Bulletin of Education and Research
August 2023, Vol. 45, No.2 pp. 67-92

The Impact of Multimedia-enhanced STEAM Activities on Foreign Language Learners' Development of Oracy Skills and Willingness to Communicate

Zeinab Hatami Nasab* and Mehrak Rahimi**

Abstract

The study explored the impact of multimedia-enhanced STEAM activities on English as a foreign language (EFL) learners' development of oracy skills and willingness to communicate (WTC) in an online course. The sample included 42EFL learners who were randomly split into two groups with 21 students in each. Before the study, both groups' listening and speaking proficiency was assessed by the listening and speaking modules of the IELTS test. Also, the WTC questionnaire was utilized to evaluate their WTC in English before the study. The experimental group received multimedia-enhanced instruction where the concepts of each domain of STEAM were taught by multimedia clips along the course. Meanwhile, the content was taught to the control group by conventional teaching materials of the textbook. The instruction was online and lasted for five months. Both groups' oral proficiency and WTC were assessed again after the study. One-way Multivariate Analysis of Variance method was used to analyze the collected data. The outcomes displayed a significant difference between the oral skills of the two groups and a non significant difference between their WTC after the treatment in favor of the experimental group. The practical significance of the results can be found in the tremendous potential of integrating STEAM curriculum with language teaching, particularly in technology-enhanced learning environments, for promoting students' interest in STEAM professions in countries like Iran that have a crisis in educating STEAM specialists. Follow-up studies on combining STEAM topics with teaching other subject matters using emerging technologies across different levels of education are recommended.

Keywords: Listening, multimedia, speaking, STEAM, Willingness to Communicate

* English Department, Faculty of Humanities, Shahid Rajaee Teacher Training University, Lavizan, 1678815811, Tehran, Iran. Email: z.hatami1374@gmail.com
** English Department, Faculty of Humanities, Shahid Rajaee Teacher Training University, Lavizan, 1678815811, Tehran, Iran. Email: rahimi@sru.ac.ir

Introduction

STEAM pedagogy (Science, Technology, Engineering, the Arts, and Mathematics), as an education initiative, combines the creative skills and understanding of the arts with hard sciences skills to raise students' interest in STEAM subjects at school while teaching them topics of more than one domain and enabling them to utilize multi-disciplinary knowledge to solve practical problems (Yang & Baldwin, 2020).The integration of the arts, as the inspiration for creativity and critical thinking (Yakman, 2008), into the curriculum, guides the students to gain the competencies of the 21st century (Stohlmann et al., 2011) and provides them with opportunities to become problem solvers, innovators, designers, and critical thinkers.

Despite its popularity, literature shows that students lose their interest in STEAM as they move along the curriculum. Educationists have examined the role of different types of programs or tasks to arouse interest in STEAM topics (e.g., Wegner et al., 2014). One line of research in STEAM education has focused on integrating technology into the curriculum to increase students' interest (Innes, 2020) and help them understand and practice various STEAM topics (Mayo, 2009). Despite generally favorable outcomes, the instructional advantages of implementing technology in STEM programs need further clarification (D'Angelo et al., 2014).

Considering the positive effect of multimodal input on learning gains, particularly in science classes, multimedia can be a suitable technology to be incorporated into STEAM programs. Instructional multimedia is evident to help learners understand the topics in a more efficient way as based on the multimedia principle "people learn more deeply from words and graphics than from words alone" (Mayer, 2014, p. 1). Multimedia increases learners' working memory capacity and helps them allocate more cognitive resources to information processing (Mayer, 2009). It makes the learning tasks less tedious and boring and increases students' interest and motivation in learning (Moreno & Mayer, 2007).

Another way to increase students' interest in STEAM topics is integrating STEAM education with various disciplines, including education policy, curriculum design, and teaching evaluation. This is often implemented in language education through content-based language instruction (CBLI). In this way, content is taught in a second language (L2) giving the content priority and thus making language learning a byproduct of learning the content. The content objectives are determined by course goals and students are evaluated based on their knowledge and competency of the content (Richards & Rodgers, 2014). The key role language plays in acquiring science and exchanging scientific knowledge cannot be denied (Yore et al., 2003). When science and language are taught together "educational success will come as a result of students learning the subject curriculum and associated language skills and literacies simultaneously" (Creese, 2005, p. 188). On the other hand, teaching STEAM topics in language classes makes language learning more authentic as the students embark on tackling real-world problems when they learn content and its associated language at the same time.

Despite the advantages of STEAM pedagogy, this approach has not gained considerable attention in curriculum design in the educational systems of many countries and teachers are not aware of the immediate and long-term benefits of the STEAM approach, particularly in countries like Iran where the education of sciences and engineering fields have become a major issue. Disappointingly, the interest of Iranian high school students in these disciplines has significantly dropped in recent years and the educational decline in hard sciences has reached a critical stage. Both national and international statistics are indicative of the gravity of the situation. Science and engineering fields are not the choices of top students and the capacities of many local universities that offer science courses are not completed (Aligholi, 2022). Iranian students do not achieve satisfactory results in international tests either and their scores are reported to be below the TIMSS scale center point (500) both in mathematics and science (https://timss2019.org/reports). These facts raise the alarm for immediate planning and action by the Ministry of Education to invest in integrated STEAM curriculums to boost students' motivation to select STEAM fields in high school and university and later as their profession.

However, due to the scarcity of research on the issue, the potential of the STEAM program is still unknown to many educators and policymakers. Empirical studies like the current one can provide educational planners with insight on how to take advantage of STEAM pedagogy to not only promote learning gains indifferent subject matters but also raise students' awareness of the value of STEAM domains and related careers. To help in resolving the issues of STEAM education both at local and global levels, this study was carried out to explore the influence of incorporating multimedia-enhanced STEAM activities into teaching English, as a school subject, on language learners' development of oral skills and WTC. The study seeks answers to the following research questions:

1. Do multimedia-supported STEAM activities impact EFL learners' development of oral skills (listening and speaking) in an online English course?
2. Do multimedia-supported STEAM activities impact EFL learners' WTC in an online English course?

Review of Related Literature

STEAM Education

STEAM was initially formed by structuring individual academic subjects into a well-designed framework to devise an integrative curriculum. Science in STEAM represents the knowledge of the natural world and its systematic study through asking wise questions, hypothesizing, and experimenting by applying standard science practices (Kelley & Knowles, 2016). Science in STEAM deals with various fields of study like physics, biology, chemistry, astronomy, geology, etc.

Technology in STEAM can be viewed from two common angles of engineering and humanities. The engineering view characterizes technology as using materials for making artifacts, tools, and equipment. The humanities view underlines the humanistic purposes of using technology and how people's preferences and needs give meaning to technology acceptance and usage (Kelley & Knowles, 2016). Merging these perspectives, technology is a vehicle to enable people to change and modify materials to meet human needs and wants (Hasanah, 2020). It is suggested that the standard content for students should provide them with plenty of instances of critical reflection on technology, disregarding it as an object, and thus making them technologically literate (International Technology Education Association, 2003).

Engineering in STEAM denotes the profession in which one learns to make a connection between mathematics and scientific principles to formulate and find solutions to engineering problems (Grasso & Martinelli, 2007). Engineering creates and promotes an understanding of the design, building, and use of engines, machines, and structures. Engineering knowledge plays an essential role in STEM education and is the key to subject integration in STEM that connects all four disciplines (Kelley & Knowles, 2016).

The arts in STEAM embrace a broad range of arts from language arts, and liberal or social arts to fine arts, physical arts, manual arts, and many others. Combining art with other components of the STEM approach is essential for the growth of students' creativity and contributes significantly to linking math and science to the requirements of the real world (Zarei et al., 2022).

Mathematics in STEAM deals with the science of patterns, relationships, formulas, and mathematical modeling. Mathematics is the basis of study skills and logical thinking and thus serves as a common language for understanding technology, science, and engineering (Dugger, 2010 as cited in Hasanah, 2020).

Keeping these five disciplines in mind, there are two definitions available for STEAM education, a traditional and a modern definition. In the traditional definition, STEAM is perceived as individual and isolated disciplines of science, technology, engineering, arts, and mathematics. This view delineates a discipline-specific educational model (Yakman, 2008). The newer and current trend underscores integrative STEAM education in which the five mentioned disciplines are merged purpose fully. In an integrative approach to STEAM, one discipline might be dominant, or all fields might be given equal attention (Yakman, 2008). Integrated STEM education is viewed as "approaches that explore teaching and learning between/among any two or more of the STEM subject areas, and/or between a STEM subject and one or more other school subjects" (Sanders, 2009, p. 21). In integrated STEM education, one, two, or all of the five mentioned disciplines are combined into one entity based on their internal kinks or their association with the problems of the world (Moore et al., 2014).

Literature on STEAM has probed into the effect of STEAM on both teachers and students. In the case of teachers, teachers' concerns and reservations about the STEAM curriculum with regard to the adaptability of STEAM lessons to local needs as well as the learning of those who experienced STEAM and those who did not were researched (Moon, 2015). Also, teachers' perceptions of STEAM (Kang, 2019) and possible changes in their perceptions and practices of STEAM as a result of training interventions (e.g., Herro& Quigley, 2017) or teaching experience (e.g., Moghal et al., 2020) have been researched. In a comprehensive review of the literature on the topic, Margot and Kettler (2019) found that while teachers appreciate the values of STEM education, they reported certain obstacles to STEM implementation including pedagogical (e.g., instructional practices and content), curriculum (e.g., flexibility) and structural (e.g., class scheduling) challenges. They also express particular concerns about students (e.g., motivation and learning gains), assessment (e.g., lack of formative and summative standardized tests), and lack of teacher support (e.g., peer collaboration, organizational support) in adopting the STEAM approach.

As for students, a majority of studies have researched the effect of STEAM on students learning gains and achievement. The result of most meta-analysis studies is indicative of a positive effect of STEAM on students' cognitive and effective learning (e.g., Kang, 2019). The impact of STEAM on students' learning motivation (Lin& Tsai, 2019), creativity (Wandari et al., 2018), and problem-solving skills (Erol & Başaran, 2022) is also evident. In this scheme, some researchers have probed into the reasons why students lose their interest in STEAM (e.g., Wegner et al., 2014) and the way students' motivation can be promoted to keep them engaged in STEAM classes and interested in the related careers (e.g., Innes, 2020). Integrating STEAM into the curriculum of other school subjects, particularly language, is one way to attain such a goal as "language industry is essential to expand and strengthen STEM fields and workforce" (Transparent Language, 2016, p. 3) due to the global nature of STEM business (Crum, 2022).

STEAM Pedagogy and Foreign Language Education

Integrating STEAM pedagogy into language curriculum is a response to internationalization of the education where the teaching of the content is expected to be carried out in multiple languages (Richards & Rodgers, 2014). It is suggested that incorporating STEM "as the connection discipline can help post-secondary language learners in STEM and non-STEM fields develop the ability to effectively communicate technical and scientific STEM content within global STEM markets" (Crum, 2022, p. 1).As for EFL, learning basic skills in English is better expressed in the form of engineering and technology (Hoffman & Zollman, 2016), and language learners' interest and motivation increase with their involvement in STEM activities (Lee & Stephens, 2020).

Integrating STEAM into the language curriculum would feed language learners with authentic materials and real-world issues and address students' needs in mastering the content knowledge and language materials (Sultana et al., 2021). STEAM assists language learners in using a patchwork of subjects taken from their daily lives instead of just fragmented knowledge (Apple et al., 2020). In this way, learners act more consciously in learning English by understanding their surroundings (LaCosse et al., 2020) bridged to science, technology, engineering, arts, and math.

Integration of STEAM pedagogy and language curriculum, however, demands attention to the interdisciplinary nature of STEAM education and instructional practices and approaches of language education (Schoettler, 2015). CBLI as a widely accepted and used model of integrating STEAM into language educationist built around the following principles (Richards & Rodgers, 2014, pp. 118-119): a second language is learned more successfully if the learners use the language as a device for learning the content; learners' needs are more reflected in a content-based instruction; and learning the content can activate the process of cognition and interaction that are critical for learning a foreign language.

A few researchers have embarked on empirical studies to examine the validation of theoretical propositions on the benefit of integrating STEM/STEAM with language teaching and learning. Fuhrman-Petersen (2013), for instance, examined the effects of a bilingual and multicultural STEM program on Thai students' English learning. The results showed that the participants' English literacy developed significantly as a result of STEM inquiry practices that encouraged communication in a democratic and collaborative atmosphere. In another study, Poese (2014) investigated the most effective ways to teach STEM vocabulary and register to non-native English speakers (NNESs). They reported that teaching discipline-specific vocabulary within a domain subject matter context was an efficient way of teaching vocabulary to adult NNES.

Bicer et al. (2015) examined the impact of STEM project-based learning methods to encourage interest in and grow the knowledge of students in the STEM disciplines. The participants included grade 8 students with different ethnic backgrounds enrolled in a summer camp. The result was indicative of a significant improvement in students' mathematical and scientific vocabulary knowledge. In the same vein, Ozturk (2021) investigated the effect of integrating STEM pedagogy with English language learning on grade 11 students' perceptions of English learning and their engagement in class activities. The results showed that while before the study the students showed low interest in English and had no knowledge of STEM, after the intervention they enjoyed the English lessons more, they scored higher and they felt more interested in STEM topics.

Tagnin and Ríordáin (2021) examined the discourse of a CBLI to understand how teachers' questions affect science content learning opportunities. The findings suggested that the strategic use of questions promoted both science understanding and language development. In a recent study, Duo-Terron et al. (2022) examined the impact of using STEAM on the linguistic and mathematical skills of Spanish primary school students. The results displayed that the transversal and coordinated use of STEAM improved the linguistic and mathematical competences of the students, particularly their speaking, oral comprehension, and calculation.

Multimedia Learning and STEAM Pedagogy

Multimedia refers to the content that is prepared by combining different media including text, audio, video, graphics, and animations. From a cognitive perspective, multimedia learning is reported to lower students' mental load as it allocates more resources to the working memory while the students are performing the task (Sweller, 2023). From a pedagogical standpoint, managing the cognitive load assists learners in understanding complex and difficult concepts more easily as the students become more engaged in the learning tasks and feel less overwhelmed by the input (Mayer, 2014).

The use of multimedia in the form of videos and films in science classes dates back to the mid-20th century. With the advent of digital technologies various multimedia forms and applications are now widely used in teaching different school subjects. As for sciences, videos ease access to concepts and ideas that are difficult or impossible to display and develop scientific literacy by providing the viewers with contextual examples (Pace & Jones, 2009). In this scheme, incorporating videos in STEAM pedagogy is an emergent research theme. The impact of videos on students' achievement and learning motivation in learning chemistry (Chang et al., 2018), their preferences for videos and type of feedback for learning physics (Ketsman et al., 2018), and their positive attitudes and low anxiety during learning mathematics (Huang et al., 2020) have been examined.

The COVID-19 pandemic seems to have triggered a gentle rise in research on the incorporation of videos into STEAM courses due to the prevalent use of online and virtual teaching and learning. To shed light on this issue, Breslyn and Green (2022) examined student and teacher use of YouTube videos for learning science during the COVID-19 pandemic. The findings showed that the students watched videos more considerably for learning science during the pandemic. However, most teachers' habits of using videos for teaching either did not change or even declined.

Huang et al. (2022) designed and implemented a video-facilitated transdisciplinary STEM curriculum during the COVID-19 pandemic. They used multi-modal video approaches including three disciplines of STEM, social service, and writing. The results indicated that students' transdisciplinary STEM knowledge as well as their empathy, interest, and self-efficacy improved significantly after the completion of the curriculum.

Karunia and Ridlo (2022) adopted a Research and Development method to examine the effect of flipped instruction (FI) combined with STEM to develop students' critical thinking skills amid the COVID-19 pandemic. Utilizing questionnaires, tests, and interviews they found that the developed tools including the syllabus, lesson plans, worksheets, and evaluation tools were rated as satisfactory with a feasibility rate of more than 80%. The result of the empirical study illustrated a significant effect of the STEM-integrated FI on students' critical thinking skills. Similarly, Zhu et al. (2022) examined the impact of short videos on students' academic performance in engineering college courses during the COVID-19 pandemic in a FI. Their result showed that short videos improved student engagement by 24.7% for the time of watching the videos and by 9.0%. for their final exam scores.

Amirinezhad (2022) incorporated digital storytelling into a STEAM curriculum to teach language and science literacy to school children in online courses at the time of the pandemic. The result showed that the students' comprehension and literacy skills improved, while their academic self-regulation did not show any growth as a result of multimodal input intervention. In the same vein, Sabeghi (2023) designed multimedia-enhanced warm-up activities for teaching reading in an integrated STEAM curriculum during the COVID-19 pandemic. It was found that multimedia presentations had significant effects on the development of language learners' comprehension and managing its associated cognitive load.

This succinct review shows that the literature on integrating STEAM, language education, and multimedia learning is scarce, particularly when oral skills are taught with instructional multimedia content in online courses. To fill this lacuna, the current study has focused on integrating multimedia-enhanced STEAM activities into teaching listening and speaking in an EFL context and examining its effect on language learners' development of oral skills and their WTC.

Method

Participants

The participants were 42 advanced EFL students aged between 20 to 22 years old in a university context. They enrolled in two conversation classes focusing on academic listening and speaking skills. The sample consisted of 28 male (67%) and 14 female (33%) students who were randomly split into two groups, i.e., experimental and control, with 21 students in each.

Instrumentation

To collect the data and answer the research questions, the following instruments and materials were used: IELTS listening and speaking modules, WTC questionnaire (WTCQ), multimedia clips, and the textbook.

IELTS test: The International English Language Testing System (IELTS) is an international standardized test of English proficiency for non-native speakers of English.

IELTS evaluates candidates' command of English in terms of listening, reading, speaking, and writing independently. For this study, IELTS speaking and listening sections were used as the pre-test and post-test to assess participants' listening and speaking proficiency before and after the study.

IELTS listening module: The IELTS listening test has four parts and 40 questions that assess candidates' listening skills with regard to the understanding of main ideas, detailed information, and speakers' purposes, opinions, and attitudes. Different question types and formats such as multiple-choice, sentence completion, matching, etc. are used (IELTS Guide for Teachers, 2019). The reliability indices of the listening paper were estimated by Cornbach's alpha and found to be .86 and .89 for the pre-test and post-test, respectively.

IELTS speaking module: The IELTS speaking test evaluates candidates' speaking skills in three parts to identify whether they can communicate effectively in English. The candidates are judged based on their fluent speech, lexical knowledge, accuracy and range of structure use, and pronunciation (IELTS Guide for Teachers, 2019). The intra-rater reliability of the speaking paper was estimated to be .87 and .91 for the pre-test and post-test, respectively.

Willingness to communicate questionnaire (WTCQ): The WTCQ is aimed to assess the participants' WTCin a given language (MacIntyre et al., 2001). The scale has 27 items clustered into four parts, i.e., speaking (8 items), reading (6 items), writing (8 items), and comprehension (5 items). The items are anchored on a 5-Likert-scale questionnaire ranging from 1 to 5 (1= almost never willing, 2= sometimes willing, 3= willing half of the time, 4= usually willing, and 5= almost always willing). The reliability of the scale was found to be .76 and .75 for the pre-test and post-test, respectively.

Textbook: The textbook utilized for the course was Viewpoint 2 (McCarthy et al., 2013). There are 12 units in this book, each of which has a specific theme that deals with the language, skills, and strategies students require to communicate competently in English (Table 1).

Multimedia: Twenty-four multimedia clips were adapted from YouTube for teaching topics related to STEAM based on the themes of Viewpoint 2. The lessons, their themes, and associated STEAM domains are presented in Table 1. As shown in Table 1, at least two STEAM domain-specific topics were included in each unit. For each unit, two multimedia clips were used to expand the topics of each domain.

Table 1
The Themes and Topics of Viewpoint 2 (McCarthy et al., 2013) and the Associated STEAM Domains

Unit	Theme	Topics	STEAM themes

1	A great read	Literature, reading habits, and favorite authors	The Arts, Science
2	Technology	Technology and its impact on life	Technology, Engineering
3	Society	Social pressures people face	The Arts, Science
4	Amazing world	Natural world	Science, Mathematics
5	Progress	Inventions, progress, and human achievements	Science, Technology, Engineering, The Arts
6	Business studies	Business and retail	Science, Mathematics
7	Relationships	Relationships, marriage, and family life	Science, Mathematics
8	History	People and events in history	The Arts, Science
9	Engineering wonders	Feats, challenges, and developments in engineering	Science, Technology Engineering, The Arts, Mathematics
10	Current events	News, who reports it, and how	Science, The Arts, Mathematics
11	Is it real?	Truthfulness of the information	Science, The Arts, Mathematics
12	Psychology	Being independent, the psychology of attraction, and the brain	Science, Technology

Research design

Pre-test-post-test control group design was utilized to perform this study. The participants were assigned into an experimental and a control group randomly and were pre-tested and post-tested on their oral proficiency and WTC before and after the instruction. As an empirical approach to research, experimental design utilizes a rigorous and objective procedure to detect casual relationships among the variables. The schematic representation of the design is shown below:

G1 Q1 T1 X Q2 T2

G2 Q1 T1 O Q2 T2

Where:

G1 stands for the experimental group
G2 stands for the control group
Q1 stands for WTCQ pre-test
T1 stands for IELTS pre-test
X stands for the treatment
O stands for no treatment
Q2 stands for WTCQ post-test
T2 stands for IELTS post-test

Procedure

Before the study, the participants of both groups took part in the IELTS test and completed WTCQ to assess their entry-level language proficiency and WTC.

Then, to create a STEAM-centered classroom, the researcher followed the six steps proposed by Riley (2016), including focus, detail, discovery, application, presentation, and link as briefly explained below:

1. Focus: The instructor selects a main question related to STEAM content to be answered or solved.
2. Detail: The teacher looks for what contributes to the problem or question. This requires activating students' background knowledge or experiences that help students talk about the question.
3. Discovery: The students work on known solutions and what is not working, based on the existing solutions. The teacher identifies what the students do not know and presents the required skills or knowledge.
4. Application: After students have digested the problem/question and have talked about the existing solutions/gaps, they may begin to develop their answers. They may utilize what the teacher has taught in stage 3, i.e., discovery.
5. Presentation: Once the students are sure of their answers/solutions, they have to share them with others. Feedback seeking is essential to help students exchange input/output.
6. Link: Students reflect on the received feedback and their solutions. Students can revise their work and give a better solution based on the feedback/reflection.

The content of the course was supported by multimedia clips for the experimental group, meanwhile, the control group had the conventional instructional materials (the textbook and workbook). Both groups were instructed via online teaching in the Learning Management System (LMS) of the academic center.

At the end of the course, both groups took part in IELTS speaking and listening papers and filled out the WTCQ as the post-test. The gathered data were inserted into SPSS 26.0 for further analysis.

Results

The impact of multimedia-enhanced STEAM activities on oral skills

To answer research question 1 and examine the effect of multimedia-enhanced STEAM activities on the development of oral skills, a one-way multivariate analysis of variance (MANOVA) was run, and IELTS speaking and listening post-test scores of the two groups were compared. As no violation of the assumptions, i.e., multivariate normality, linearity, multi-collinearity, and homogeneity of variances was observed (Pallent, 2020), the result of MANOVA was examined (Table 2).

Table 2

The Result of Multivariate Tests on IELTS Listening and Speaking Post-tests

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Group	Pillai's Trace	.145	3.295	2.000	39.000	.048	.145
	Wilks' Lambda	.855	3.295	2.000	39.000	.048	.145
	Hotelling's Trace	.169	3.295	2.000	39.000	.048	.145
	Roy's Largest Root	.169	3.295	2.000	39.000	.048	.145

As Table 2 shows, the difference between the control and experimental groups in combined dependent variables, i.e., oral proficiency, reached the significance level [Wilks' Lambda = .855; F (39) = 3.295; *p* = .048; partial eta squared=.145]. Therefore, Tests of Between-Subjects Effects were considered (Table 3).

Table 3

The Results of Tests of Between-Subjects' Effects

Source	Dependent Variable	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	Listening	440.381	1	440.381	5.394	.025	.119
	Speaking	36.214	1	36.214	6.742	.013	.144
Intercept	Listening	41990.095	1	41990.095	514.344	.000	.928
	Speaking	2545.929	1	2545.929	473.976	.000	.922
Group	Listening	440.381	1	440.381	5.394	.025*	.119
	Speaking	36.214	1	36.214	6.742	.013*	.144
Error	Listening	3265.524	40	81.638			
	Speaking	214.857	40	5.371			
Total	Listening	45696.000	42				
	Speaking	2797.000	42				
Corrected Total	Listening	3705.905	41				
	Speaking	251.071	41				

As Table 3 shows, upon checking the dependent variables independently, both differences were statistically significant, indicating that the control and experimental groups' listening and speaking post-test scores were different at the end of the experiment. Descriptive statistics of the participants' performance on the post-test are depicted in Table 4.

Table 4.
Descriptive Statistics of IELTS Post-test Scores Across Groups

Test	Group	Mean	SD
Listening	Experimental	34.857	7.391
	Control	28.381	10.423
Speaking	Experimental	8.714	1.927
	Control	6.857	2.651

As shown in Table 4, the experimental group outperformed (Mean = 34.857, SD= 7.391) the control group (Mean = 28.381, SD = 10.423) in the listening post-test. In the same vein, the experimental group outperformed (Mean = 8.714, SD= 1.927) the control group (Mean=6.857, SD=2.651) in speaking post-test.

The impact of multimedia-enhanced STEAM activities on WTC

To answer research question 2 and examine the impact of multimedia-enhanced STEAM activities on EFL learners' WTC, another one-way MANOVA was conducted and both groups' post-test scores on four parts of the WCTQ were compared. After testing the preliminary assumptions, the result of MANOVA was examined (Table 5). Based on Table 5, no significant difference between the control and experimental groups in combined dependent variables is observed [Wilks' Lambda = .984; F (39) = .148; *p* = .963; partial eta squared=.016]. This indicates that the participants' WTCQ post-test scores were not significantly different at the end of the experiment.

Table 5
The Results of Multivariate Tests on WTCQPost-test

Effect		Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Group	Pillai's Trace	.016	.148	4.000	37.000	.963	.016
	Wilks' Lambda	.984	.148	4.000	37.000	.963	.016
	Hotelling's Trace	.016	.148	4.000	37.000	.963	.016
	Roy's Largest Root	.016	.148	4.000	37.000	.963	.016

However, examining the descriptive statistics (Table 6) shows that the mean values of the experimental group in all four components of the WTCQ were higher than those of the control group at the end of the study.

Table 6
Descriptive Statistics of WTCQ Post-test across Groups

WCTQ	Group	Mean	SD
Speaking	Experimental	28.619	4.387
	Control	27.952	3.653
Reading	Experimental	23.095	7.822
	Control	21.666	4.661
Writing	Experimental	30.428	6.815
	Control	29.619	4.758
Comprehension	Experimental	7.142	2.515
	Control	6.904	2.142

Discussion

The study investigated the effects of multimedia-enhanced STEAM activities on EFL learners' development of oral skills and their WTC in English. The results displayed that the oral skills and WTC of the learners who received instruction based on multimedia clips developed as a result of the experiment. This outcome can be interpreted from different angles. First, how multimodal input contributed to the understanding of the content, here the STEAM topics, more efficiently and effortlessly. Second, the way the comprehended notions and concepts aided language learners in speaking and interaction processes. Third, the role the mutual relationship of speaking skills and deep understanding of the themes of the talks played in speaking self-efficacy and WTC.

The impact of multimedia-enhanced STEAM activities on oral skills

The value of multimodal input in promoting listening comprehension of language learners in general English courses when scientific topics are not involved is evident (Sayyadi et al. 2022). This generally occurs as multimedia adds contextual clues, visual features (Rost, 2011), and cultural awareness (Sanguino, 2020) to the input and thus decreases the mental load of information processing. What this study, in line with previous works, adds to the literature is that STEAM-based video clips contribute significantly to the understanding of scientific notions and concepts in language classes. The value of science videos in learning in fields such as earth science, physics, and chemistry (Lin et al., 2016) has already been documented. Video clips can make boring and abstract content more exciting and vivid (Guan et al., 2018) and often include visualization and simulation of scientific concepts and phenomena (Breslyn & Green, 2022). Science videos provide students with higher-order cognitive learning (Giannakos et al., 2015), increase awareness of the content (Kolas, 2015), extend the time of the study (Vural, 2013), and function as a tutorial for self-study (Sings, 2004).

Further, multimedia makes learning more active and engaging (Mayer, 2014) as multimodal input improves learning motivation (Choi & Johnson, 2005) and lowers learning anxiety (Shirazi & Rahimi, 2023). This is why students are fond of science learning videos and a consistent rise in watching these videos has been observed in recent years (Hibbert, 2014). One main reason why students like to watch science videos is that these videos can promote personalized learning and address students' learning preferences and needs (Wells et al., 2012). The students not only can adjust their pace of learning science with the instructional content by watching the videos repeatedly (Zarrinfard et al., 2021), but also they can select the teacher whose videos they like most (Breslyn & Green, 2022). This leads to more satisfaction from the instruction (Zhang et al., 2006) and more positive attitudes toward learning (Giannakos et al., 2015) that itself guarantees higher achievement and learning gains (Ketsman et al., 2018). Another reason is that video clips let students visualize the concepts and relate the materials to the surrounding world. This would increase their critical thinking skills (June et al., 2014) and deeper engagement (Giannakos et al., 2015) in the learning tasks that ultimately create genuine enthusiasm for scientific issues. The finding in agreement with previous research shows that video clips, as a component of a larger learning ecosystem, are valuable instructional content for online STEAM courses (Breslyn & Green, 2022).

In addition to paving the way for understanding scientific concepts and notions, the videos promoted the speaking skills of the participants by creating unique opportunities for group discussion (Bennett et al., 2010). In other words, video clips could stimulate interaction in an integrated STEAM course and assist language learners in comprehending STEAM topics more efficiently and talking about them more fluently. Notably, speaking in a foreign language is a challenging job for many EFL students due to the limited exposure they have to the foreign language. Speaking consists of three main phases of conceptualization, formulation, and articulation (Levelt, 1989). While in conceptualization imprecise or unclear notions become clear and the speaker vaguely decides about the message, in the formulation phase the message is poured in lexical and grammatical casts, and ultimately the message is spoken out. The distinctive characteristics of videos including delicate and intriguing illustrations of processes, concepts, and notions in addition to the synthesis of linguistic and paralinguistic features can hugely contribute to students' speaking particularly when they are to conceptualize and formulate their messages. The video clips along with narrations and subtitles increase students' understanding of the content and thus fill the head of the students with ideas and opinions as well as lexical items. Finding the right notion and expressing opinions are among the most difficult parts of the speaking skills as most of the time students complain about lacking what to say and how to say it (Dabiri & Pourhosein Gilakjani, 2019). As for this study, it can be inferred that watching STEAM-related clips activated students' background knowledge of the topics of interest and provided them with the opportunity to collect ideas on the topic to be discussed thus easing the process of speaking. Meanwhile, the STEAM-related videos functioned both as the source of comprehensible input and output.

The impact of multimedia-enhanced STEAM activities on WTC

The findings revealed that although both groups' WTC developed at the end of the experiment, no significant difference was found between them. This shows that STEAM activities could develop both groups' WTC in English and help students have more positive perceptions of their communication abilities. The results are in line with the current literature that students perceive STEAM integration in everyday teaching and learning as motivating and inspiring (Dare et al., 2018) and that language learners' WTC is related to topic familiarity (Karimkhanlooei et al., 2022).

Notably, the students were more willing to speak with their peers during the course because they were members of a virtual community (Zhou, 2023) that is less anxiety-provoking and threatening for EFL learners. Language learners are reported to show more WTC in online classes (Sheldon, 2008) as online environments are more comfortable (Calderwood &Kvarfordt, 2022), safer (Reinders & Wattana, 2015), and less face-threatening (Paik, 2022).

Another reason is that video clips, in comparison to just reading about the STEAM topics, function as a stimulator of students' communication and involve students in meaningful and authentic activities (Ketsman et al., 2018). This convinces the students that they are talking about real problems and they help to resolve world issues by contributing to the discussions. Interactive videos have the potential to transform "the viewers' experience from passive listeners to engaged watchers that interact with the content" (Ketsman, 2018, p. 269). This can improve student interaction (Vural, 2013) and time spent on speaking tasks and thus the development of their speaking skills and their motivation to talk (Sayyadi et al., 2022).

It should, however, be noted that the mean values of the experimental group who worked on multimedia-based STEAM activities were higher in all four components of WTCQ. In other words, those students who experienced oral practices with video clips showed a higher enthusiasm to communicate in English both in oral and written manners. This finding illustrates that video clips boosted the participants' efficacy and WTC but not to the level of their oral skills development. This may be justified by the fact that changing people's beliefs and attitudes is more challenging and time-consuming than changing skills and competencies and this change often does not take place promptly (Mason & Scrivani, 2004).

Conclusions

The current study was an attempt to integrate multimedia-enhanced STEAM activities into language instruction where oral skills were taught to advanced EFL learners. The findings suggest that STEAM activities improve language learners' oral skills and assist them in processing oral input more efficiently and producing output more fluently and accurately. It was also inferred that STEAM pedagogy is a firm approach to promote students' WTC in a foreign language.

The findings, however, should be expounded by considering the limitations the researchers encountered in the process of performing the study. First, due to practicality issues, the study was carried out with two online classes, and the multimedia-enhanced STAM activities were compared to text-based STEAM activities in the e-learning environment. It would be more insightful if the study be replicated while online and face-to-face instructions are compared. Second, the sample included advanced learners of English in the context of higher education. Including proficiency level in the design of the study and performing the study in the context of secondary education is recommended. Third, due to the goal of the course, STEAM activities focused on just teaching oral skills and written skills were not included in the course. Therefore, teaching and assessing English reading and writing in an integrated STEAM course and evaluating its impact on students' development of language and science literacies need follow-up studies. Last, as face-to-face instruction was halted during the COVID-19 pandemic, participants' WTC outside of the class was not assessed. Future studies on both inside and outside the classroom WTC in integrated STEAM courses are recommended. Observation studies of the participants' performance during communication are also suggested to have a more in-depth analysis of students' change of behavior by triangulating the quantitative data.

Considering the gained results, the study contributes to the literature in three ways. First, it demonstrates that STEAM and language education can be effectively integrated and this combination leads to more learning gains. Second, it displays the role of technology, particularly instructional multimedia, in promoting language learners' ease of cognitive processes in the domain of receptive and productive language skills. Third, it supports the advantages the STEAM approach can offer to promote students' motivation in selecting more interesting topics to communicate orally in a foreign language.

References

Aligholi, H. (2022). The dire situation of 'basic sciences' in the country. *The World of Economy, 5434*, 3859385.

Amirinejad, M. (2022). *Effects of integrating two types of digital storytelling into a STEAM program on the development of language learners' academic self-regulation and metacognitive strategies awareness*, [master's thesis]. Shahid Rajaee Teacher Training University.

Apple, M. T., Falout, J., & Hill, G. (2020). The relationship between future career self-images and English achievement test scores of Japanese STEM students. *IEEE Transactions on Professional Communication, 63*(4), 372-385.

Bennett, J., Hogarth, S., Lubben, F., Campbell, B., & Robinson, A. (2010). Talking science: The research evidence on theuse of small group discussions in science teaching. *International Journal of Science Education, 32*(1), 69-95 https://doi.org/10.1080/09500690802713507.

Bicer, A., Boedeker, P., Capraro, R.M., & Capraro, M.M. (2015). The effects of STEM PBL on students' mathematical and scientific vocabulary knowledge. *International Journal of Contemporary Educational Research, 2*(2), 69-75.

Breslyn, W., & Green, A.E. (2022). Learning science with YouTube videos and the impacts of Covid-19. *Disciplinary & Interdisciplinary Science Education Research, 4*(13). https://doi.org/10.1186/s43031-022-00051-4.

Calderwood, K., A. & Kvarfordt, C. L. (2022). How teaching online impacts safety and comfort: Experiences of students and instructors in the context of learning counseling skills online. *International Journal of Scholarship of Teaching & Learning, 16*(2), Art 15. https://doi.org/10.20429/ijsotl.2022.160215.

Chang, S.C., Hsu, T.C., Chen, Y.N., & Jong, M. (2018). The effects of spherical video-based virtual reality implementation on students' natural science learning effectiveness. *Interactive Learning Environments, 28*, 1-15. https://doi.org/ 10.1080/10494820.2018.1548490.

Choi, H. J., & Johnson, S. D. (2005). The effect of context-based video instruction on learning and motivation in online courses. *The American Journal of Distance Education*, *19*(4), 215-227. https://doi.org/10.1207/s15389286ajde1904_3.

Creese, A. (2005). Is this content-based language teaching? *Linguistics & Education, 16*, 188-204.https://doi.org/10.1016/j.linged.2006.01.007.

Crum, S. (2022). Second language teaching with STEM. *Frontiers in Education, 7*, Art 903804. https://doi.org/10.3389/feduc.2022.903804.

D'Angelo, C., Rutstein, D., Harris, C., Bernard, R., Borokhovski, E., &Haertel, G. (2014). *Simulations for STEM Learning: Systematic Review and Meta-Analysis*. SRI International.

Dabiri, D., & Pourhosein Gilakjani, A. (2019). Impact of pre-speaking activities on Iranian intermediate EFL learners' oral performance. *International Journal of Research in English Education,4*(2),89-104. https://doi.org/10.29252/ijree.4.2.89.

Dare, E. A., Ellis, J. A., & Roehrig, G. H. (2018). Understanding science teachers' implementations of integrated STEM curricular units through a phenomenological multiple case study. *International Journal of STEM Education, 5*(1), 1-19. https://doi.org/10.1186/s40594-018-0101-z.

Duo-Terron, P., Hinojo-Lucena, FJ., Moreno-Guerrero, AJ., & López-Núñez, JA. (2022) STEAM in primary education: Impact on linguistic and mathematical competences in a disadvantaged context. *Frontiers in Education, 7,* Art 792656. https://doi.org/10.3389/feduc.2022.792656.

Erol, M., & Başaran, M. (2022). The effect of STEAM education with tales on problem-solving and creativity skills. *European Early Childhood Education Research Journal*. https://doi.org/10.1080/1350293X.2022.2081347.

Fuhrman-Petersen, R. J. (2013). The effects of STEM inquiry practices on English language acquisition in a first-grade classroom in Thailand. Graduate Research Papers 36. Available online: https://scholarworks.uni.edu/grp/36.

Giannakos, M., Chorianopoulos, K., &Chrisochoides, N., (2015), Making sense of video analytics: Lessons learned from clickstream interactions, attitudes, and learning outcome in a video-assisted course. *The International Review of Research in Open and Distributed Learning 16*(1), 260-283.https://doi.org/10.19173/irrodl.v16i1.1976.

Grasso, D., Martinelli D. (2007). Holistic Engineering. *The Chronicle of Higher Education, 53*(28), p. B8. https://doi.org/10.1007/978-1-4419-1393-7_2.

Guan, N., Song, J., & Li, D. (2018). On the advantages of computer multimedia-aided English teaching. *Procedia Computer Science, 131*, 727-732. https://doi.org/10.1016/j.procs.2018.04.317 IELTS Guide for teachers. (2019). itels.org

Hasanah, U. (2020). Key definitions of STEM education: Literature review. *Interdisciplinary Journal of Environmental and Science Education, 16*(3), e2217. https://doi.org/10.29333/ijese/8336

Herro, D., & Quigley, C. (2017). Exploring teachers' perceptions of STEAM teaching through professional development: Implications for teacher educators. *Professional Development in Education, 43*(3), 416-438.https://doi.org/10.1080/19415257.2016.1205507.

Hibbert, M. C. (2014). What makes an online instructional video compelling? EDUCAUSE Review. Available online: https://er.educause.edu/ articles/2014/4/what-makes-an-online-instructional-video-compelling

Hoffman, L., & Zollman, A. (2016). What STEM teachers need to know and do for English language learners (ELLs): Using literacy to learn. *Journal of STEM Teacher Education, 51*(1), Art 9. https://doi.org/10.30707/JSTE51.1Hoffman.

Huang, M.C.L., Chou, C.Y., Wu, Y.T., Shi, J.L, Yeh, C.Y.C., Lao, A. C., Fong, H., Lin, Y.F., & Chan, T.W. (2020). Interest-driven video creation for learning mathematics. *Journal of Computers in Education, 7*, 395-433. https://doi.org/10.1007/s40692-020-00161-w

Huang, B., Siu-Yung Jong, M., & Chai, C. S. (2022). The design and implementation of a video-facilitated transdisciplinary STEM curriculum in the context of COVID-19 pandemic.*Educational Technology & Society, 25*(1), 108-123.

Innes, P. I. (2020). *The effects of technology on student interest in STEAM education*. Honors Theses 259. University of Dayton. Available online: https://ecommons.udayton.edu/uhp_theses/259

June, S., Yaacob, A., & Kheng, Y. (2014). Assessing the use of YouTube videos and interactive activities as a critical thinking stimulator for tertiary students: An action research. *International Education Studies 7*(8), 56-67. https://doi.org/10.5539/ies.v7n8p56.

Kang, N.H. (2019). A review of the effect of integrated STEM or STEAM (science, technology, engineering, arts, and mathematics) education in South Korea. *Asia-Pacific Science Education*, *5*(1), 1-22. https://doi.org/10.1186/s41029-019-0034-y.

Karimkhanlooei, G., Motamed, N., &Gharebaghi, H. (2022). Effective factors in medical students' willingness to communicate in the course of English for Specific Purposes. *Journal of Medical Education Development*, *15*(45), 34-46

Karunia, R., &Ridlo, S. (2022). STEM integrated flipped classroom learning tools on biodiversity materials to improve students' critical thinking skills. *Journal of Biology Education, 11*(2). https://doi.org/10.15294/jbe.v11i2.58584.

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education*, *3*(1), 1-11. https://doi.org/ 10.1186/s40594-16-0046-z

Ketsman, O., Daher, T., &Colon Santana, J. A. (2018). An investigation of effects of instructional videos in an undergraduate physics course. *E-learning and Digital media*, *15*(6), 267-289.https://doi.org/10.1177/2042753018805594.

Kolas, L. (2015, June). *Application of interactive videos in education* [Paper presentation]. International Conference on Information Technology-based Higher Education and Training (ITHET), Lisbon, Portugal.

LaCossem J., Canning, E.A., Bowman, N.A., Murphy, M.C., Logel, C. (2020). A social-belonging intervention improves STEM outcomes for students who speak English as a second language. *Science Advances, 6*(40), eabb6543. https://doi.org/10.1126/sciadv.abb6543

Levelt, W.J.M. (1989). *Speaking: From intention to articulation.* MIT Press.

Lee, O., &Stephens, A. (2020). English learners in STEM subjects: Contemporary views on STEM subjects and language with English learners. *Educational Researcher*, *49*(6), 426-432. https://doi.org/10.3102/0013189X20923708

Lin, J. J. H., Lee, Y.H., Wang, D.Y., & Lin, S. S. J. (2016). Reading subtitles and taking notes while learning scientific materials in a multimedia environment: Cognitive load perspectives on EFL students. *Journal of Educational Technology & Society*, *19*(4), 47-58.

Lin, C.L., &Tsai, C.Y. (2019). The effect of a pedagogical STEAM model on students' project competence and learning motivation. Journal of Science Education & Technology, 30, 112-124. https://doi.org/10.1007/s10956-020-09885-x

MacIntyre, P. D., Baker, S. C., Clément, R., & Conrod, S. (2001). Willingness to communicate, social support, and language-learning orientations of immersion students. *Studies in Second Language Acquisition*, *23*(3), 369-388. https://doi.org/1017/S0272263101003035.

Mason, L., & Scrivani, L. (2004). Enhancing students' mathematical beliefs: an intervention study. *Learning & Instruction, 14*(2), 153-176. https://doi.org/10.1016/j.learninstruc2004.01.002.

McCarthy, M., McCarten, J., & Sandiford, H. (2013). *Viewpoint 2*. Cambridge University Press.

Margot, K.C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: a systematic literature review. *International Journal of STEM Education, 6*(2). https://doi.org/10.1186/s40594-018-0151-2

Mayer, R. E. (2009). *Multimedia learning* (2nd ed). Cambridge University Press.

Mayer, R. E. (2014). Cognitive theory of multimedia learning. In R. E. Mayer (Ed.), *Cambridge Handbook of multimedia learning* (2nd ed., pp. 43-71). Cambridge University Press

Mayo, M. J. (2009). Video games: A route to large-scale STEM education? *Science*, *323*(5910), 79-82. https://doi.org/10.1126/science.1166900.

Moon, D. (2015). Teacher's 'stages of concerns' and 'levels of use' on STEAM education. *The Journal of Korean Association of Practical Arts Education, 28*(1), 35-52.

Moore, T. J., Stohlmann, M. S., Wang, H. H., Tank, K. M., Glancy, A. W., & Roehrig, G. H. (2014). Implementation and integration of engineering in K-12 STEM education. In S. Puzer, J. Strobel, and M. Cardella (Eds) *Engineering in pre-college settings: Synthesizing research, policy, and practices* (pp. 35-60). Purdue University Press.

Moreno, R., & Mayer, R. E. (2007). Interactive multimodal learning environments. *Educational Psychology Review, 19*, 309-326. https://doi.org/10.1007/s10648-007-9047-2.

Ozturk, O. (2021). STEM integrated English lessons. *SALEE: Study of Applied Linguistics and English Education, 2*(2), 119-136. https://doi.org/10.35961/ salee.v2i02.248

Pace, B. G., & Jones, L. C. (2009). Teaching with web-based videos. *The Science Teacher,* 47-50.

Paik, S. (2022). The effect of online English-medium instruction on performance of English face-threatening speech acts. *English Teaching, 77*(4), 103-128. https://doi.org/10.15858/engtea.77.4.202212.103.

Pallant, J. (2020). *SPSS survival manual: A step-by-step guide to data analysis using IBM SPSS.* Routledge.

Poese, M. (2014). *A critical investigation on ESL/EFL instruction for adult NNES STEM professionals and college students* [doctoral dissertation]. Seattle University.

Reinders, H., & Wattana, S. (2015). Affect and willingness to communicate in digitalgame-based learning. *ReCALL, 27*(01), 38-57.https://doi.org/ 10.1017/ S0958344014000226

Richards, J. C., & Rodgers, T. S. (2014). *Approaches and methods in language teaching*. Cambridge University Press.

Riley, S. (2016). 6 steps to creating a STEAM classroom. https://artsintegration.com/ 2016/02/25/6-steps-to-creating-a-steam-centered-classroom

Rost, M. (2011). *Teaching and researching listening* (2nd ed). Longman

Sabeghi, Z. (2023). *The impact of STEAM-based pre-reading activities on EFL learners' development of reading comprehension and managing its associated cognitive load in virtual classes*, [master's thesis]. Shahid Rajaee Teacher Training University.

Sanders, M. (2009). STEM, STEM education, STEMmania. *Technology Teacher, 68*(4), 20-26.

Sanguino, D. M. G. (2020) *Using video materials to help EFL learners facilitate their listening comprehension skill* [master's thesis]. Pontifical Bolivarian University.

Sayyadi, M., Rahimi, M., Ebrahimpour, R., & Amiri, S. H. (2022). Applying multimedia learning principles in task design: Examination of comprehension development in L2 listening instruction. *English Teaching & Learning*, https://doi.org/ 10.1007/s42321-022-00132-7.

Schoettler, S. D. (2015). *STEM education in the foreign language classroom with special attention to the L2German classroom* [master's thesis], Portland State University.

Sheldon, P. (2008). The relationship between unwillingness-to-communicate and students' Facebook use. *Journal of Media Psychology, 20*(2), 67-75. https://doi.org/10.1027/1864-1105.20.2.67

Shirazi, N., & Rahimi, M. (2023). Effects of a multimedia-enhanced GE course on undergraduate Computer Engineering students' development of reading skills and growth mindset. *IEEE Transaction on Education, 66*(4), 300-310. https://doi.org/10.1109/TE.2023.3235784

Sings, C. (2004).Interactive video tutorials for enhancing problem-solving reasoning and meta-cognitive skills of introductory physics students. In *AIP Conference Proceedings 720*(pp. 177-180). Melville New York. https://doi.org/10.1063/ 1.1807283.

Stohlmann, M., Moore, T. J., & Roehrig, G. H. (2012). Considerations for teaching integrated STEM education. *Journal of Pre-College Engineering Education Research*, *2*, 28-34. https://doi.org/10.5703/1288284314653.

Sultana, N., Kahwaji, H., & Kurup, P. M. (2021). The influence of teaching English in STEM education for ESL learners amidst a changing world after COVID-19. *International Journal of Learning and Teaching, 7*(2), 175-180. https://doi.org/10.18178/ijlt.7.2.175-180.

Sweller, J. (2023). Discussion of the special issue on cognitive load theory. *British Journal of Educational Psychology, 93*(2), 402-410. https://doi.org/ 10.1111 / bjep.12606

Tagnin, L., & Ríordáin, M. N. (2021). Building science through questions in Content and Language Integrated Learning (CLIL) classrooms. *International Journal of STEM Education 8*(34). https://doi.org/10.1186/s40594-021-00293-0.

Transparent Language (2016). STEM is missing an important subject: languages medium. Available online: https://medium.com/@TransparentLanguage/stem-is-missing-an-important-subject-languages-e831a0ad5cc9.

Vural, F. (2013). The impact of a question-embedded video-based learning tool on e-learning. *Educational Sciences: Theory and Practice 13*(2), 1315-1323.

Wegner, C., Strehlke, F., & Weber, P. (2014). Investigating the differences between girls and boys regarding the factors of frustration, boredom, and insecurity they experience during science lessons. *Themes in Science and Technology Education*, *7*(1), 35-45.

Wells, J., Barry, R., & Spence, A. (2012). Using video tutorials as a carrot-and-stick approach to learning. *IEEE Transactions on Education*, *55*(4), 453-458. https://doi.org/10.1109/TE.2012.2187451.

Yakman, G. (2008). STEAM education: An overview of creating a model of integrative education. https://www.researchgate.net/publication/327351326_STEAM_Education_an_overviewof_creating_a_model_of_integrative_education.

Yang, D. & Baldwin, S.J. (2020). Using technology to support student learning in an integrated STEM learning environment. *International Journal of Technology in Education and Science, 4*(1), 1-11.https://doi.org/10.46328/ijtes.v4i1.22.

Yore, L. D., Bisanz, G. L., & Hand, B. M. (2003). Examining the literacy component of science literacy: 25 years of language arts and science research. *International Journal of Science Education, 25*, 689-725. https://doi.org/10.1080/09500690305018.

Zarei, M., Zeinalipour, H., & Samawi, A. (2022). Identify the components of the STEAM curriculum in elementary school. *International Journal of Paediatrics, 10*(4), 15789-15801. https://doi.org/10.22038/IJP.2021.57034.4471.

Zarrinfard, S., Rahimi, M., &Mohseny, A. (2021). Flipping an on-campus general English course: A focus on technology complexity of instruction and learners' levels of impulsivity. *International Journal of Educational Technology in Higher Education, 18*(45). https://doi.org/10.1186/s41239-021-00280-z.

Zhang, D., Zhou, L., Briggs, R., & Nunamaker, J. F. (2006) Instructional video in e-learning: Assessing the impact of interactive video on learning effectiveness. *Information & Management, 43*(1), 15-27.https://doi.org/10.1016/j.im.2005.01.004.

Zhou, A. (2023). Investigating the impact of online language exchanges on second language speaking and willingness to communicate of Chinese EFL learners: a mixed methods study. *Frontiers in Psychology, 14,* Art 1177922. https://doi.org/10.3389/fpsyg.2023.1177922

Zhu, J., Yuan, H., Zhang, Q. et al. (2022). The impact of short videos on student performance in an online-flipped college engineering course. *Humanities and Social Sciences Commutations, 9,* Art 327. https://doi.org/10.1057/s41599-022-01355-6.