Pedagogical Purposes of Using Open Educational Resources in STEM Education: A Case Study in a STEM High School in Egypt

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Abstract

Science, technology, engineering, and mathematics (STEM) schools in less advanced countries are challenged to maintain students' motivation and interest in STEM fields mainly due to a lack of suitable materials and teacher competence. In a context where STEM teachers generally lack the capacity to design and develop good instructional materials, utilizing existing quality open educational resources (OER) as instructional materials can be an effective way to support STEM education at little or no additional cost. This study explored how and why STEM teachers in a less advanced country, where teaching and learning materials are lacking and the students' interest in STEM is generally low, utilize OER. Qualitative research particularly, a case study, was conducted through interviews with six (6) teachers and nine (9) students in a STEM high school in Egypt, and through class observations and syllabi analysis. The analysis revealed that STEM teachers utilized a variety of OER predominantly for three pedagogical purposes, namely: promoting and maintaining students' interest in STEM fields, seeking information needed for learning, and developing student competencies required in the STEM workforce. Findings suggest that OER can be effectively employed, for promoting student motivation and providing subject content in less advanced countries. OER plays an important role as a substitute for textbooks, positively impacting students' active learning and competency building.

Keywords: *motivation, open educational resources (OER), pedagogical purposes, STEM education*

Introduction

Development of STEM education and challenges

Recognizing the importance of the STEM workforce, advanced countries have dedicated a lot of attention and effort towards implementing robust STEM educational strategies and preparing students to enter the STEM workforce. A prime example is the USA where STEM has been recognized as the cutting edge in policy agenda (The Committee on STEM Education, 2018). In Europe, it has been a European Commission's key policy since 1990 and several Western European countries have also emphasized on STEM for framing educational and industrial national policies (Blackley & Howell, 2015).

The K-12 STEM schools were established to promote STEM education and provide a unique learning environment with an advanced integrated curriculum, professional teachers, training opportunities, and immersion in real-life situations. As reported by Erdogan and Stuessy (2015), STEM school students tend to perform better in mathematics and science tests in comparison with students from traditional schools. The main feature of the STEM education curriculum worldwide is the subject integration between science, technology, engineering, and math (Bybee, 2010). However, the idea of curriculum integration is not as easy as putting different subject areas altogether as it is more complex and challenging (Wang et al., 2011). There is no clear framework or approach among all countries on how to integrate the four subjects together (Bell, 2016). Each country integrates differently according to its national education policy. Despite those differences,

the method and practice of teaching, or pedagogy, is almost the same (Carter, 2013). In STEM, project and problem-based learning is the primary pedagogy where students learn through a real-world situation. According to Tsupros et al (2009), it is better than learning atomistically. This transition from traditional classroom setting, which is teacher-centered, to student-centered approach and from the view that a student is not just a consumer, but a co-producer is essential for cultivating a STEM independent learning environment. However, despite their success, STEM schools have faced challenges, most noticeably, with maintaining students' motivation and interest (American National Governor's Association, 2007; Young et al., 2017).

A number of less advanced countries have addressed STEM issues within their public education system by focusing on developing qualified teachers in the areas of science and technology (Marginson et al., 2013), but a lack of solid policies and action plans at the national level, leading to lower achievement in STEM education with a lack of quantity and quality in their STEM workforces is still observed (Passey et al., 2016). World recognition of science and technology for socio-economic development has created a climate for strengthening STEM education in less advanced countries (Kennedy & Odell, 2014; UNESCO, 2002). In addition, several attempts to promote STEM education at state and national levels have been observed, especially in Egypt (Charlifue, 2018; Omran, 2019), Brazil (Horta, 2013), Sri Lanka (Kumara, 2019), Ethiopia (UNESCO, 2017), and Russia (Smolentseva, 2013).

Labov et al. (2010) and Sanders (2008) argued that the goal of STEM education is to support students in learning to apply the basic content and practices of STEM disciplines to situations they encounter in life. However, despite considerable momentum in recent years, achieving the goal remains a significant challenge facing education communities, especially in less advanced countries. Achieving the goal requires educators to provide students with experience in applying knowledge and skills to real-life through an interdisciplinary approach integrating the four STEM components (Bybee, 2013; Ryu et al., 2019). Further, STEM educators must develop well-designed instructional materials (Shernoff et al., 2017) and implement high-quality teaching practices (Ejiwale, 2013).

Possibilities of OER in addressing STEM challenges

It is recognized that good instructional materials aid in preparing students for real-life while maintaining their interest in the STEM fields. In a less advanced country, where STEM teachers generally lack the capacity to design and develop good instructional materials, utilizing high quality open educational resources (OER), as instructional materials, is an effective way in supporting STEM education at little or no additional cost.

The term *OER*, developed during the 2002 UNESCO Forum on the Impact of Open Courseware for Higher Education in Developing Countries (UNESCO, 2002), is defined as "teaching, learning, and research resources with an intellectual property license that permits them to be reused, reworked, remixed, and redistributed" (D'Antoni, 2009). Such resources are often in the form of video clips, images, audio files, newspaper articles, online quizzes, and multimedia (Jung & Hong, 2016; Rahayu & Sapriati, 2018) and can be freely modified according to specific instructional needs and conditions. The goal of OER is the creation of universally accessible educational materials offered freely and openly to be used in teaching, learning, and research for educators and learners (Bissell, 2009). This open learning environment positively influences student motivation (Kew et al. 2018) and helps develop critical thinking skills (Rahayu & Sapriati, 2018), technology skills (Tsai, 2018), and soft and academic skills (Pitt et al., 2013).

Recognizing the varied benefits and rapid growth of OER, some teachers encourage their students to use OER as supplementary materials. Others employ open textbooks to save their students some money. On the other hand, some academic institutions go as far as providing credits to their students who use free online resources and materials in order to gain the knowledge they need to acquire competency in specific areas (Smith & Casserly, 2006). The purpose of using OER differs depending on the types of OER adopted, the pedagogical benefits that teachers recognize in adopting OER, and the motivational and learning advantages perceived by students in using OER.

As a result of its adoption by educators and researchers in higher education, several pedagogical benefits of OER have been identified. In Canada, OER was used to develop ideas and inspiration for students to supplement existing coursework, together with preparation prior to actual teaching (Jhangiani et al., 2016). Jung and Hong (2016) found that OER provided better content and promoted active and deeper learning (effectiveness aspect), as well as gained and maintained attention and interest through the use of multimedia and hyperlinks (appeal or motivation aspect).

To date, there have been a limited number of studies conducted on the integration of OER and its pedagogical benefits in the context of STEM education. Ryu et al. (2019) investigated how preservice teachers in the USA utilized and modified online resources in an integrated STEM class and found that hands-on science experiments, existing integrated STEM lesson plans, scholarly research relevant to the selected lesson topics, and contextual information from newspapers were often employed in the STEM class. Yang (2017), in a study investigating the experience of graduate students when utilizing various forms of instructional materials in a STEM online course in the USA, found that besides the materials provided, the majority of the students used other online resources to help understand the content. While these studies help STEM teachers and students in understanding the overall use of free materials on the Internet, they do not address important questions such as what types of OER are being used in STEM schools and how these are being integrated into the classes to improve teachers' pedagogical practices, especially in the context of less advanced countries.

Objectives

The aim of this research was to investigate the pedagogical purposes of using OER in STEM education in a STEM school in Egypt that was selected as a case study. The following questions were posed:

1. What types of OER are used by teachers in the STEM school?
2. What are the pedagogical purposes of OER as employed by teachers in the STEM teaching process?
3. How are OER integrated with the teaching and learning process according to each pedagogical purpose?

Methodology

A case study was employed to allow researchers to examine, descriptively and heuristically, a phenomenon or case within a specific context (Merriam, 1998). The case study's main characteristics were research questions posed directly to teachers, and observations in natural classroom settings were conducted (Yin, 2014).

The case

A boarding school, established in 2014 as one of 14 STEM high schools in Egypt, was chosen as the case study. Similar to the other 13 STEM schools in Egypt, the school follows common features found in specialized STEM schools across the USA. In 2018, it had 301 enrolled students and 25 teachers. The maximum capacity of a STEM class was set at 25 students. Biology, Chemistry, Earth Science, Mathematics, and Physics formed the STEM subjects, and Arabic, English, and either French or German were the non-STEM subjects. Students also undertook some elective subjects such as Computer Science and Physical Education, with most subjects taught in English. The total grade for each subject is comprised of two parts. The first 40% is given to the exam scores and attendance, and the remaining 60% is allotted to the capstone project, a measurement of how students applied the subject in analyzing and solving a real-world problem. Students worked in teams from the beginning of the semester until the final presentation to analyze one of Egypt's real-world challenges before coming up with their solutions.

Participants

Six (6) teachers and nine (9) students agreed to participate in the study. By applying purposive sampling, the teachers were selected with consideration to subject taught, gender, and years of teaching experience (see Table 1), and three (3) students were selected from each grade (see Table 2).

Table 1

Teacher Participants in the Study

Code	Teaching Experience before STEM	Teaching Experience in STEM	Gender	Subject Taught
T1	6	5	F	Physics
T2	23	5	M	Math
T3	9	5	M	English
T4	25	4	M	Geology
T5	27	3	F	Chemistry
T6	9	5	M	Biology

Table 2

Student Participants in the Study

Code	Grade	Gender
S1	Grade 12	M
S2	Grade 12	M
S3	Grade 12	F
S4	Grade 11	M
S5	Grade 11	M
S6	Grade 11	F
S7	Grade 10	F
S8	Grade 10	F
S9	Grade 10	F

Data collection

After the approval from the Research Ethics Committee of the researchers' institution for sufficient consideration to participants' sense of dignity, respect for their human rights, and protection of their personal information, interviews with teachers and students, along with classroom observations and syllabi analysis, for the purpose of data triangulation, were conducted between September and October 2018. The researchers, as observers, provided an outsider's unbiased and impartial approach during data collection.

An open-ended semi-structured interview in Arabic was conducted and recorded with the six (6) teachers and the nine (9) students. The interview with teachers consisted of two parts: 1) questions relating to types of OER often used by the teacher in class, including ways and extent to what type of OER is utilized during the teaching process, and 2) questions clarifying the pedagogical purposes and the challenges faced when using OER and the types of OER having the largest impact on student motivation. Other questions also emerged during the course of the interview. The interview with students consisted of six (6) questions on learning while integrating OER in their sessions and their perceived learning outcomes. Student interviews were used to confirm and triangulate data collected from teacher interviews.

The Technology Integration Observation Protocol (TIOP), developed by Maxfiled et al. (2011) was employed, with the authors' permission, for observations to assess classroom activities and interactions, both among and between students and the teacher, together with how technology is integrated, what technologies are used, and the level of integration achieved with the curricular objective. To observe accurately and descriptively the extent to which OER was employed and integrated into the classroom environment, and to confirm the teachers' self-reported information given in the interviews to avoid over-reporting the amount of OER in use, two 80-minute direct observations were conducted in the classrooms of the interviewed teachers. The researcher's observation journal, using TIOP, followed a low inference descriptors strategy, allowing for precise, almost literal detailed descriptions of people and situations without any evaluation (Bashir et al., 2008).

The course syllabi of the six teachers were analyzed to identify the following: types of the OER listed, main teaching and learning activities employed, and expected skills gained for each session. With this, additional information gathered from the interviews and observations were confirmed and refined.

Data analysis

The interview data collected from the teachers were analyzed through a three-phased open coding approach characterized by merging all the concepts from the raw data and grouping them into conceptual categories (Khandkar, 2009). First, at the preparation stage, recordings of interviews were transcribed and translated into English, and data files were organized and labeled. Then, at the data reduction and exporting stage, irrelevant interview question responses were eliminated before all the remaining data were exported into NVivo 12 pro qualitative research software. Finally, at the coding and thematizing stage, coding schemes were generated. The unit of data analysis was phrased with one idea as a chunk. After carefully reviewing the coded data, tentative labels for data chunks were created and grouped as sub-categories and again refined. Three primary themes or pedagogical purposes emerged from the chunks: maintaining motivation, seeking information, and developing students' competencies (see Table 3).

The nine (9) codes found under the pedagogical purpose of maintaining motivation were compared to the motivational strategies of four dimensions of Attention, Relevance, Confidence, and Satisfaction (ARCS) model of motivation for exploring to what extent teachers are utilizing OER to motivate students. ARCS model is a motivational design helping teachers identify problems with student motivation and design strategies which can be used to make instruction match the interests and needs of students according to its four dimensions (Keller, 2010). It has been widely validated as a method for systematic improvement of learner motivation and performance in e-learning settings. This comparison explored in what way using OER as instructional materials in teaching and learning in STEM schools can determine students' motivation.

Interview data collected from the students were analyzed to confirm the themes that had emerged from the teachers' interviews. After reviewing students' stories and their daily experiences with OER, a narrative analysis was conducted manually to explore students' approaches to their use of OER.

Classroom observation was analyzed. From the protocol answers, the types of OER used in classrooms were listed and compared with teachers' interviews. Key themes were then identified throughout the protocol answers, together with the researcher's observation journal, to help describe the mode of OER integration inside each classroom.

Prior to teacher interviews and class observations, the six syllabi were examined individually to get a basic understanding of each class topic and important components for class activities. In addition, the syllabi analysis reflection journal was written to identify the types of OER mentioned in the syllabus and how each type of OER related to a specific activity.

Results

Types of OER used in STEM education

The teachers employed several types of OER throughout the STEM teaching and learning process. Based on the teacher' interviews, as confirmed by student interviews, classroom observations, and syllabi analysis, four main types of OER were used in STEM sessions. These included: 1) pdf references used as online textbooks, 2) videos, 3) educational websites, and 4) online quizzes. Additional materials, such as massive open online courses (MOOCs) and references made from Google Scholar were introduced to students.

The predominant type of STEM session OER was online textbooks. Pdf references were directly downloaded from the Internet to be used as textbooks by the students. Moreover, students were given the freedom to study either from the textbook references listed in the syllabus or to search alternative online references. A number of the references included in the syllabi were made available in the library as hardcopy books.

Videos were the next most popular OER. Videos were used daily, primarily to assist students in comprehending concepts presented in STEM classes. The primary source of videos was YouTube; however, the teachers also used other websites to broadcast instructive animations and documentary videos, such as the university's own or those from educational organizations. Videos from Khan Academy were played in a mathematics class to assist pupils in better understanding mathematical concepts.

Online sites for simulations of statistics and calculations were also referenced. Geogebra, an open software that dynamically integrates geometry, algebra, spreadsheets, graphing, statistics, and calculus for all grade levels, was frequently used for supplementary material.

Online quizzes, such as those offered by CliffsNotes, were sometimes used in addition to the quizzes found on Google Drives.

Pedagogical purposes of OER use

From the analysis of teacher interviews on the pedagogical purposes of OER use, 107 chunks were identified and categorized as follows: 1) maintaining motivation, 2) seeking information, and 3) developing student competencies (see Table 3). These findings were confirmed with data collected from the students' interviews, classroom observations, and syllabi analysis.

Table 3

Categorization of Pedagogical Purposes of Using OER inside STEM Sessions

Categories of Pedagogical Purposes	Sub-categories	Codes
Maintaining Motivation (47 chunks-44%)	Support linking to real-life application (15 chunks)	1. Real-life connections (9 chunks) 2. Project-based learning (6 chunks)
	Bringing excitement to the session (14 chunks)	3. Visual media attention (9 chunks) 4. Varieties (5 chunks)
	Supporting a well-planned session (9 chunks)	5. Time management (3 chunks) 6. Brainstorming (3 chunks) 7. Session closure (1 chunk)
	Encouraging students' engagement (9 chunks)	8. Challenges (5 chunks) 9. Activities (4 chunks)
Seeking Information (43 chunks-40%)	Teaching STEM content (33 chunks)	10. Achieving learning outcomes (12 chunks) 11. Confirming and expanding content understanding (11 chunks) 12. Pinpointing the main concept (10 chunks)
	Supporting further learning (10 chunks)	13. Guiding students to deep learning (7 chunks) 14. Supporting students' research (3 chunks)
Developing Student Competencies (17 chunks-16%)	Improving active learning skills (11 chunks)	15. Group discussion skills (5 chunks) 16. Peer coaching skills (3 chunks) 17. Debating skills (2 chunks) 18. Problem solving skills (1 chunk)
	Improving independent learning skills (6 chunks)	19. Information evaluation skills (3 chunks) 20. Self-directed learning skills (3 chunks)

Maintaining motivation

Maintaining motivation, with 47 chunks (44% of the whole chunks), was the most common reason for using OER. Specifically, OER was utilized to support linking to real-life applications (15 chunks), bring excitement to the session (14 chunks), support a well-planned session (9 chunks), and encourage students' engagement in the session (9 chunks).

Science teachers used OER to make real-life connections to the lesson content. T5, a Chemistry teacher, explained that when students watch animation videos about polymers, they relate every substance around them to real life. T6, a Biology teacher, confirmed that animation videos about DNA helped students imagine what is happening inside their bodies. Students became motivated and performed better when they were offered a class relevant to their real life, met their goals, and, most importantly, was related to their assignments. Teachers' utilization of OER in linking the topics with real-world examples was observed in the STEM sessions where a project-based learning approach was adopted. In this environment, students work on real projects, requiring them to search through different types of OER. Teachers believed that the strategy of letting students search and choose OER by themselves allows them some control over the content and thereby increases their motivation.

Moreover, teachers used OER to bring excitement during an 80-minute STEM session that has no break. Observations showed that visuals and animations were presented to retain students' attention and prevent sleeping during the session. T2, a Mathematics teacher, and T1, a Physics teacher, confirmed that visual media induced a sense of immersion amongst students causing more excitement than reading a reference book or viewing presentation material during the session. Teachers were observed to include a variety of OER in their syllabi to suit all students' preferences and reduce boredom levels during an 80-minute session. In nearly all cases, classroom observations showed that teachers used at least three different types of OER during the session. However, students stated the importance of a teacher's ability to choose suitable OER and utilize each type effectively in retaining their attention.

Teachers utilized OER as a method of time management during the session, as T3 noted. Classroom observations supported T3's point; teachers usually start a session with a video or other OER. Towards the middle of the session, students were asked to read some pdf references on their personal computer for a specific activity. Five teachers reported using OER primarily for brainstorming activities to help maintain students' levels of interest. Table 4 shows that, at 43%, videos were the most frequently employed OER in motivating students during the session. Most teachers selected YouTube videos to begin their sessions; educational websites followed videos at 15%. For T4, showing students a short video at the beginning of the session promoted improved understanding of new concepts while grabbing their attention. Online quizzes used as session closures were observed in T6's and T3's classrooms. T3 reported online quizzes helping structure sessions and indicate students' understanding of the topic. Also, according to T3, properly concluding the session is very important in STEM as the topics are open, and classroom discussions can confuse some students.

Some teachers used OER to challenge students. T2 and T4 reported that such OER increased student motivation, engagement, and participation. Moreover, downloading challenging questions from university websites helped stimulate their students. Teachers employed OER to support activities in the learning process by treating the hands-on activities as real learning experiences for STEM education. T2 deemed such activities were necessary for motivating students and engendering

enthusiasm. Students reported YouTube videos, or simulation movies, prior to specific scientific experiences or a fab lab activity helps to understand how the experiment can be conducted or how the object is built. However, as T4 mentioned, the lack of facilities makes it difficult for teachers to provide hands-on activities such as scientific experiments. OER, such as YouTube videos, were therefore used to replace the hands-on activities.

Seeking information

The teachers identified seeking information, with 43 chunks (40%), as the second most common use of OER during STEM sessions. Specifically, OER was used to teach STEM content (33 chunks) and support further student learning (9 chunks) (see Table 3).

Each syllabus included the learning outcomes to be achieved, the concepts students will learn in each session, and the related OER. Students often had to search for additional OER to study all the concepts listed in the syllabi as the list of OER did not cover all concepts. However, T1 pointed out the difficulty in preventing students from using specific references. It was found that some OER used by the students were too advanced for the required learning outcomes. STEM education and its syllabi is open to any resources. T5 and T3 agreed with T1 and emphasized the importance of the syllabi in open STEM education environments in serving as a guide to limit students` searches for OER based on specified parameters. Students were encouraged to go beyond the materials and textbooks suggested by the teachers and to learn various STEM topics that are freely accessible to them. T5 and T6 commented that this openness encourages students to use OER, especially videos, to confirm and expand their understanding of topics studied. In this open learning environment, students were required to conduct online searching to understand the concept or the topic of the session. All teachers found this process to help students pinpoint the central concept. The teachers also agreed that when students search by themselves and identify the key concept, they do not forget the information as easily.

Teachers sometimes guide students in utilizing OER for further learning beyond what they should learn in class. T1 shared some messages from former STEM students, now university students, telling her that they are using the same references she recommended to study from during their STEM school days. Teachers also emphasized the role of OER in supporting students' research. STEM students often participate in national and international high school competitions and to prepare for those competitions they use various OER, especially academic and scientific research papers, as references for their projects. S3, a grade 12 student, commented that "without my OER computer stored digital library, I would never have been able to enter any competition and win" and complained that most of the STEM teachers lack the advanced knowledge needed to win such competitions. The teachers agreed that some pupils have a greater understanding than their teachers in some areas.

Developing student competencies

The third pedagogical purpose of using OER, measuring 17 chunks or 16% of the total chunks, was to develop students' competencies. As seen in Table 3, 11 chunks were on improving students' active learning skills while the remaining six (6) chunks were on achieving independent learning skills.

Teachers utilized OER to develop students' higher-order thinking skills, such as debating and critical thinking and to develop lower-order thinking skills such as group discussion, which

are both essential for active learning. T4 explained how dividing videos into chunks enhanced students' thinking skills during group discussion. Showing a short segment of the video prior to discussion helped students develop a better understanding of a discussion topic step-by-step so building confidence to discuss the topic, in full, with their team members. Three teachers reported using OER to enhance students' peer coaching skills. T1 reported that some of the students used MOOCs or other OER and explained the content to fellow students. T5 mentioned that sometimes students explained a new topic of which the teachers were unaware. T6 used debate activities to develop and utilize students' analytical and critical thinking skills.

Students reported what they have learned from pdf materials and presented and defended their opinions. It was noted that they understood that locating OER which contained good content and were written logically is the key to improving their debating skills. T4 reported that problem-solving skills were acquired while using OER, in which students were tasked with solving real-life problems. Students also reported using all OER available to understand the problem before taking systematic steps towards solving it.

Teachers also used OER to enhance students' independent learning skills, allowing them to take control of their learning process and assume responsibility for their learning. The OER also aided in developing students' confidence which, in turn, increased learning success. T1 stated the freedom given to students in selecting their resources helps develop information evaluation skills in assessing whether certain resources enhance their performance. As the students have to decide which materials are more beneficial, they went through a lot of materials thus acquiring evaluating skills which helped them assess the quality and usefulness of materials. As T3 and T6 commented, while selecting their own resources, students also developed "self-directed learning skills," which they applied to new learning. S1 said, "I learned about this note-taking strategy when watching a video. It was very helpful for me, and I advised my friends to use it. I then explained it to my teacher, he found it interesting and now uses it in our class. I am happy because he always mentions my name when he applies this strategy". S9 added that a teacher's encouragement and praise boosted her confidence.

Types of OER used for each pedagogical purpose

Teachers reported using certain OER more often than others in accordance with pedagogical purposes (see Table 4).

Videos were the most frequently utilized OER to maintain student motivation. Research papers and online quizzes were the least effective in bringing interest and enjoyment to students as they demanded more effort and time, causing stress and anxiety in students.

Pdf references were the most frequently used OER to provide information and course content; the reason was that instead of adopting hardcopy textbooks, the school used online textbooks as its main instructional materials. T1 stated, "If you ask me to describe what STEM is, I will say it is an open education system. For students to learn and for us to teach, OER is our STEM textbooks".

Reading materials were the most common OER used to develop student competencies. Teachers reported reading pdf references improved low-order thinking skills, such as group discussion, and high-order thinking skills, such as critical thinking. T3 explained that students comprehend the information better when read as texts as it stimulates their thinking, allowing them to present their understanding logically. S7 reported, "Reading materials in English helped me improve

my thinking strategies. I can easily express my ideas in Arabic but am not used to defending my opinion in English. The more I read texts in English, the more I learn how ideas are presented in English".

Table 4

Types of OER Used inside STEM Sessions according to Each Pedagogical Purpose

Types of OER	Maintaining Motivation	Seeking Information	Developing Student Competencies
pdf references (online textbooks)	3 chunks (6%)	18 chunks (42%)	5 chunks (29%)
Videos	20 chunks (43%)	6 chunks (14%)	3 chunks (18%)
Online quizzes	3 chunks (6%)	0 chunks (0%)	1 chunk (6%)
Educational websites	7 chunks (15%)	6 chunks (14%)	4 chunks (23.5%)
Research papers	2 chunks (4%)	2 chunks (5%)	0 chunk (0%)
Other	12 chunks (26%)	11 chunks (25%)	4 chunks (23.5%)
Total	**47 chunks (100%)**	**43 chunks (100%)**	**17 chunks (100%)**

Discussion

OER for content learning and teacher training

Previous studies in advanced countries (Jhangiani et al., 2016; Jung & Hong, 2016; Jung et al., 2016) reported OER being frequently used as supplementary resources, mostly to promote student motivation and improve teaching effectiveness in higher education. Contrastingly, this case study, conducted in a STEM high school in a less advanced country, found OER to be used as the main resource for teaching and learning. The school, not having a fixed curriculum with any formal textbooks, required the students and teachers to use OER as their textbooks, not just to promote motivation, but also to study new content and develop learner skills necessary for inquiry-based STEM learning. This highlights the importance of selecting high-quality OER, especially in a context where OER replaces traditional textbooks and is used as the main source for content learning. As noted in several studies (Erdogan & Stuessy, 2015; Peters-Burton et al., 2014; Shernoff et al., 2017), appropriate and continuous professional development is a necessity for STEM teachers to discover, create, adapt, revise, and manage high-quality OER that are both relevant and effective in achieving desired outcomes in STEM learning.

An argument can be made that schools must provide training and update teachers on selecting relevant, high-quality OER and adapting them for their students. However, considering the lack of resources for STEM schools, in less advanced countries, to offer professional development, one feasible solution appears to be the utilization of several freely available OER training modules, developed by various organizations such as UNESCO, OER Africa, OpenStax, Open Education Consortium, and others, as self-training materials, followed by peer tutoring and support sessions.

OER for student motivation

Teachers use OER for maintaining student motivation, and this is consistent with previous studies explaining how OER motivates students and keeps their attention in diverse educational settings (Jung & Hong, 2016; Kew et al., 2018). Motivation is what learners want to achieve or desire, and it decides the direction and the magnitude of student behavior towards learning (Keller, 2010).

Keller's ARCS model is of a motivational design helping teachers identify problems with student motivation and design strategies which can be used to make instruction match the interests and needs of students in the four categories of ARCS. Each of these categories suggests sub-categories of motivational strategies to incorporate into instructions, as shown in Table 5.

When applying the ARCS framework to the nine codes under the category of maintaining motivation seen in Table 3, it can be seen that seven codes are related to Attention, as shown in Table 5 below. The teachers observed tend to apply a wide range of strategies when using OER, mostly to gain students' attention. While the teachers promote inquiry arousal by engaging students in such activities as brainstorming, project-based learning, and addressing learning challenges with OER, they do not apply two other important attention strategies for effective inquiry-based learning in STEM education, namely, "questioning" and "hypothesis generating" as also indicated in Pedaste et al. (2015). This may be explained by the lack of teacher competencies in effective OER use or the lack of teachers' understanding of inquiry-based pedagogies (Fitzgerald et al., 2019).

Table 5

Assignment of ARCS Categories and Sub-categories into Codes Emerged from the Study

ARCS Model Categories and Sub-categories		Codes Emerged from the Study
Attention	Perceptual Arousal	1. Real-life connection 3. Visual media attention
	Inquiry Arousal	2. Project-based learning 6. Brainstorming 8. Challenges 9. Activities
	Variability	4. Varieties
Relevance	Goal Orientation Motive Matching Familiarity	N/A
Confidence	Learning Requirement	5. Time management 7. Session closure
	Success Opportunities	N/A
	Personal Control	
Satisfaction	Intrinsic Reinforcement External Reward Equity	N/A

Another important observation from Table 5 is that the teachers did not use strategies to promote relevance and satisfaction when utilizing OER. This observation explains why teachers encounter difficulties modifying and producing OER on their own to meet the demands and expectations of their students in the future. According to El Nagdi and Roehrig (2020), most teachers attribute their lack of knowledge and skill in using technology and generating OER to a lack of professional development opportunities.

Confidence is linked to time management and session closure since they teach students about the learning requirements for each session. According to the teachers, students pay more attention when the session time is carefully organized and follow a regulation class plan that incorporates OER in innovative ways. This finding aligns with Mega et al. (2014), who argue the positive effects of time management on self-regulated learning, motivation, and learning outcomes.

OER for building student competencies

Inquiry-based STEM learning focuses on engaging students in the learning process and applying the knowledge learned to real-world problems. Students also need to build competencies for successful STEM learning, such as active and independent learning skills. The present study reveals that OER is used not only for gaining and maintaining student motivation along with teaching new concepts but also for developing some student competencies required for successful STEM learning. Its findings are consistent with a recent study conducted by Rahayu and Sapriati (2018) that states students' critical thinking skills are further developed using OER. These competencies are critical for equipping students with the knowledge, skills, and attitudes needed to learn beyond graduation from STEM schools successfully.

The OECD Learning Framework for 2030 states that any type of education needs to equip students with skills and competencies to become active, responsible and engaged citizens and identifies a broad range of cognitive, and meta-cognitive skills such as critical thinking, creative thinking, problem-solving, learning to learn and self-regulation (OECD 2018). The present study's findings show how students are gaining various competencies while integrating OER as part of their learning process and categorically suggest that OER use effectively supports the OECD Framework and equips STEM students with 21st-century competencies.

Conclusion

STEM teachers were found to be integrating pdf references, videos, educational websites, and online quizzes as OER throughout the STEM teaching and learning process. The study identified three pedagogical purposes of OER use in the context of STEM education in a less advanced country: 1) maintaining motivation, 2) seeking information, and 3) developing student competencies. Teachers reported using certain OER more often than others in accordance with pedagogical purposes. Videos were the most frequently utilized OER to maintain student motivation. Pdf references were the most frequently used OER to provide information and course content. Reading materials were the most common OER used to develop student competencies. Findings also showed that the integration of OER in STEM education promotes student engagement and provides students with the opportunity to open their minds, widen their visions, and explore the outside. Therefore, a strong argument can be put forward that OER has a positive influence in motivating, teaching new content, and developing 21st-century competencies for STEM school students in Egypt and other developing nations.

The study contributed to the limited literature on using open educational practice applications such as OER in K-12 education (Tlili et al., 2021). Findings of this case study question if having textbooks is essential for student learning and whether OER can substitute them in the future. The role of textbooks is to deliver specific knowledge through the medium of text where students can learn directly from what they are reading with a limited analysis process. By providing preselected content, textbooks set an agenda and guide students' minds to what they will learn. Conversely, they tend to limit the students' intellectual curiosity and inquiring mind. OER, offered in different modes and types, may have a better potential to meet the different learning needs and styles of students and even improve their ability to learn (Davy, 2007; Grasha & Yangarber-Hicks, 2000). Having stated this, the argument needs to be confirmed empirically in future studies.

Some limitations of the study need to be pointed out with a view towards future research. The study was conducted at only one STEM school in Egypt. It would be desirable to consider the

effect of varied geographical locations and investigate more than one school. Also, data were collected and reported across different STEM subjects. It would be interesting to analyze the results according to each subject separately and possibly identify different methods of utilizing OER across varied STEM areas.

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