليم العلوم والتكنولوجيا والهندسة والرياضيات (STEM) بكلية التربية، جامعة المنصورة، وتم تبني المدخل شبه التجريبي باستخدام التطبيق القبلي- البعدي للادوات على مجموعة معالجة واحدة من طلاب المستوى الأول ببرامج STEM (ن=21) لتحقيق هدف البحث، وتم أيضا تصميم واستخدام أدوات البحث والتي تضمنت قائمة لتحديد مهارات الفهم القرائي باللغة الإنجليزية، وقائمة لتحديد مهارات التنور البصري اللازمة لطلاب برامج STEM، واختبار مهارات الفهم القرائي، بالإضافة إلى مقياس التنور البصري، وقد أدى استخدام اختبار Wilcoxon للعينات المرتبطة فى التحليل الإحصائى للبيانات الى اثبات أن المستوى البعدى لعينة الدراسة فى كلا من مهارات الفهم القرائي والتنور البصري أفضل من المستوى القبلى، وتؤكد هذه النتائج أن استخدام فصل جوجل التفاعلي له أثر كبير في تعزيز مهارات الفهم القرائي والتنور البصري لدى طلاب برامج STEM بكليات التربية.

الكلمات الدالة: فصل جوجل، مهارات الفهم القرائي باللغة الإنجليزية، التنور البصري، طلاب برامج تعليم العلوم والتكنولوجيا والهندسة والرياضيات (STEM).

Introduction:

It is well-known that today's youth are tomorrow's innovators and leaders. They are our *Generation Z* or *Post-Millennials*. They are our most diverse population group yet are considered to be digital natives. The nature of today's communication is overwhelmingly visual. Images, as modes of communication, play a dominant role in our daily activities and are especially prominent in the lives of young people. Today's students were born in image-saturated environments, the era of internet, digital technologies and touchscreens. Their communication practices are mediated visually, including photo and video creation and sharing, video chatting, and the visual language of emoticons, GIFs, and emojis. However, the moment students enter university classrooms, they are thrown into almost a completely textual world. Such highly textual context may cause an alienation from the course material and content. In consequence, contemporary millennial, and post-millennial generations, although usually technologically savvy, are often visually illiterate (Brumberger, 2011).

While Gen z students or digital natives are well-versed in the use of technology and born into image-saturated environments, their transition into university classrooms often exposes them to a predominantly textual learning environment. This disconnects between their visual communication practices and the textual nature of academia can lead to a sense of alienation from course materials and content. With this in mind, many students, despite their technological proficiency, struggle with visual literacy skills, including interpreting and evaluating images for effective communication. Faculty members often assume students possess competence in image production and critical evaluation due to their exposure to digital media. However, evidence suggests that students tend to be more proficient in dealing with words rather than visual imagery (Emanuel, Baker& Challons-Lipton, 2016; Kędra & Žakevičiūtė, 2019).

Since World War II, science, technology, engineering, and mathematics have been considered as vital knowledge and abilities that should be mastered by all citizens (both students and workers) and as a basis for national competitiveness. However, during the past two decades, several reports have pointed out current weakness of educational systems in different countries, especially in the developing countries, in helping students to understand how to solve real-world problems using knowledge gained through the study of science, technology, engineering, and mathematics (Bybee, 2013; National

Governors Association 2007). As a result, STEM educational reform has become a topic of discussion in political, economic, and educational circles around the world.

STEM is an acronym coined in the competitive and modern world and mostly refers to interdisciplinary science, technology, engineering and mathematics education. These four areas are entangled rather than separated into four disciplines because these skills, required in real world applications, are considered for success. STEM education mostly aims to support undergraduate level students in developing the skills needed for a STEM career, which responds to the need for competent professionals in the real world (Reeve, 2014).

STEM Education was originally called Science, Mathematics, Engineering and Technology (SMET) (Sanders, 2009), and was an initiative created by the National Science Foundation (NSF). This educational initiative was to provide all students with critical thinking skills that would make them creative problem solvers and ultimately more marketable in the workforce. It is perceived that any student who participates in STEM Education, particularly in the K-12 setting would have an advantage even if they chose not to pursue a post-secondary education or would have a greater advantage if they did attend college, particularly in a STEM field (Butz et al., 2004, White, 2014).

Undoubtedly, English has firmly established itself as the global language of technology. The professional world and the labor market in several fields force students to have not only technical competencies, but also a strong command of English, the lingua franca of science and technology today (Gimenoa, Seiza, Siqueiraa& Martínez, 2010). Therefore, STEM students need to have a good command of the English language in order to be efficient in reviewing scientific literature related to their content areas.

Students pursuing an education in science are in dire need to develop their individual reading potential and skill. STEM themes are to be included in the reading texts given to students, wherein, they learn to read and interact with text (what is written, how it is written and why). This active interaction with the words on the page will push the readers into the realm of effectiveness and they will be urged to develop more scientific dispositions towards their learning (Devardhi, 2020). “Meaning” implied within the text becomes more alive to them (Pearson, Moje & Greenleaf, 2010). Additionally, according to Cervetti et al. (2012) and Cervetti et al. (2009), high quality STEM reading material can optimize a student's "involvement in inquiry experiences, grasp of science concepts, and understanding the nature of science.

Diagrams can help students to visualize and understand abstract concepts while reading STEM subjects, which can promote student engagement and interest in these subjects, particularly for those who struggle with reading comprehension or language barriers in STEM subjects. It has been shown that visuospatial forms are important for learning within STEM subjects, and that the cognitive and psychological literature covers various key aspects of visualization and how it relates to teaching STEM subjects (Gates, 2018). Within science texts, the frequency of visualizations can reach 14 graphics per 10 pages (Roth& Bowen, 1999). Despite the frequency of use, students struggle to understand the information within visualizations due to experiential learning, incorrect student knowledge, and difficulties associated with the task (Krejci, Shirma, Hector& Raphael, 2020)

Regrettably, the current landscape of higher education overlooks visual literacy as a fundamental learning outcome, despite its undeniable significance for college students' success in coursework and research endeavors (Krejci, Shirma, Hector, & Raphael, 2020). Nevertheless, with the ever-growing prominence of technology within STEM fields, the importance of visual literacy is poised to escalate.

The use of artificial intelligence, virtual reality, and other emerging technologies will require STEM professionals to develop new visual literacy skills. As such, STEM educators must continue to find innovative ways to incorporate visual literacy into their curricula to prepare students for the future workforce.

Need for the research:

Science, engineering, technology and mathematics (STEM) courses rely extensively on visuals in lectures, readings and homework to improve knowledge. However, undergraduate students do not automatically acquire visual literacy and lack of intervention from instructors could be limiting academic success (Krejci, Shirma, Hector, and Raphael, 2020). As English is widely used in the instruction of STEM subjects, the students need to develop higher order analytical skills and also be able to communicate their findings or learning to the academic world of experts and laymen as well. Thus, the enhancement of reading skills will be the first step towards success in their individual scientific domains (Devardhi, 2020). Furthermore, tertiary education should take advantage of visual modes of knowledge and knowing by introducing at least some elements of visual literacy education across all disciplines (ACRL, 2011; Bleed, 2005; Felten, 2008).

Teaching visual literacy to STEM students can be challenging, primarily due to the technical nature of the subject matter. Additionally, many STEM students may not have prior experience with visual arts or design, making it difficult for them to develop visual literacy skills. Another challenge is finding the right balance between teaching technical skills and developing creativity and innovation. Accordingly, the need is urgent to develop STEM students' reading skills as well as their visual literacy skills in order to support them in their academic study and qualify them to be successful future teachers.

Statement of the problem:

The problem of the current study was identified in the need of first year STEM freshman students to develop their EFL reading comprehension skills as well as their visual literacy skills which greatly affect their success in STEM fields of study.

Questions of the research:

The current research sought to find an answer to the following main question:

What is the effect of IGC on both EFL reading comprehension and visual literacy skills among STEM freshman students?

The following sub-questions were also answered:

1) What are the EFL reading comprehension skills that should be mastered by STEM freshman students according to experts' viewpoints?
2) What are the visual literacy skills necessary for STEM freshman students at faculties of education according to experts' viewpoints?
3) What is the effect of IGC on EFL reading comprehension skills among STEM freshman students?
4) What is the effect of IGC on visual literacy skills among STEM freshman students?

5) What is the relationship between students' visual literacy skills and their EFL reading comprehension skills improvement?

Hypotheses:

The current research attempted to verify the following hypotheses:

1) There is a statistically significant difference at (≤ 0.05) level between the mean ranks of the treatment group students on the pre- and post- administrations of the reading comprehension skills test in favor of the post- administration of the test.
2) There is a statistically significant difference at (≤ 0.05) level between the mean ranks of the treatment group students on the pre- and post- administrations of the visual literacy skills inventory in favor of the post- administration of the inventory.
3) There is a positive correlation between students' visual literacy skills and the improvement in their reading comprehension skills.

Instruments:

The following instruments were designed and used in the current research:

1) An EFL reading skills checklist to specify the necessary skills that should be mastered by STEM freshman students. (Prepared by the researchers)
2) A visual literacy skills checklist to specify the visual literacy skills necessary for STEM freshman students. (Prepared by the researchers)
3) A reading comprehension skills test to measure the level of STEM freshman students' reading skills before and after the experimental treatment. (Prepared by the researchers)
4) A visual literacy skills inventory to measure the level of STEM freshman students' visual literacy skills before and after the experimental treatment. (Prepared by the researchers)

Purpose:

The present research aimed at:

1) specifying the reading comprehension skills that should be mastered by STEM freshman students.

2) identifying the visual literacy skills necessary for STEM freshman students in their field of study.
3) determining the effect of IGC on EFL reading comprehension skills among STEM freshman students.
4) determining the effect of IGC tasks on visual literacy skills among STEM freshman students.
5) determining the relationship between visual literacy skills and improvement of reading comprehension skills among STEM freshman students.

Significance:

It is hoped that the current research would contribute to:

1) directing the attention of EFL curriculum planners towards the importance of integrating IGC tasks as fruitful systematic means in EFL instruction in STEM programs at Faculties of Education.
2) helping EFL instructors to adapt their teaching practices to suit the requirements of developing the 21st century skills in their students through implementing IGC tasks in their teaching.
3) facilitating the Enhancement of Higher-Order Thinking Skills through the Development of EFL Reading Proficiency among STEM Freshman Students
4) helping STEM freshman students to develop their visual literacy skills in a way that helps them improve their academic reading skills and language proficiency.
5) attracting the attention of researchers in the field of EFL to GC as a powerful application that can be employed for developing language skills.

Delimitations

The current research was restricted to the following delimitations:

1) Seven reading comprehension skills identified through the reading skills checklist.
2) Seven domains of visual literacy skills specified through the visual literacy skills checklist.

3) A purposive sample of first year STEM students (N= 21), Faculty of Education, Mansoura University.

Definition of Terms:

Interactive Google Classroom (IGC):

Google Classroom is a free educational service provided by Google for facilitating instruction delivery, creating, distributing, and grading assignments in a paperless way. Interactive Google Classroom provides various interactive features that support the teaching/learning process. Learners can interact with multiple content types such as Video clips, PowerPoint presentations, PDF files, Word documents, and website URLs. They can communicate and discuss topics covered in class, and teachers can observe student discussion and written comments. IGC enables teachers to provide feedback efficiently, and communicate with their classes. It integrates many features of Google such as Google Drive for assignment creation and distribution, Google Docs, Sheets and Slides for writing, Gmail for communication, and Google Calendar for scheduling.

Reading comprehension:

Pardo (2004) defined reading comprehension as the process in which the reader interacts and constructs meaning from the text using the background knowledge and information included in the text (p. 272).

Reading comprehension is the process of analyzing information and integrating it with memory structure to create mental and dynamic representation of a text (Madden, 2004).

Reading comprehension is defined as the ability to understand a written text, elicit information and use background knowledge to reconstruct meaning. In order to reach the goal of reading to learn, students have to understand the meaning of the text; in other words, they have to read with comprehension (Vaughn & Edmonds, 2006).

Reading comprehension was operationally defined as a process of decoding the written text with all its linguistic and extralinguistic features, interacting with it and integrating the meaning with memory structure to create mental and dynamic representation of the text. STEM students' full comprehension is represented through the score they get on the reading comprehension test.

Visual literacy skills:

Wileman (1993) defines visual literacy as "the ability to 'read,' interpret, and understand information presented in pictorial or graphic images" (p. 114). Associated with visual literacy is visual thinking, described as "the ability to turn information of all types into pictures, graphics, or forms that help communicate the information" (Wileman, p. 114).

A similar definition for visual literacy is "the learned ability to interpret visual messages accurately and to create such messages" (Heinich, Molenda, Russell, & Smaldino, 1999, p. 64).

The Association of College and Research Libraries (ACRL) defines visual literacy in their 2011 publication ACRL Visual Literacy Competency Standards for Higher Education as "a set of abilities that enables an individual to effectively find, interpret, evaluate, use, and create images and visual media. Visual literacy skills equip a learner to understand and analyze the contextual, cultural, ethical, aesthetic, intellectual, and technical components involved in the production and use of visual materials" (ACRL, 2011). This definition by the ACRL was adopted as the operational definition in the current research since it perfectly fits the target purpose and the target skills required from STEM students.

STEM freshman students:

Shaughnessy (2013) defines STEM education as the solving of problems based on science and mathematics concepts and procedures that incorporate applied engineering strategies and use of technology. At the other extreme, Sanders (2009) defines it from a different approach that attempts to understand all STEM disciplines as a cohesive entity, whose teaching is integrated and coordinated via the resolution of real-world problems. Bybee (2013) considers STEM education as a spectrum that has an "interdisciplinary nature" in its nucleus, focused on the solving of real problems.

STEM freshman students are graduates of public secondary school, scientific section. They are student teachers enrolled in and admitted to the first grade of Science, Technology, Engineering and Mathematics programs (STEM) at the Faculty of Education, Mansoura University. They are specialized in Biology, Mathematics and chemistry programs. They got qualified to work in STEM high schools.

Review of Literature:

The following section sheds light on the main variables of the current study which are STEM education, the reading skills, visual literacy, and IGC.

The concept of STEM education translates to more than the subjects that make up the acronym (science, technology, engineering, mathematics). STEM education, in the larger view, is an *approach to learning* that emphasizes student-centered, collaborative learning. The interdisciplinary approach that STEM offers gives students the opportunity to make sense of the world in a more authentic way instead of learning about STEM through isolated and de-contextualized facts (Basham, Israel, & Maynard, 2010). It is these authentic experiences that promote meaningful engagement in real-world applications of learning. A STEM curriculum and teaching approach can create learning environments designed to engage *all* learners in *doing* STEM (Israel & Maynard, 2013).

STEM education and reading instruction should be considered closely related in supporting content-related literacy. STEM and reading both involve acts of inquiry through processes to discover, find out, and investigate (Cervetti, Pearson, Barber, Hiebert, & Bravo, 2007). Students who actively engage in both reading and STEM continually think through processes such as predicting, inferring, and questioning. In addition, because teachers usually present STEM content through nonfiction texts (including primary texts, reading textbooks, etc.), the ability to use reading and writing to acquire new content understanding is critical to students' success in STEM learning (Israel & Maynard, 2013).

STEM integration offers students one of the best opportunities for experiencing learning in a real-world situation, instead of learning fragments and then having to assimilate them at a later moment. Students, via STEM integration gain a deeper understanding of each discipline contextualizing concepts, widen understanding of STEM disciplines via exposure to socially and culturally relevant STEM contexts, and increase interest in STEM disciplines as channels are increased for students to read and survey huge amounts of research and articles (Martín-Páez& Aguilera, 2019). Consequently, developing reading skills is a necessary requirement for STEM students to be able to manage their academic tasks.

Undoubtedly, reading is the key to improving communication skills since students are encountered with a variety of vocabulary, syntactic structures and information while engaging in the reading process. The process of Reading is the process of constructing meaning from a text using both 'bottom-up' and 'top-down' approaches. Top-down approach involves using background knowledge to process or understand a text. The reader moves from larger concepts to smaller details. On the other hand, the bottom-up approach begins with the smaller details and works its way upwards. That means the reader initially focuses on individual words and then tries to connect them into patterns of understanding (Devardhi, 2020)

Reading is an effective process of rebuilding the information capacity of human beings, shaping ideas and beliefs, and acquiring personality. This process is an intellectual activity in which an individual's biological, psychological, physiological properties work collectively. Comprehension is the essential target of a reading activity (Epçaçan, Epçaçan& Ulas, 2010). Reading comprehension is an important skill and includes a range of multiple skills. Visualizing while reading is an engaging and enjoyable way to boost and get control of comprehension as well as increase retention. By creating mental images from words on a page, both verbal and visual-spatial representational systems are tapped making abstract concepts more concrete, meaningful and memorable (Canadian International School, n.d.).

Dawoud (2013) considers reading as essential to learning and the backbone for students' achievement across different school subjects. Also, there is no quality learning without quality reading instruction. In addition, Farrell (2009) points out that reading helps the learners in many ways; entertains, educates, communicates, and informs students about the past, the present, and even the future.

According to Harmer (2010), reading is very important for a variety of reasons such as; in the first place, many students want to be able to read texts in English either for their careers, for study purposes or simply for pleasure. Moreover, it is useful for the process of language acquisition. Additionally, reading texts also provides good models for English writing. Finally, reading texts provides opportunities to study language: vocabulary, grammar, Pronunciation, and constructing sentences, paragraphs and texts.

When designing curricula, the inclusion of general skills training such as reading and critical thinking is often overlooked, focusing instead on factual content and technical skill development. Students are typically provided with reading lists, with an inevitable chance of failure in considering whether they have the skills to engage with the materials listed. This is particularly true within STEM disciplines; scientific text is characterized by being written in the abstract sense, being very concept dense and using high levels of technical terminology (Fang, 2005). These conventions and ways of writing differ between the STEM disciplines. However, to develop the next generation of STEM graduates there is a dire need to pay more attention to how technical reading skills are being taught (Hubbard, 2021).

The association between reading comprehension and visual images can be explained by intellectual imagination theory which proposes to submit information providing organization from reading a text, association and revision of information by reconstructing it (Gambrell and Koskinen, 2001). The most important cognitive theory is double coding theory that was developed by Paivio (1971) explaining the relation between consisting visual imagination with reading comprehension, reading visual text and comments. Double coding theory considers both verbal and visual coding together and advocates that understanding in that ‘Learning’ actualizes by means of verbal and visual coding which is in interaction with it (Epçaçan, Epçaçan& Ulas, 2010).

In today's fast-paced digital age, visuals have become an essential aspect of communication. From social media to academic research, visuals have the power to convey complex ideas and concepts quickly and effectively. As STEM fields continue to grow and evolve, the importance of visual literacy skills has become increasingly evident. STEM students need to develop the ability to create and interpret visual representations of data and concepts to succeed in their fields (Ah-Namand& Osman, 2018). Visual literacy, together with critical thinking and other convergent information literacy skills, has become a significant talent in our technology-focused world. Nevertheless, many shortcomings still exist in this regard. Incredible as it may seem, EFL/ESL university students need to raise their critical awareness of how ideology shapes the verbal and visual communication modes (Kędra& Žakevičiūtė, 2019).

Especially now, in the digital age, it is inevitable to integrate dual form of information: picture and text, despite that finally everything is a picture since also text, when perceived by vision, is the part of visual literacy (Supsakova, 2016). Visual literacy and education lead to several advantages in language education: Visual elements provide better comprehension of texts, improve several types of verbal skills, increase students' interest and motivation, allow active presentation of certain content when compared to written texts, improve the organization of ideas, transform complex concepts to simple and meaningful concepts, and lead to permanent knowledge (Stokes, 2005; Duchak, 2014; Kaya, 2020).

Hodgdon (1995) illustrates the contributions of visual literacy in learning as providing a conscious interaction between reader and text, regaining learner's attention, strengthening describing and remembering words, motivating learners, providing quick learning in order to complete an assignment, rescuing from dependence in learning and increasing the chance of being independent learners, providing learning by describing subjects step by step. It is absolute that writing advocated with visual constituents enhances comprehension levels. Visuals in books are much more important in terms of students having reading problems.

Visual literacy is essential for 21st century learners and those who teach. It is critical that students develop skills to create and utilize visual illustrations to communicate and contribute to a global dialogue. Because most of our students have access to smartphone devices that have camera functionality, the integration of visual literacy into their education becomes paramount. Classrooms can become spaces for students to effectively communicate in and contribute to analytical and global dialogue for discussions of various disciplines. Scholarly work with images requires research, interpretation, analysis, and evaluation skills specific to visual materials. These abilities cannot be taken for granted and need to be taught, supported, and integrated into the curriculum (Lundy& Stephens, 2015; Mohammed, 2019).

Visual Literacy is a competency of interpreting visual messages properly as well as expressing readings by means of visual description and expression. Visual Literacy is an accomplishment of understanding, using images and indicators and expressing yourself with them (Epçaçan, Epçaçan& Ulas, 2010). A visually literate individual is both a critical consumer of visual media and a competent contributor to a body of shared knowledge and culture (*The Association of College and Research Libraries (ACRL), 2011*).

In an interdisciplinary, higher education environment, a visually literate individual is able to:

- Determine the nature and extent of the visual materials needed
- Find and access needed images and visual media effectively and efficiently
- Interpret and analyze the meanings of images and visual media
- Evaluate images and their sources
- Use images and visual media effectively
- Design and create meaningful images and visual media
- Understand many of the ethical, legal, social, and economic issues surrounding the creation and use of images and visual media, and access and use visual materials ethically (Arslan& Nalinci, 2014).

The visual literacy intervention shows promising results in improving student academic success and should be considered for implementation in other general education STEM courses (Krejci et al., 2020). The findings of Kleiman and Dwyer (1991) indicate that the use of color graphics in instructional modules promotes achievement, particularly when learning concepts. In addition, Kaya (2020) confirms that visual reading awareness education had a significant impact on the development of writing and verbal skills of middle school students. Teaching visual literacy to STEM students offers several benefits that can enhance their academic and professional careers. First, visual literacy can help students become better communicators. By learning how to create and interpret visuals, students can effectively convey complex ideas and data to a broader audience, including non-STEM professionals. Second, visual literacy can improve critical thinking skills. By analyzing and interpreting visual data, students can develop a more in-depth understanding of complex concepts and identify patterns and trends that may not be evident through text alone; leading to more innovative problem-solving and research outcomes. Third, visual literacy can help STEM students become better collaborators. Visuals can facilitate discussions and brainstorming sessions, allowing team members to visualize and share their ideas more effectively; resulting in a more efficient and effective collaboration, which is crucial in STEM fields where teamwork is essential (Gates, 2018; Kaya, 2020).

Todays' youth grow up in an increasingly globalized and digitalized world, where information and ideas are more accessible and distributed more widely, and in more forms, than ever before (Sturken & Cartwright, 2009). Online learning is changing the way teaching and learning is taking place on university campuses especially in the areas of content delivery, assessment and communication. However, new technologies will not fundamentally change the role of educators, but can have a major effect on how various teaching approaches can be applied in radically different technological and organizational environments. One of the prominent technologies that can be used to provide innovative learning/teaching online for supporting students' engagement and achieving their desired goals is Google Classroom.

Google classroom (GC) is a new tool introduced in Google Apps for Education in 2014. It is one of the popular e-learning platforms that have rapidly diffused into the education system worldwide. GC is a free educational web service that aims to simplify creating, distributing, and grading assignments in a paperless way. It enables teachers to provide feedback efficiently, and communicate with their classes with ease online or in a blended manner. Besides, it offers various pedagogical and technological features and is accessible to anyone with internet access. Like the physical classroom, a teacher can create a class for a course and invite other teachers and learners to join the class. Upon joining, they would all become members of the virtual class and can have immediate access and be connected (Sukmawati & Nensia, 2019 and Zakaria, et al., 2021).

An appealing factor for GC is being an interactive teaching tool that integrates many features of Google such as Google Drive for assignment creation and distribution, Google Docs, Sheets and Slides for writing, Gmail for communication, and Google Calendar for scheduling. Apart from its impressive educational and digital features, it is offered for free and can be used by any institution, specifically those with limited resources to set up their own Learning Management System. Further, learners can communicate and discuss topics covered in class, and teachers can observe student discussion and written comments through this learning application. Video clips, PowerPoint presentations, PDF files, Word documents, and website URLs can all be shared as assignments (Zakaria, et al., 2021 and Zuñiga-Tonio, 2021) .

Pappas (2015), Sudarsana, et al. (2019) and Susanti and Junining (2021) mentioned that there are several ways in which GC could be beneficial to both students and educators. The following advantages are listed:

- Easy to use and accessible from all devices: In addition to being easily delivered and being accessible from all computers, mobile phones, and tablets; it is really easy to add as many learners as possible, create Google documents to manage assignments and announcements, post YouTube videos, add links, or attach files from Google Drive.
- Effective communication and sharing: through Google Docs which are saved online and shared with a limitless number of people, it is possible to create an announcement or assignment and learners can access it immediately through their Google Drive, as long as it is shared with them. Besides, Google Docs are easily organized and personalized in Google Drive folders (Khalil, 2018).
- Speeding up the assignment process and saving time: Assignment process has never been quicker and more effective as in GC since it integrates and automates the use of other Google apps, including docs, slides, and spreadsheets; this makes the process of administering document distribution, grading, formative assessment, and feedback is simplified and streamlined (Iftakhar, 2016).
- Effective feedback: GC provides the opportunity to offer online support to learners right away; this means that feedback becomes more effective, as fresh comments and remarks have a great impact on learners' minds.
- Paperless: By centralizing eLearning materials in one cloud-based location, educators can easily go paperless and stop worrying about printing, handing out, or even losing learners' work.
- Clean and user-friendly interface: Staying loyal to clean Google layout standards, GC invites you to an environment where every single design detail is simple, intuitive, and user-friendly.

- Great commenting system: Learners can comment on specific locations within pictures for a variety of online courses. Furthermore, it is possible to create URLs for interesting comments and use them for further online discussion.
- Free and for everyone: GC is a free tool and educators can also join it as learners, which means that an educator can create a GC for him/herself and colleagues and use it for faculty meetings, information sharing, or professional development (Hamidah, Irmayanti & Afandi, 2022).

Google Classroom, consequently, offers many advantages over the traditional classroom teaching style. The most influential advantages lie in its accessibility, students' scheduling flexibility, and adaptability for working. It promotes the achievement of specific functions such as simplifying the students-teacher communication, and the ease of distributing and grading assignments. It allows the students to submit their work to be graded by their teachers online within the deadlines. Similarly, teachers can have a complete vision concerning the progress of each student, and they can return work along with the necessary comments so that the students can revise and modify their assignments.

However, Scragg (2018) mentioned that there are few reservations regarding using GC. For example, unique accounts for students should be created in order to keep a classroom completely private, which means remembering or forgetting new passwords. Although GC records student grades, it does not contain a full-fledged grade book; this requires exporting Google Sheets to universal database files compatible with other grade book apps. Moreover, Zakaria & Abd Manaf (2020), when investigating the advantages and difficulties in GC from the students' viewpoint, concluded that the difficulties were: hard to grasp, late or no teachers' response, no in-person association, unreliable connection and lack of management support. It was also emphasized that such difficulties did not drastically influence its usability if the students are familiar with the online stage and are ready to work around the limitation. Thus, GC would be an educational instrument that transforms technology into learning experience, provides an effective learning management system and constructs a successful online learning community.

Different research was conducted to examine the use of GC in education generally and for language instruction particularly. For example, Santos (2021) and Zuñiga-Tonio (2021) assessed the participants' use of GC and evaluated its acceptability as a tool of supporting flexible language learning and teaching. The respondents agreed that GC is very useful, easy to use and they would recommend its use to others. Several benefits were also mentioned including (a) easy monitoring of tasks, assignments, projects and announcements; (b) accessible storage of learning materials (ex. backup files); (c) motivating students to manage time; and to perform well.

In the field of teaching/learning English as a foreign language, numerous institutions tend not to be confined to the traditional teaching approaches through integrating language learning with modern technology especially with the start of the COVID-19 pandemic. GC is regarded as one of the highly recommended platforms that would bring positive effects on the teaching and development of the English language skills. Several studies were conducted to investigate its use for improving students' different language skills. The following part highlights this with a special focus on reading which the core of the current research is.

Abu Bakar & Noordin (2018) explored learners' engagement in GC activities in an ESL context at tertiary level. They assessed learners' engagement and perceptions regarding the GC activities in the Communicative English course. The study has shown that GC has a high potential to engage low English proficiency learners owing to its user-friendly features that make it easy, accessible, flexible and fun to use. With GC too, teachers can manage their classes better, keep track of students' progress easier, and most importantly be able to conduct classes anywhere and anytime. Supporting this, Sukmawati & Nensia (2019) emphasized that GC has an important role in English learning/teaching since students can focus on their discipline because the assignments have deadlines. Interaction between students and lecturer and between student and other students is also enhanced through private comments.

Furthermore, Albashtawi & Al Bataineh (2020) investigated the effect of using GC on the EFL reading and writing performance of diploma students in Irbid, Jordan, in addition to assessing their attitudes toward using it as an innovative online platform. Administering a reading and writing test and a questionnaire led to proving that GC improved the reading and writing performance of Syrian students. Students also showed positive attitudes toward using

GC in terms of its ease of use, usefulness, and accessibility. Consistently, GC led to enhancing the communicative reading skills for students in the fourth grade of secondary school in a study conducted by Gao-Chung, Salsavilca-Manco, Sotelo-Guadalupe, Guadalupe-Sifuentes & Diaz-Guadalupe (2020).

In addition, Al-Ewesat & Al-Ghzewat (2022) indicated that teaching with the use of GC platform had a positive effect on the development of reading skills in the Arabic language among third-grade students in the Directorate of Education in Karak. This was attributed to the fact that GC provides the opportunity for students to understand the text well, and to determine the semantics of words and styles, feelings and meanings contained in the text, which increases students' activity toward expressive reading and increases their self-confidence. Moreover, Khusnah, Anwar & Asmara (2022) indicated that the use of small group discussion in GC significantly influenced students' reading comprehension as GC made it easy to share whatever reading materials they wanted such as YouTube videos, notes, documents, and assignments.

Based on the previously mentioned review about reading comprehension, visual literacy, and GC, it can be concluded that real reading has to do with thinking, learning, and expanding the reader's knowledge and horizons. It has to do with building on past knowledge, mastering new information, and connecting with others' minds. In reading, readers, and especially STEM students, can also engage with images and visual materials across disciplines throughout the course of their education since they are required to think from different perspectives and create meaning from images. Being skilled in visual literacy enables those students to be stronger readers; the contrary is also true as reading improves their visual literacy skills. However, while STEM students are expected to read, understand, use, and create images in academic work, they are not always prepared to do so; these abilities cannot be taken for granted and need to be taught, supported, and integrated into their curriculum. The insertion or integration of technological developments in the learning process is highly recommended as learning can take place without being limited by space and time. IGC was selected, in the current research, to make reading learning activities more efficient, productive, creative, and to improve collaboration and communication; it has a high potential to engage low English readers owing to its user-friendly features that make it easy, accessible, flexible and fun to use, in addition to being easy for instructors to manage their classes better and successfully keep track of their students' progress.

Methodology:

The following section includes participants, design, instruments and the treatment procedures followed in the current research.

Participants:

Participants of the research were twenty-one (N= 21) students enrolled in the first year of STEM programs at Faculty of Education, Mansoura University. They were purposely assigned to be the treatment group. They studied their English course and were trained using the IGC activities. Students' age ranged between 18 and 19 years old. They had the same experience of learning English as a foreign language; starting from the first year at the primary stage. They constitute a homogenous group of students who graduated from the scientific section at the general secondary stage (math and science subdivisions). They were admitted to STEM programs according to their choices into Biology (n= 11), Mathematics (n= 4), and Chemistry (n= 6) programs. All in all, at the first level, all of them study the same courses as specialization begins at the second level.

Design:

The current research adopted the quasi-experimental approach using a pre- post administration to one treatment group design to investigate the effect of utilizing the IGC for enhancing the EFL reading comprehension and visual literacy skills of first grade STEM students at faculties of Education.

Instruments:

The following instruments were designed by the researchers and administered for achieving the purposes of the current research:

A. The EFL reading comprehension skills checklist

A checklist was designed for identifying the EFL reading comprehension skills necessary for first year STEM students at Mansoura Faculty of Education. The skills in the questionnaire were prepared based on reviewing literature related to STEM and reading skills. The initial form of that checklist was presented to some EFL specialists to check its validity and select the most appropriate skills for the target students. The checklist was also distributed to the target STEM participants in order to identify their reading comprehension needs. The purpose of the research was explained and clarified to those students before responding to the questionnaire.

Based on the EFL specialists' comments as well as the students' responses, some necessary modifications were made and the final list of the reading comprehension skills necessary for STEM students included the following:

1. Skimming
2. Scanning
3. Identifying the meaning of specialized terminology
4. Understanding the logical flow of ideas in a text or a visual display
5. Interpreting and analyzing visual displays
6. Evaluating
7. Summarization
8. Visualizing

B. The visual literacy skills checklist

A checklist was prepared for determining the visual literacy skills required from first year STEM students at Mansoura Faculty of Education. The checklist included various skills adapted from different sources based on reviewing previous literature related to visual literacy skills and STEM education. The main source of these skills was the ACRL Visual Literacy Competency Standards for Higher Education provided by the American Library Association (2011). The initial form of that checklist was submitted to some EFL specialists to check its validity and select the most appropriate skills for the target students. Based on the jurors' viewpoints, some necessary modifications were made and the final agreed upon visual literacy skills necessary for STEM students were as follows:

1. Understanding the nature of the visual displays
2. Finding and accessing needed graphs and visual media
3. Interpretation and analysis of images and visual media
4. Evaluating images and their sources
5. Using visual displays effectively
6. Designing and creating meaningful graphs and visual media

7. Considering the ethical, legal and social issues regarding the use and creation of visual media

The final version of the visual literacy skills checklist is presented in (appendix A).

C. The EFL reading comprehension skills test:

An EFL reading comprehension skills test was designed for: determining the participants' pre-and post-levels in the target reading comprehension skills. The test items were specified to ensure that each skill is addressed and measured. Some visual literacy aspects were considered in different test items. When stating the questions, it was also important to ensure that the texts are appropriate to the language level of the target students; and the instructions and wording of the test are explicitly and clearly stated to help the students' reach the correct response.

The EFL reading comprehension skills test consisted of two texts, seven items per text; thus the total test items were fourteen. All the test items are multiple choice questions except for items (7 and 14) that assess summarization and visualization. For these skills, the students were required to either transform a text into a visual display (visualization) or summarize a text with its graph in his/her own words (summarization). These two items, in particular, were scored in light of a 4-point scale rubric as the students had to respond with a qualitative output. Thus, the scores of those skills (max score is 4) are different from the other skills in which the maximum score is two marks for each single skill. The following table illustrates the specification of the reading comprehension test.

Table 1:

Specification table of the EFL reading comprehension test

Skills	Items	No. of questions	Marks
Skimming	1, 8	2	2
Scanning	2, 9	2	2
Identifying the meaning of specialized terminology	3, 10	2	2
Understanding the logical flow of ideas	4, 11	2	2
Interpreting and analyzing visual displays	5, 12	2	2
Evaluating	6, 13	2	2
Summarization	7	1	4
Visualizing	14	1	4
Total	**14**	**14**	**20**

To establish the validity of the test, it was presented to a number of TEFL specialists to evaluate the questions in terms of coverage of the target skills, appropriateness to the participants and clarity of the language used. The jurors provided their points of view indicating that the test measures the target reading comprehension skills and is appropriate for the target students.

The internal consistency and reliability of the EFL reading comprehension skills test were estimated through the test pilot administration conducted to (10) first year students from the chemistry section of the specific program, Mansoura Faculty of Education. Results of this pilot study were as follows:

Firstly, the correlation coefficient between the score of each sub-skill and the total score of the test was measured, and the results are shown in the following table.

Table 2:

The correlation between the score of each sub-skill and the test total score

Skills	**Correlation coefficient**	**Sig. level**
Skimming	0.86	0.01
Scanning	0.87	0.01
Identifying meaning of specialized terminology	0.88	0.01
Understanding the logical flow of ideas	0.9	0.01
Interpreting and analyzing visual displays	0.91	0.01
Evaluating	0.85	0.01
Summarizing	0.87	0.01
Visualizing	0.84	0.01

Table (2) illustrates that the correlation coefficients between the score of each sub-skill and the total score of the test are positive at 0.01 level which supports the valid internal consistency of the EFL reading comprehension skills test.

Secondly, the reliability of the test was also assessed by getting the value of (α Cronbach) which was 0.724. This indicates that the reading comprehension skills test is reliable and can be administered as one of the research instruments. The final version of the test is presented in (appendix B).

The time of the test was also calculated by getting the sum of time spent by all the students of the pilot study to complete the test and dividing it by students' number (10). Thus, 45 minutes would provide an appropriate time for the students to answer all questions.

D. The visual literacy skills inventory:

The visual literacy skills inventory was designed to measure the level of STEM freshman students' visual literacy skills before and after the experimental treatment. The inventory consisted of seven domains with thirty seven statements addressing the target seven visual literacy main skills previously determined; a 4-point Likert scale (1) poor, (2) developing, (3) good, and (4) professional) was used to reflect students' different levels. To assess how valid the inventory is, it was presented to a number of TEFL specialists to evaluate the statements in terms of their appropriateness and clarity. The jurors provided their points of view indicating that the inventory was clear and appropriate to assess students' visual literacy abilities.

The internal consistency and reliability of the visual literacy skills inventory were estimated through the inventory pilot administration to (10) students other than the main target group. Results of this pilot study were as follows:

Firstly, the correlation coefficient between the score of each domain and the total score of the inventory was assessed, and the results are presented in the following table.

Table 3:

The correlation between the score of each domain and the inventory total score

No.	Domains/ Skills	Correlation coefficient	Sig. level
1	Understanding the nature and extent of the visual displays needed	0.81	0.01
2	Finding and accessing needed graphs and visual media	0.8	0.01

No.	Domains/ Skills	Correlation coefficient	Sig. level
3	Interpretation and analysis of images and visual media	0.92	0.01
4	Evaluating images and their sources	0.93	0.01
5	Using visual displays effectively	0.904	0.01
6	Designing meaningful graphs and visual media	0.95	0.01
7	Considering the ethical, legal and social issues of using and creating visual media	0.834	0.01

The previous table shows that the correlation coefficients between the score of each domain and the total score of the inventory are positive at 0.01 level which supports the valid internal consistency of the visual literacy skills inventory.

Secondly, the reliability of the test was also assessed by getting the value of (α Cronbach) which was 0.896. This indicates that the visual literacy skills inventory is reliable and can be administered as one of the research instruments. The final version of the inventory is presented in (appendix C).

In addition, the time of the inventory was estimated by getting the sum of time spent by all the pilot students to complete the inventory and dividing it by students' number (10). Thus, 20 minutes would provide an appropriate time for the students to respond to the inventory.

The Treatment

Designing the proposed IGC-based training

The Proposed IGC training was designed based on the main phases of ADDIE instructional design model illustrated in the coming section.

ADDIE phases followed in the treatment were:

1. ***Analyze***: this phase included studying and analyzing the target linguistic needs of the participants. Reviewing literature related to STEM in addition to analyzing the reading skills checklist distributed to the target students to determine their reading revealed that STEM teachers need various reading comprehension and visual literacy skills (as listed earlier). They mentioned that such skills of reading comprehension together with visual literacy would enhance their imagination and strengthen their critical thinking skills.
2. ***Design***: this phase maps out the process of how learners will achieve the desired learning objectives. It included the procedures followed in the design of the proposed IGC training. These procedures started with identifying the main goals of that training, content design, materials design and methodology. These procedures are explained as follows:

   2-1. Target goals of the IGC training were identified as:

   - Developing the reading comprehension skills previously identified through administering a questionnaire aiming at analyzing and identifying the needs of STEM students.
   - Improving the visual literacy skills necessary for STEM students.

   2-2. Content: the content of the IGC training was presented in six modules other than the orientation module. The content included authentic reading comprehension texts with related visual displays in the various STEM fields (science, technology and mathematics) supported by using multiple interactive activities. For designing the content of the IGC training, certain criteria were taken into consideration:

- Learnability: organizing the content of each module in a gradual manner (starting with the simpler activities to the advanced interactive tasks).
- Readability: considering the appropriateness of the vocabulary and syntax which should be compatible with students' linguistic needs and levels.
- Coverage: incorporating the vocabulary and structures that have wider coverage in STEM students' specializations.
- Usefulness: focusing on the forms and skills of the language that are socially required and useful for the students.

2-3. Materials and experiences: authentic materials were employed in the design of the IGC training. The topics were carefully selected to cope with STEM students' different areas of study. GC was chosen to be the interactive medium for presenting the reading and visual literacy activities. Different media and online resources were employed through such a platform due to the facilities it provides for both the instructor and the students.

For the instructor: it helped to

- Start a video meeting.
- Create and manage classes, topics, assignments, and grades online without paper.
- Add materials to assignments, such as YouTube videos, internet links, a Google Forms survey, and other items from Google Drive.
- Give direct, real-time feedback.
- Use the class stream to post announcements and engage students in question-driven discussions.

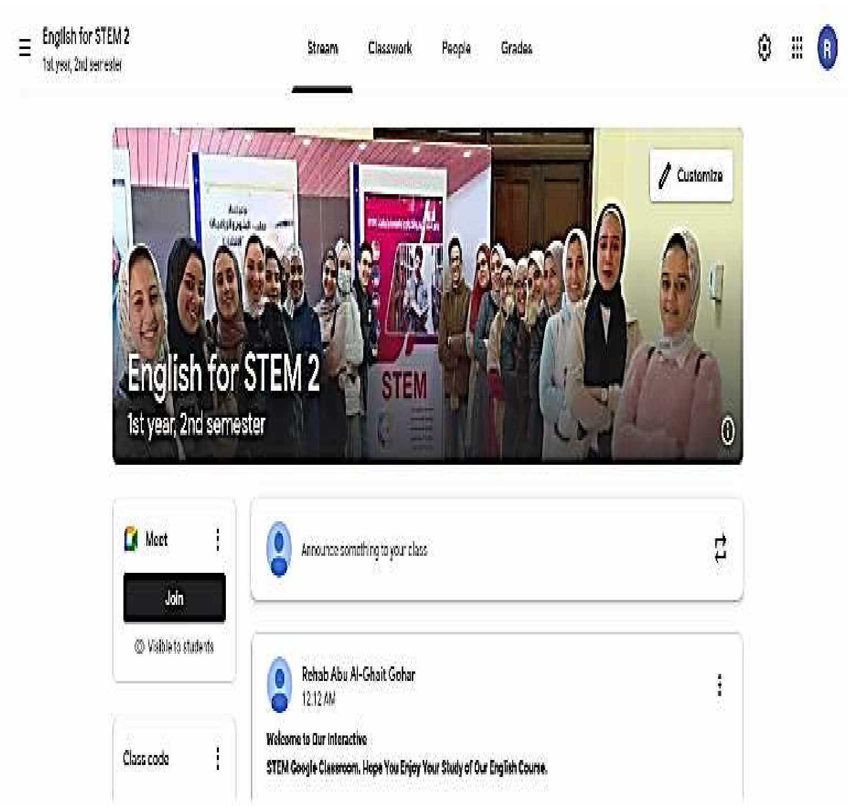
GC enabled students to:

- Track classwork and submit assignments.
- Check originality, feedback, and grades.
- Share resources and interact in the class stream or by email.

2-4. Methodology: different reading strategies were employed in the IGC training. Those strategies were grouped in pre-reading (previewing, activating prior knowledge, using graphs or figures, asking guiding questions and regulating the mood for the reading process), while-reading (skimming, scanning, taking notes, checking understanding, guessing meaning, using contextual clues and rereading) and post-reading (answering questions, summarizing, evaluating, interpreting, analyzing and visualizing).

3. ***Develop***: this phase included finalizing the design of the modules proposed IGC training (see appendix D). It also included the integration of GC for delivering instruction and training. The following figure presents the main page of the IGC designed for "English for STEM 2" freshman students at Mansoura Faculty of Education.

Figure 1: *Home page of the IGC*

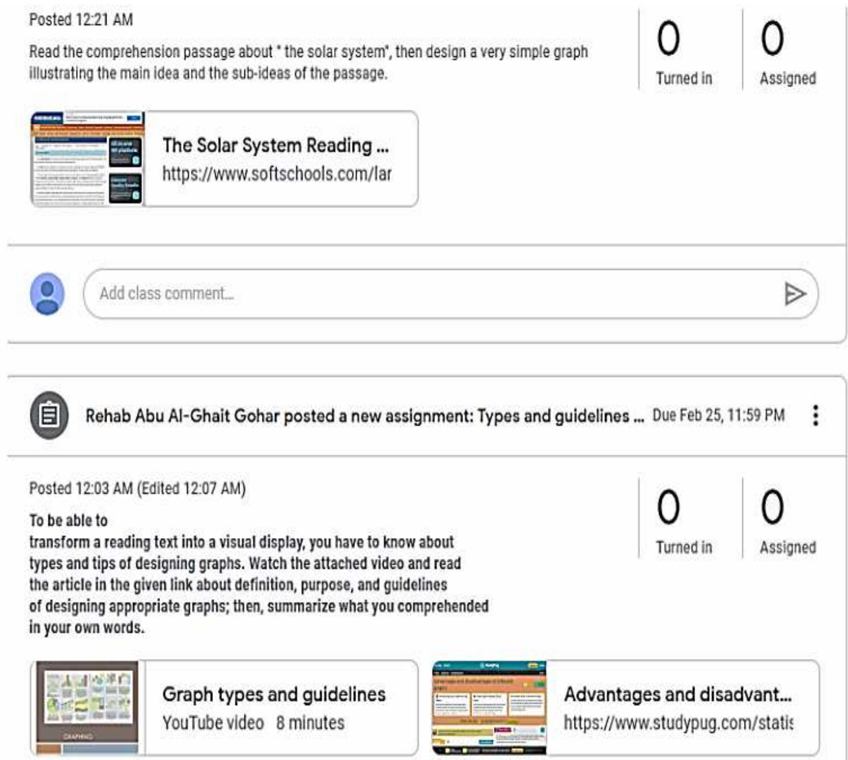


4. ***Implement***: implementation dealt with the actual delivery of the proposed IGC training to the students. This phase started

with pre-assessment of the target participant through **pre-administering the research instruments** (the EFL reading comprehension skills test and the visual literacy skills inventory) to reveal the students' actual levels concerning the target skills. The proposed IGC training was then implemented throughout the second semester of the academic year 2021/2023, through the following procedures:

- An orientation module was conducted to the target treatment group to raise their awareness concerning the IGC training; its objectives, features and phases of each module. Students were required to install the GC app to their mobiles or laptops and then join the class through the given class link or code. This module aimed also at familiarizing the students with the reading comprehension and visual literacy skills which are the target of the course.
- The students studied the main IGC modules following the pre-while-post strategies of teaching reading. The modules facilitated students' interaction with either the content, their peers or the instructor. Throughout the modules, students practiced multiple assignments and were exposed to various materials such as YouTube videos, internet links, a Google Forms survey, and other items from Google Drive. They received direct constructive feedback on their work and were able to track their progress and grades. The following figure presents a screenshot of the interactive assignments posted on the students' google classroom.

Figure 2: *Sample assignments on the IGC*



5. ***Evaluate***: this phase measured the efficiency of the IGC training. It consisted of:

- Formative evaluation, where students' interactions, performance and responses to the IGC assignments are continuously graded and evaluated and where instant feedback supported students' improvement of their reading skills.
- Summative evaluation, which focused on the overall effectiveness of the proposed IGC through **post-administering the research instruments.** The following part presents the related results of the pre- and post-administrations.

Results:

Testing the first hypothesis:

Non-parametric Wilcoxon signed-rank test for dependent samples was used to test the first hypothesis which is" There is a statistically significant difference at (≤ 0.05) level between the mean ranks of the treatment group students on the pre- and post- administrations of the reading comprehension skills test in favor of the post- administration of the test”. The following table illustrates the results.

Table 4:

Comparison between the treatment group's pre-post- administrations of the EFL reading comprehension skills test

Skills	Ranks	N	Mean Rank	Sum of Ranks	Z	Sig
Skimming	Negative Ranks	0	0	0	4.18	0.01
	Positive Ranks	20	10.5	210		
	Ties	**1**	**--**	**--**		
Scanning	Negative Ranks	0	0	0	4.07	0.01
	Positive Ranks	19	10	190		
	Ties	**2**	**--**	**--**		
Identifying meaning of terminology	Negative Ranks	0	0	0	4.3	0.01
	Positive Ranks	20	10.5	210		

Skills	Ranks	N	Mean Rank	Sum of Ranks	Z	Sig
	Ties	**1**	**--**	**--**		
Understanding the logical flow of ideas	Negative Ranks	0	0	0	3.99	0.01
	Positive Ranks	19	10	190		
	Ties	**2**	**--**	**--**		
Interpreting and analyzing visual displays	Negative Ranks	0	0	0	3.84	0.01
	Positive Ranks	18	9.5	171		
	Ties	**3**	**--**	**--**		
Evaluating	Negative Ranks	0	0	0	3.96	0.01
	Positive Ranks	19	10	190		
	Ties	**2**	**--**	**--**		
Summarizing	Negative Ranks	0	0	0	4.16	0.01
	Positive Ranks	21	11	231		
	Ties	**0**	**--**	**--**		
Visualizing	Negative	0	0	0	4.18	0.01

Skills	Ranks	N	Mean Rank	Sum of Ranks	Z	Sig
	Ranks					
	Positive Ranks	21	11	231		
	Ties	**0**	**--**	**--**		
Total	**Negative Ranks**	**0**	**0**	**0**	**4.04**	**0.01**
	Positive Ranks	**21**	**11**	**231**		
	Ties	**0**	**--**	**--**		

Results shown in the above table illustrate that the estimated Z-value is significant at 0.01 level for each particular skill and for the total score. This reflects the statistically significant difference between the mean ranks of the experimental group's pre-post-administrations of the EFL reading comprehension skills test in favor of the post-administration due to using the proposed IGC. Thus, the first hypothesis is proved and accepted.

The effectiveness level of the IGC in improving STEM students' EFL reading comprehension skills was also assessed through using Mac Gogian's equation. Results are presented in the following table.

Table 5:

The effectiveness levels of IGC in improving the EFL reading comprehension skills

Skills	Measurement	Mean	SD	Effectiveness
Skimming	Pre	0.81	0.402	%95.8
	Post	1.95	0.218	
Scanning	Pre	0.81	0.402	%91.6
	Post	1.9	0.301	
Identifying meaning of terminology	Pre	0.81	0.402	%88.24
	Post	1.86	0.359	
Understanding the logical flow of ideas	Pre	0.62	0.498	%86.23
	Post	1.81	0.402	
Interpreting and analyzing visual displays	Pre	0.62	0.498	%89.86
	Post	1.86	0.359	
Evaluating	Pre	0.43	0.507	%93.63
	Post	1.9	0.301	
Summarizing	Pre	1	0	%79.33
	Post	3.38	0.498	
Visualizing	Pre	1.24	0.436	%84.42
	Post	3.57	0.507	
Total	**Pre**	**6.33**	**1.354**	**%87.13**
	Post	**18.24**	**.700**	

The previous table shows that the effect levels range between 79.33% to 95.8% and is 87.13% for the total, which supports the high effectiveness of the IGC in improving STEM students' EFL reading comprehension skills.

Testing the second hypothesis

Non-parametric Wilcoxon signed-rank test for dependent samples was used to test the second hypothesis which is" There is a statistically significant difference at (≤ 0.05) level between the mean scores of the treatment group students on the pre- and post- administrations of the visual literacy skills inventory in favor of the post- administration". The results are illustrated as follows:

Table 6:

Comparison between the treatment group's pre-post- administrations of the visual literacy skills inventory

Domains	Ranks	N	Mean Rank	Sum of Ranks	Z	Sig
Understanding the nature and extent of the visual displays needed	Negative Ranks	0	0	0	4.06	0.01
	Positive Ranks	21	11	231		
	Ties	**0**	**--**	**--**		
Finding and accessing needed graphs and visual media	Negative Ranks	0	0	0	4.06	0.01
	Positive Ranks	21	11	231		
	Ties	**0**	**--**	**--**		
Interpretation and analysis of images and visual media	Negative Ranks	0	0	0	4.04	0.01
	Positive Ranks	21	11	231		

Domains	Ranks	N	Mean Rank	Sum of Ranks	Z	Sig
	Ties	**0**	**--**	**--**		
Evaluating images and their sources	Negative Ranks	0	0	0	4.07	0.01
	Positive Ranks	21	11	231		
	Ties	**0**	**--**	**--**		
Using visual displays effectively	Negative Ranks	0	0	0	4.04	0.01
	Positive Ranks	21	11	231		
	Ties	**0**	**--**	**--**		
Designing meaningful graphs and visual media	Negative Ranks	0	0	0	4.04	0.01
	Positive Ranks	21	11	231		
	Ties	**0**	**--**	**--**		
Considering the ethical, legal and social issues of using and creating visual media	Negative Ranks	0	0	0	4.05	0.01
	Positive Ranks	21	11	231		
	Ties	**0**	**--**	**--**		

Domains	Ranks	N	Mean Rank	Sum of Ranks	Z	Sig
Total	Negative Ranks	0	0	0	4.02	0.01
	Positive Ranks	21	11	231		
	Ties	0	--	--		

Table (6) illustrates that Z-value is significant at 0.01 level for each particular domain and for the total score. This reflects the statistically significant difference between the mean ranks of the experimental group's pre-post-administrations of the visual literacy skills inventory in favor of the post-administration due to using the proposed IGC. Consequently, the second hypothesis is proved and accepted.

Moreover, the effectiveness level of the IGC in enhancing the visual literacy skills was also measured through using Mac Gogian's equation. The following table presents these results.

Table 7:

The effectiveness levels of IGC in enhancing the visual literacy skills

Domains	Measurement	Mean	SD	Effectiveness
Understanding the nature and extent of the visual displays needed	Pre	4.67	0.73	%91.17
	Post	15	0.894	
Finding and accessing needed graphs and visual media	Pre	4.9	0.625	%91
	Post	15	0.775	
Interpretation and	Pre	6.43	1.165	%88.32

Domains	**Measurement**	**Mean**	**SD**	**Effectiveness**
analysis of images and visual media	Post	18.38	1.071	
Evaluating images and their sources	Pre	8.81	1.03	%81.87
	Post	24.52	0.981	
Using visual displays effectively	Pre	11.62	1.359	%89.25
	Post	29.81	1.123	
Designing meaningful graphs and visual media	Pre	7.9	0.768	%83.17
	Post	21.29	1.189	
Considering the ethical, legal and social issues of using and creating visual media	Pre	3.76	0.768	%79.73
	Post	10.33	0.966	
Total	**Pre**	**48.1**	**2.827**	**%86.32**
	Post	**134.33**	**3.864**	

Table (7) illustrates that the effect levels range between 79.33% to 95.8% and is 87.13% for the total, which supports the high effectiveness of the IGC in enhancing STEM students' visual literacy skills.

Testing the third hypothesis

The third hypothesis stated that "There is a positive correlation between students' visual literacy skills and the improvement in their reading skills". Spearman correlation coefficient was used to verify this hypothesis. The following table illustrates the value of the correlation coefficient and its significance.

Table 8:

Establishing the correlation between reading comprehension and visual literacy

Correlation coefficient	Reading comprehension	Relation direction	Relation strength	Sig. level
Visual literacy	0.848	Positive	Strong	0.01

Table (8) shows that there is a strong positive correlation between the students' scores in reading comprehension and their scores in visual literacy since the value of "r" (= 0.848) is significant at 0.01 level. Therefore, the third hypothesis is verified and accepted.

Discussion:

The current study attempted to investigate the effect of the interactive Google classroom on EFL reading comprehension and visual literacy skills among STEM students at the faculty of Education. The results revealed a statistically significant difference at (0.01) level between the mean ranks of the treatment group on the pre- and post-administrations of the reading comprehension test in favor of the post-administration. This means that STEM students' reading comprehension skills improved as a result of applying the interactive Google Classroom. Moreover, there was a statistically significant difference between the mean ranks of the treatment group on the pre- and post- administrations of the visual literacy inventory in favor of the post- administration. Consequently, this indicates that STEM students' visual literacy skills were enhanced as a result of implementing Google classroom interactive activities. Finally, the study highlighted a positive correlation between visual literacy and reading comprehension skills and that visual literacy can contribute much to enhancing reading scientific texts.

The present study provides evidence for the effectiveness of using GC in developing STEM students' EFL reading comprehension and visual literacy skills. The findings of the current study corroborate the previous relevant studies that investigated the effect of using GC on developing language skills; Abu Bakar & Noordin (2018), Albashtawi & Al Bataineh (2020), Gao-Chung, Salsavilca-Manco, Sotelo-Guadalupe, Guadalupe-Sifuentes & Diaz-Guadalupe (2020), Al-Ewesat & Al-Ghzewat (2022), and Khusnah, Anwar & Asmara (2022). The achieved results could be attributed to the benefits of incorporating interactive Google classroom in teaching, which is in fact an advanced electronic platform that allows for more interactive and engaging activities. It has very useful features that aid both teachers and students to achieve high levels of performance in the targeted skills.

Generally speaking, STEM students who participated in the study expressed their satisfaction with the interactive GC and its features; they found them different, encouraging, interesting, and challenging to a degree that ignited their motivation to learn and develop their reading comprehension and visual literacy skills. They were especially interested in the idea of relating visual features of texts to the full comprehension of scientific texts. Further, they were excited about surveying, analyzing, and designing visual illustrations that verify their full comprehension of the texts they read.

IGC was convenient and easy to access anytime and anywhere. The interactive activities offered a special attraction for the treatment students who used such a virtual class as a substitute for face-to-face classes. GC media facilitated students' interaction with the different reading materials in an organized manner through, for example, the "classwork" menu which grouped the files task files and material files. Through GC, the instructor as well as the students can send and share files, graphs and videos; in addition, all assignments, Google Docs, Sheets, and slides can be easily accessed. The feedback and comments given to the students in a formative style positively affected their performance and greatly motivated them. Asking students to change the reading texts into graphs and vice versa enabled them to visualize their thoughts and express their characters in a freely constructive manner which had a significant impact on their reading comprehension and visual literacy skills. Thus, GC facilitated a more purposeful and effective teaching/learning process by simplifying instruction delivery and assessment, increasing collaboration, and fostering communication.

Conclusion:

In conclusion, visual literacy is becoming increasingly important in STEM fields, where complex data and ideas need to be communicated accurately and effectively. STEM students must develop visual literacy skills to become better readers, communicators, critical thinkers, and collaborators. Incorporating visual literacy into STEM education can enhance learning outcomes and prepare students for their future careers. By embracing the power of visuals, STEM students can unleash their creativity and innovation and make a significant impact in their fields. Moreover, the insertion of an innovative technological tool such as GC in the learning/teaching process is highly recommended as learning can take place without being limited by space and time. GC is a free platform that enhances communication with students, organizing class events and materials, and keeping records. This simplifies the process and facilitates providing students with timely feedback that positively affects their performance.

Recommendations:

Based on the results of the current study, the following recommendations are suggested:

1. There should be much attention directed to orienting university students in general and STEM students in particular in visual literacy as it is an inevitable demand in the current digital era.
2. Reading skill instruction should be fostered in higher education across all disciplines as reading skill does not develop automatically. It is the gateway for students to acquire knowledge and access scientific materials needed in their course of study.
3. GC should be incorporated in instruction with other technological platforms and tools for the advantage of students, instructors, and the educational process in general.
4. Researchers should shed more light on STEM education and investigate various variables that can positively affect their achievement, language skills development, and their thinking.

Suggestions for further research:

In the light of results and recommendations proposed by the current study, the following research topics are suggested:

- The effectiveness of using GC activities in developing EFL academic writing skills of STEM students at faculties of Education.
- The effect of implementing the IGC in developing some affective variables of secondary STEM school students; especially autonomous and self-regulated learning.
- Investigating language problems of STEM freshman students at faculties of Education.
- A proposed training program based on digital tools for developing visual literacy skills of student teachers at faculties of Education.

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