Can YouTube videos facilitate teaching and learning of STEM subjects in high schools?

Wilson O. Otchie, Margus Pedaste, Emanuele Bardone, and Irene-Angelica Chounta.

Abstract—Science is a body of knowledge that explains the phenomena of our world through observations and experimentation. Many nations have developed because of the attention they give, and the investment they put into science education. However, globally, students’ interest in science tends to wane and so is a drop in their numbers as they transition from elementary to secondary schools. Many factors were associated with the cause in the drop of students’ numbers and interest. Since observations and experiments are the fundamentals in science teaching, we propose the use of YouTube STEM videos as effective learning resources for the teaching of science in high schools. This approach could potentially help to bridge the gap between theory and practice and likewise help to reverse the perception about science. For instance, YouTube STEM videos could motivate students, especially those in the underprivileged schools that lack the basic science resources to take up science programs. The study reviewed previous studies and conducted an empirical study with selected Estonian high school teachers to have their perspectives and insights into using YouTube videos to teach STEM subjects. Interviews with open-ended questions were administered to participants to have their perspectives and insights on teaching STEM lessons with YouTube videos. Results show that all participating teachers find YouTube videos more interactive and effective for STEM teaching and learning. Hence, the increase in the frequency of its use in teaching.

Index Terms—High schools, STEM, STEM teachers’ perspectives, YouTube STEM videos.

I. INTRODUCTION

The advancement in technology and the surge in appetite for digital devices as a way of life have turned 21st-century education into a melting pot of the technological ecosystem. This makes the current generation of high school students more dependent on digital resources and up-to-date information. Hence, a big challenge to science, technology, engineering, and math (STEM) teachers. For instance, they are expected to use this variety of digital resources to meet the expectations of their students. Nonetheless, this is not the case. Students’ interest in STEM subjects is dwindling and the reasons are not far-fetched.

STEM subjects consist of but not limited to Biology, Chemistry, Physics, and Math. These are more practical and inquiry-based subjects that are mostly taught with activities such as observations and experiments. Experiments help students to interact with scientific tools and natural resources to enable them to understand and develop a positive relationship with their environment. That said, the teaching of STEM subjects - like Physics, Chemistry, Biology, and Math - in high schools is perceived to be more driven by concepts and theories rather than activities and experiments [1]. Since the last two decades, this problem has potentially led to a persistent drop in students’ numbers and interest in STEM programs particularly as they transition from elementary to high school education [2], [3], [4].

Most teachers are still using the traditional method of teaching STEM subjects, which is more of a teacher-centered approach, thus making the subjects more abstract and less interactive [5], [6], [7].

The lack of science laboratories and resources in most schools in addition to the cost to train STEM teachers which many schools could not afford [8] cannot be underestimated. From the student’s perspectives, STEM teaching lacks the most practical components, thus focusing more on concepts and theories [9]. Others are uncertain and reserved especially when it comes to working with corrosive acids and other dangerous chemicals. According to them, only the sight of living or dead animals are enough grounds to develop disaffection for the subject [8]. Besides, students’ lack of interest in STEM subjects stems from the fact that most topics are not so relevant and applicable to students’ real-life and social environment [10]. Others claim STEM-related professions are seen to be challenging but earnings are relatively low [11].

Currently, the focus on education is gradually shifting from the previous acquisition of knowledge to a more practical and realistic approach through critical thinking. Besides, STEM-related jobs are now technologically and skills-driven, and this could be a wake-up call to STEM teachers to scale-up their teaching skills. This development necessitates a departure from the traditional methods of teaching STEM subjects to a more pragmatic and interactive one that could equip the STEM student with the skills necessary for them for the future job market. In this day and age, there is a repertoire of technology tools at the disposal of STEM teachers that could potentially augment conventional STEM experiments, thus enhancing teaching and learning. Computer-assisted learning (CAL), virtual reality (VR) and augmented reality (AR) technology, wikis, blogs, and social media sites like Facebook, Twitter, and YouTube are innovative tools that could potentially enhance the work of teachers and engage and motivate contemporary STEM students to learn.

The rationale for conducting this study is the fact that there is a continues decrease in the number of STEM students globally due to the reasons mentioned earlier. Similar concerns in the approach of teaching science lessons were identified in Estonian science teachers [6]. Most research theories have established that learning becomes more effective when pictures are introduced [12], [13]. Consequently, YouTube, a social media app, has the affordances that could potentially address this problem. The study, therefore, looks at how YouTube videos could be integrated into

Received July 25, 2020, Accepted August 23, 2020, Published online September 30, 2020.

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teaching STEM subjects in high schools and how teachers could maximize it’s impacts in the teaching process. As an interactive social media tool, YouTube has affordances that could potentially transform it into an effective pedagogical tool for teaching including STEM subjects. Launched in 2005, YouTube usage has soared and currently has 2 billion active users worldwide [14]. Thus, making it the second most used social media app after Facebook. That said, the purpose of YouTube is for individuals to create and upload video content for sharing. This means all kinds of scientific information and resources could be available for STEM teachers and students in YouTube [15]. Hence, the anxiety among stakeholders to integrate YouTube video as a tool for teaching STEM education [16], [17], [18]. There are studies on learning with videos, thus outlining how YouTube videos could be incorporated into STEM lessons [19]. However, the study tries to find answers to the following research questions.

RQ1: How do teachers use YouTube in teaching STEM?
RQ2: How does YouTube enhance students’ interest in STEM?
RQ3: How often STEM teachers use YouTube videos in their lessons?

II. LITERATURE REVIEW

There is a large volume of published studies describing the role of videos as potentially effective educational tools [26], [27], [28], [29], and YouTube videos form a classical example. As a content-generating social media app, YouTube video has grown in scale and scope to become a house-hold name. Thus, it allows individuals to create, upload, view, and share video contents on its platform, like personal video clips, musical videos, videos on wildlife, marine and terrestrial ecosystems, human anatomy, the Galaxies, the Solar system, etc. [20]. The list is endless. Subsequently, studies have established the effectiveness of multimedia learning [25]. Therefore, videos become potential tools to send messages across and this could also be very effective pedagogically according to literature. For instance, there are many potentials in YouTube apps that makes it a suitable multimedia tool and the preferred platform for politicians, universities, hospitals, NGOs, etc. to propagate their messages remotely to their global audience [20]. In education, using videos as a form of multimedia learning dates back many years in history. For instance, the famous statement by Thomas Edison in 1922 that, “the motion picture is destined to revolutionize our educational system and that in a few years, it will supplant...the use of textbooks” [30] (p. 9), and many other similar interventions that came which ultimately failed to see the light of day (ibidem). According to [30] (p. 17), “most teachers used films infrequently in classrooms.” However, despite these failures, videos are still seen as potential educational tools. For example, YouTube videos are potential e-learning tools, thus allowing teachers and students to create, upload, and share learning materials and resources [31].

There are many studies done on the pedagogical potentials of YouTube [32], [33], [34], [35]. However, not much has been said about how YouTube videos on STEM education could facilitate the distribution of knowledge across multi- and cross-disciplines. For example, climate change topics cut across disciplines, from Biology, Chemistry, Physics, Environmental science, among others. Again, most studies focused on colleges, and little was said about its impact on high school education. Furthermore, a lot of studies focused on students’ perspectives on learning with YouTube videos but little was heard about teachers’ views. It’s also significant to know how YouTube videos are articulated pedagogically and the constraints and challenges if any. Again, it is important to mention that YouTube could be combined with other social media apps like Google Classroom, Facebook, etc. for more effective pedagogical results. [31]. Learning resources such as texts, images, audio, and YouTube video links could be uploaded and shared with students via Google Classroom. Again, a lot of studies on STEM education with YouTube are needed to establish the pedagogical advantages and potential constraints.

For example, a study was conducted by [33], to ascertain the pedagogical impact of learning STEM subjects with YouTube videos. In this study, 385 students from two colleges were asked in a survey to provide their perspectives and insights on the usage and effectiveness of YouTube videos as pedagogical tools in learning biology and chemistry. Results from the study shows that 56% of participating students agreed that YouTube videos were useful and related to topics in Biology and Chemistry. Also, the study found that over 75% of participants always search YouTube for educational content. Cherif and colleagues then concluded that most participants use YouTube videos for educational purposes, however, the study was unable to establish the potentials constraints and challenges students may encounter during the process.

Similarly, [20], surveyed 596 undergraduates US college students who took physics laboratory courses at different levels during their program. They found out that many students do consult YouTube videos to learn about the physics topics they encounter in the classroom. However, they also observed this practice to be more prevalent amongst college students than high school students [20].

According to a more recent study by [16], YouTube videos were used for teaching and learning of Chemistry in a high school. A quasi-experiment was conducted on two groups of participating students: Experimental (n=47) and control groups (n=60) respectively. This study, based on investigating the effectiveness of introducing open-source YouTube videos in the teaching and learning of Group Properties, a topic in Chemistry. After conducting a pretest and post-test protocols, it was found out that 1) at the pretest, the experimental group recorded 12% while the control group had 5% score and 2) during the post-test, the experimental group recorded 25% performance in learning with YouTube videos and control group recorded 5%. Therefore, the performance of the experimental group was doubled between the pre and post-test while the control group score remained unchanged. Nevertheless, the pass rate differences between the groups were only statistically significant for the post-test (p = 0.001) [16]. Again this further demonstrates the pedagogical potentials of using YouTube videos as tools during STEM lessons.

A. Theoretical perspectives of multimedia learning

Many claims continue to emerge about the potential use of multimedia tools in education. But how can we accept these claims to avoid repeating past mistakes? The solution is not far-fetched. A rational explanation is by using instructional techniques that are grounded in research-based theory. The study delves into Mayer’s cognitive theory of multimedia learning as the lens to have a world view on this subject. Historically, Mayer’s concept had its origin from Paivio, Sweller, and others who had established the importance of multimedia in learning [20], [21], [22], [23], [24].

According to Mayer’s cognitive theory of multimedia learning, “people learn more deeply from words and pictures than from words alone” [25]. This forms the origin for Mayer’s theory which suggests three key protocols when it comes to learning with multimedia:

1. There exist two distinct channels when it comes to information processing. Thus, the auditory and visual channel otherwise called Dual-Coding theory;
2. Each of the channels has a limited capacity (similar to Cognitive Load);
3. Learning is a practice that filters, selects, organizes, and
integrates information based on previous knowledge.

To Mayer, humans can only process a limited amount of information at a time as they create mental pictures to make the incoming information more meaningful. Also, Mayer recognizes the three memory stores and their distinct and coordinated roles. Thus, sensory memory receiving, and temporarily storing information which is then transferred to working memory, for onward processing and creation of concepts. This is later sent to the long-term memory for permanent storage. Mayer’s concept brings to the fore the fact that the brain cannot interpret multimedia presentations like texts, pictures, audio information in an equally selected form, instead, these are selected and structured to produce more consistent, coherent, and rational mental concepts. Mayer’s theory in addition to others lays a firm premise to our choice of using YouTube videos as potential tools for the teaching and learning of STEM subjects in high schools.

III. METHODS

The use of qualitative study is a well-established approach in giving a descriptive account [36],[37],[38] from interviews conducted between May-September, 2019 with selected high school teachers in Estonia. The benefit of this approach is that it addresses the how and why research questions and enables a deeper understanding of experiences, phenomena, and context [39].

We chose Estonian teachers as participants because in Estonia there is high penetration, appreciation, and use of the internet and other digital platforms among the Estonian population [6]. The study employed a purposive sampling protocol [40], thus targeting high school teachers with experience in teaching with YouTube videos to share their insights and perspectives on the digital resource. After a series of email correspondence, detailing to teachers the purpose of the study, 11 teachers eventually agreed to participate in the study. Thus, they voluntarily signed the consent forms accordingly. In terms of profile, all the 11 teachers (91% =female) have had between 2-35 years’ experience of teaching and 2-8 years of using YouTube as a teaching tool (see Table 1). Semi-structured interviews with open-ended questionnaires were administered [40]. This was conducted remotely via Zoom and lasted between 25-40 minutes. The video transcripts were transcribed into textual format. Inductive coding was used to create categories and sub-categories from the texts to address the following overarching questions. 1. How do teachers use YouTube in teaching STEM? 2. How does YouTube enhance students’ interest in STEM? and 3. How often STEM teachers use YouTube videos in their lessons?

Table 2 illustrates teaching as a category and meaningful use as a sub-category. There are also some excerpts from the interview with participants that focused on interaction, information, and access as outcomes of teaching and learning with YouTube.

### TABLE II

<table>
<thead>
<tr>
<th>Category</th>
<th>Sub-Category</th>
<th>Result</th>
<th>Excerpts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teaching</td>
<td>Meaningful use</td>
<td>Interaction</td>
<td>“...My students watch a YouTube video to see how the bonds in the double-helical structure of DNA are formed …very interactive, interesting and revealing” (PT003).</td>
</tr>
<tr>
<td>Interaction</td>
<td></td>
<td></td>
<td>“I select for example a short YouTube video on the Solar System during a Physics lesson which the students observe how the planets revolve around the Sun……and then they answer some questions in their workbooks” (PT009)</td>
</tr>
<tr>
<td>Information</td>
<td></td>
<td></td>
<td>“…..the students watch YouTube video during a lesson to hear how some scientific words in Biology are correctly pronounced” (PT006)</td>
</tr>
<tr>
<td>Access</td>
<td></td>
<td></td>
<td>“… students can search for information with YouTube so quickly to do their assignments” (PT0010)</td>
</tr>
</tbody>
</table>

Table 3 shows an overview of learning affordances on YouTube. Learning affordances and flexibility to learn are codes for category and sub-category respectively. Excerpts from the interview were cited which resulted in outcomes like availability of teaching notes, more student activity among others.

### TABLE III

<table>
<thead>
<tr>
<th>Category</th>
<th>Sub-Category</th>
<th>Result</th>
<th>Excerpts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning affordances</td>
<td>Flexibility to learn</td>
<td>Availability of teaching notes</td>
<td>“...when a student misses my lesson or cannot understand, he can go to check at home or watch the video what others have done and do it later” (PT009).</td>
</tr>
</tbody>
</table>

IV. RESULTS

The study looks at how YouTube videos could be integrated into teaching STEM subjects in high schools and how it impacts teaching. As an interactive social media tool, YouTube has some affordances that could potentially transform it into an effective pedagogical tool for teaching including STEM subjects. The video transcripts were transcribed into textual format. Inductive coding was used to create categories and sub-categories from the texts to address the following overarching questions. 1. How do teachers use YouTube in teaching STEM? 2. How does YouTube enhance students’ interest in STEM? and 3. How often STEM teachers use YouTube videos in their lessons?

Table 2 illustrates teaching as a category and meaningful use as a sub-category. There are also some excerpts from the interview with participants that focused on interaction, information, and access as outcomes of teaching and learning with YouTube.
first research question, here is what one participant said, “I select for example a short YouTube video on the Solar System during a Physics lesson which the students observe how the planets revolve around the Sun…..and then they answer a list of questions in their workbooks” (PT009). Similarly, a teacher could pause the video intermittently and explain the process or even ask the students to reflect and comment. In the case of STEM subjects, videos can play a very critical role. For example, apart from visual clarity, videos provide the opportunity for the student to see how for example chemical and physical reactions in Chemistry occur or view the process of a life cycle of a plant or an animal in a Biology lesson. This however makes STEM lessons very interactive, interesting, and more realistic. For example, drawing and labeling of scientific equipment, living things, physical or chemical processes, etc. which takes a lot of the study time has now been replaced with videos. Teachers can now focus more on supervision, explanation, and assessment.

Furthermore, YouTube videos on scientific experiments could be used to complement the traditional hands-on approach. Thus, fewer resources will be used. For example, no broken glassware, no chemicals will be spilled or used and no fear for a potential accident. A video on the forest or marine ecosystem could be so graphic that there is no need to embark on an ecological trip with the students. The life cycle of the dangerous animals like the lion, cobra, etc. could be watched remotely. Thus, eliminating the potential fear factor. Notwithstanding, students have the opportunity to watch these videos again when they get home.

The second question in this research was to ask teachers how YouTube videos enhance students’ interest in STEM subjects. Essentially, YouTube videos make it possible to create virtual classes for students across remote locations. For example, YouTube videos of STEM experiments in Chemistry, Biology or Physics could be screened in classrooms, thus removing potential risks and any fear a few students may entertain for traditional science experiments. For example, accidentally spilling corrosive acids or breaking glassware or even encountering live reptiles, amphibians, caterpillar, etc. [8]. This provides more potential benefits to students than the traditional face-to-face or “brick and mortar” approach to teaching and learning. Consequently, it becomes possible for learning to take place in a virtual environment which we describe as e-learning. YouTube STEM videos could augment many science practical lessons especially those schools in underserved communities that lack the needed scientific resources. Furthermore, the interactive nature of these resources potentially places the students at the center of learning. Thus, the students become active participants in the learning process as they actively construct learning in a way as espoused in the constructivists’ school of thought. According to one participant, “…you can use the latest materials. So today instead of a textbook, I would look at the Notre Dame fire because it happened yesterday” (PT006). This provides students with current information that most textbooks lack.

The last question for the study was to determine how often teachers use YouTube videos during their lessons. Table 4 emerges as the category that illustrates the frequency teachers use YouTube videos in their lessons. During the interview, it was discovered that almost all teachers use YouTube videos more frequently in their lessons. Besides, this was not consistent with previous studies where teachers use social media relatively less for teaching, learning, and research [43]. However, it was noted that all participants depend on YouTube videos for most lessons, but others combine it with Facebook, Google classroom, and their school’s learning

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**TABLE IV**

<table>
<thead>
<tr>
<th>Category</th>
<th>Sub-Category</th>
<th>Tool</th>
<th>Excerpts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency of use</td>
<td>Classroom</td>
<td>YouTube</td>
<td>&quot;I use Ted-Ed YouTube videos a lot in class.” (PT001).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>YouTube</td>
<td>&quot;I use YouTube in all my lessons. It has a lot of good videos.&quot; (PT006).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>YouTube</td>
<td>&quot;I use SM (YouTube) every day in my lessons because the videos give different perspectives&quot; (PT003).</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Google</td>
<td>I share YouTube video links to my students using google classroom” (PT007).</td>
</tr>
</tbody>
</table>

**V. DISCUSSIONS**

Several reports have shown that YouTube videos, particularly on STEM topics have pedagogical significance and could potentially be tools for teaching and learning purposes. An initial objective of the study was to understand how high school teachers use YouTube videos to teach STEM lessons and their pedagogical impact. Notwithstanding the reviews done, we made a content analysis to have some insights and perspectives about teachers’ pedagogical encounters with YouTube videos. Recorded video transcripts from the 11 participating teachers were transcribed and inductively coded into categories to enable us to answer the overarching research questions.

The first question in this study sought to determine how teachers use YouTube videos in their lessons. Essentially, teaching with videos does not only make teaching interesting and interactive, it as well enhances learners’ understanding [25]. To teach a lesson with YouTube videos, the teacher must develop a positive attitude with technology, thus making this study consistent with previous studies [41], [42]. A positive attitude motivates the teacher to create or search for videos that have relevant and accurate pedagogical information on that lesson. Besides, the videos must be short to improve students’ concentration and learning [29]. Concerning the
management systems. Subsequently, they use it daily which according to one participant, “YouTube video gives them different perspectives” (PT003). Thus, making their teaching more innovative and interactive. However, one participant uses YouTube only when he finds it necessary. According to him not all his lessons require technology. Ultimately, YouTube videos are potential pedagogical tools which could make teaching and learning more interactive and interesting [16], [19], [33] Finally, the findings from this study reflect those of previous studies including [16], [19], [33] which also establish that YouTube is a potentially effective pedagogical tool and could enhance the teaching and learning of STEM subjects.

VI. CONCLUSIONS

This study set out to establish the veracity in using YouTube videos as a pedagogical tool for teaching in high schools. One of the more significant findings to emerge from this study is that teachers could use YouTube videos on STEM topics to make teaching more realistic, interactive, and relevant to the needs of the student. This could potentially motivate more students to take up science. Certainly, the study establishes that YouTube videos have come to stay. Hence, many teachers have seen it as a tool that could potentially bridge the learning gap, thus promoting better and effective teaching and learning. Many studies have confirmed the potential pedagogical potentials in YouTube. Subsequently, STEM subjects have been experiencing lower students’ enrolment due to a cocktail of reasons mentioned. That said, it’s time educational stakeholders speak with one voice on the issue of technology integration in the high school curriculum. YouTube integration into teaching could potentially reverse the tide and motivate more students to turn to STEM courses. The study recommends that, teaching science lessons using YouTube videos could help those deprived schools without the requisite science resources. Again, further studies should focus more on how high school teachers and other stakeholders could create video version of the practical topics in the science textbooks going forward. It cannot be said that this study was conducted without any constraints. Our choice of English as the language for the study was one major constraint to getting more teachers to participate in the study because most teachers would have preferred the interview in Estonian which is predominantly spoken.

REFERENCES

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