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Rocks Really Rock: Generating positive impacts in middle and high school students' attitudes toward geology via Web Google-Earth electronic field trips.

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Abstract. Earth Sciences (ES) are relevant to society and its relationship to the Earth system. However, ES education, in K-12 environments in the United States, face several challenges including limited exposure to ES, lack of awareness of ES careers, and low ES literacy. International associations have recognized these challenges and recommended that Earth scientists improve the public's perception of the relevance of ES. In recent years, informal science communication/outreach platforms such as the "Streaming Science" model of electronic field trips (EFT), which connect K-12 classrooms with STEM professionals, have gained popularity as an educational technology tool. EFTs are inexpensive, have spatiotemporal benefits, and have proven an effective informal science education pathway for introducing STEM content into formal classrooms to increase positive attitudes and interest in STEM careers. Nevertheless, EFTs in ES for K-12 environments have not been widely disseminated, and their impact in ES education has yet to be studied.

This study presents the creation and implementation of an EFT in geology called "Rocks Really Rock: An Electronic Field Trip across Geological Time." The program was implemented in seven schools in Spring 2022. The EFT was built in web Google Earth and had six stops that featured pre-recorded videos recorded in different locations in Idaho-U.S. The lead presenter/author used multimedia and science-communication strategies such as storytelling to develop and teach concepts related to geologic time, rock formation, and landscape-forming geological process. The content aligned with four specific topics listed in the National Science Foundation's Earth Sciences Literacy Principles and intersected with the Next Generation Science Standards for middle school classrooms.

Participating students (n = 120) completed a post-assessment after the program implementation to evaluate its impact. Results showed the EFT positively impacted students' attitudes toward geology, geology careers, and their perceptions of geology literacy. We identified the three main factors that determined positive attitude change of K-12 students toward ES were: 1) the use of videos and Web Google Earth platform for creating outreach materials for K-12 students, 2) the use of storytelling to craft the content of the EFT, and 3) the asynchronous interactions between teacher-student-scientist. The results indicated a statistically significant positive change in attitudes toward geology, suggesting that participating in the EFT increased students' positive attitudes toward ES. These findings demonstrate the potential of expanding EFT to other ES fields and reaching

middle/high school students. We suggest that EFTs are effective outreach tools that can address the challenges in ES education and can be extended to other ES areas and distributed to students in middle/high schools and homeschools, to support science educators in ES education.

1 Introduction

Earth Sciences (ES) education in U.S. K-12 environments faces multiple challenges such as: 1) low exposure to ES in the science curricula, 2) low awareness of ES careers, and 3) poor literacy of ES concepts (Adetunji et al., 2012; Hoisch & Bowie, 2010; LaDue & Clark, 2012). International associations, ES educators, and K-12 teachers have recognized these barriers (GSA Position Statement- Promoting Earth Science Literacy for Public Decision Making, 2013; King, 2013; LaDue & Clark, 2012; Petcovic et al., 2018), and they have emphasized the need to strengthen K-12 ES education, develop ES-literate citizens, and advocate for the implementation of informal science-learning strategies (outreach) in K-12 environments. However, there are few studies that have quantitatively assessed the impact of individual ES' outreach strategies on students.

ES outreach via electronic field trips (EFTs) is a potentially effective way to address some of the challenges in ES K-12 education. In recent years, the outreach format of EFTs has grown in popularity, engaging K-12 students and teachers in two-way conversations with subject matter experts. EFT models such as the Streaming Science model, have proven to be an effective outreach pathway for delivering science, engineering, technology, and mathematics (STEM) content to formal education environments such as K-12 classrooms (Adedokun et al., 2011; Beattie et al., 2020; Loizzo et al., 2019). The adaptability of delivering content in multiple formats (e.g., live-stream or pre-recorded video) and the ability of EFTs to use science-communication (scicomm) strategies (e.g., digital multimedia, storytelling) have proven to have a positive impact on students' perceptions and attitudes toward scientists, science careers, and science overall (Beattie et al., 2020; Dahlstrom, 2014; Loizzo et al., 2019). These changes in attitudes and perceptions can simultaneously influence interest in related careers and learning (Lyon et al., 2020; McNeal et al., 2014). Collectively, these findings demonstrate that the use of EFTs provides a unique opportunity to develop informal ES learning tools and bring them into formal K-12 education environments.

In the following study, we present the creation, implementation, and evaluation of a pre-recorded EFT in geology topics created in web Google-Earth called Rocks Really Rock: An Electronic Field Trip across Geologic Time. The EFT introduced middle-school and high-school students to the concepts of geologic time, rock formation, and landscape-forming geologic processes. The EFT had six designed stops shown on a map of the United States. Each stop featured a pre-recorded video of the lead author who used science communication storytelling strategies to explain geology-related topics that aligned with four specific topics listed in the Earth Sciences Literacy Principles (ESLP) (Wysession et al., 2012). The geology topics intersected with the Next Generation Science Standards for middle school classrooms (NGSS Lead States, 2013). In addition, we examined the implementation of the EFT using a quantitative design and evaluated the impacts of the program on K-12 school students via

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a post-assessment survey in three main areas: a) attitudes toward geology, b) attitudes toward geology careers, and c) perceptions of geology literacy.

2. Background Literature

2.1 Challenges of ES education and the role of outreach and science communication

Literacy and awareness of ES topics (e.g. atmospheric sciences, climate sciences, planetary sciences, environmental sciences, geology, and oceanography) are essential to understanding critical societal challenges related to the Earth system including climate change, natural resource management, natural hazards, access to reliable and safe mineral and energy sources, and planetary exploration, among others (Clary, 2018; Tillinghast et al., 2019; Wysession et al., 2012). Building an ES-literate society depends on high-quality education, and K-12 school settings have the potential to reinforce positive attitudes toward ES content and careers and build ES literacy (King, 2013; Levine et al., 2007; St. John et al., 2021; Tillinghast et al., 2019). However, only a small percentage of students in the United States receive formal education in ES, and literacy in ES is particularly low compared to other science fields and other countries (Gates & Kalczynski, 2016; Gonzales & Keane, 2011; LaDue & Clark, 2012; Programme for International Student Assessment & Organisation for Economic Co-operation and Development, 2019).

Low exposure to ES content in K-12 environments also impacts the lack of awareness of ES careers among both students and teachers, and the difficulty students have connecting science classroom content to career pathways (Brown & Clewell, 1998; Levine et al., 2007; Gonzales & Keane, 2011; Sherman-Morris et al., 2013; McNeal et al., 2014; Locke et al., 2018). For example, geology, a branch of ES, has had the lowest numbers for major recruitment compared to other STEM careers in the last decades (Levine et al., 2007; Locke et al., 2018). Some studies suggested that students who choose to study STEM majors generally make the decision during high school and even earlier (Maltese & Tai, 2011; Tai et al., 2006). Thus, growing interest in ES and improving recruitment to ES careers should begin with increased exposure to engaging STEM content, careers/majors, and raised awareness of future pathways during middle and high school.

Several strategies have been developed to support formal ES education and increase awareness and literacy such as integrating ES literacy standards into traditional science courses (Hanks et al., 2007; Levine et al., 2007; McNeal et al., 2014). For example, in 2011, various Earth scientists and educators created the Earth Sciences Literacy Principles (ESLP) (Wysession et al., 2012). The American Geosciences Institute (AGI) disseminated these principles, which define the important and essential ES information to be taught, to K-12 ES teachers (Wysession et al., 2012). Furthermore, in the United States, the Framework for K-12 Education (National Research Council, 2012), and the subsequent release of the Next Generation Science Standards (NGSS) created a guide for the core ideas and practices that all K-12 students should learn before graduating from high school (NGSS Lead States, 2013). The implementation of these standards introduced a significant amount of ES content into the high school curriculum and increased the emphasis on ES (LaDue & Clark, 2012; Lyon et al., 2020). However, even though the

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NGSS has placed ES as a core component of the secondary science curriculum, several challenges remain, including the lack of understanding or misunderstanding of ES-related concepts among college-bound students (Pyle et al., 2018), the deficiency of ES instructional resources, the lack of support for school-level ES instruction from the science education community, and the lack of ES-focused teacher training (King, 2013).

Altogether, these challenges in ES education call for a need for new approaches to support the ES K-12 curriculum (King, 2013), such as the reinforcement of students' positive attitudes toward ES through outreach and scicomm. Positive attitudes toward science are a set of affective behaviours such as (1) the manifestation of favourable attitudes toward science and scientists, (2) the enjoyment of science learning experiences, (3) the development of interest in science and science-related activities, and (4) the interest in pursuing a career in science. These behaviours can influence students' interest in science careers and in STEM learning ((Fitzakerley et al., 2013; Lyon et al., 2020; McNeal et al., 2014; Osborne et al., 2003). Researchers have commonly measured attitudes toward science using questionnaires with Likert-scale items, which ask students to use a rating scale to indicate a favourable or unfavourable opinion about a statement. The ability to use these responses in statistical analysis has made them a widely used and reliable tool for measuring attitudes toward science topics (Osborne et al., 2003).

Outreach and scicomm have the potential to have a positive impact on the development of positive attitudes toward ES careers and ES literacy. Outreach refers to the activities or processes whose main objective is to promote awareness of STEM in real life, the pursuit of STEM careers, and to motivate non-experts to learn STEM topics (Crawford et al., 2021; Jeffers et al., 2004; Vennix et al., 2017). Outreach can use scicomm strategies to achieve these goals because they have the potential to increase non-expert science-learners' comprehension (literacy), interest, and engagement (Dahlstrom, 2014), and can be used to increase positive attitudes toward STEM subjects and careers (Burns et al., 2003; Choi et al., 2020; Schmidt & Kelter, 2017). In addition, if the scicomm strategies are aligned with specific learning goals, they can have a positive impact in content area literacy (Hildenbrand, 2022).

2.2 Electronic Field Trips (EFTs)

Digital outreach strategies such as EFTs have shown the potential to extend scientific research and information about science concepts and careers to a range of formal, informal, and non-formal audiences, allowing viewers to visit virtually any locations around the globe (Beattie et al., 2020; Cassady & Kozlowski, 2008; Evelpidou et al., 2021). For example, The Streaming Science Project is an online outreach platform that includes college-student-created EFTs and other multimedia to introduce audiences to STEM topics and experts1F1F. The Streaming Science EFT model (Loizzo et al., 2019) connects science-experts with K-12 students by showcasing live webcasts or pre-recorded videos from various science fields. Using this approach, the Streaming Science EFT model has positively impacted students' perceptions and attitudes about scientists, science careers, and science in general (Barry et al., 2022; Beattie et al., 2020; Loizzo et al., 2019).

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EFTs can follow different technology formats, from partially to fully immersive augmented reality experiences (usually referred to as virtual field trips), to both pre-recorded and live-streaming video broadcasts, and they can be created using different platforms (e.g., ArcGis Stories, desktop and web-Google-Earth, and virtual reality platforms). Previous studies have shown that students can benefit from virtual field experiences, which have several advantages over in-person field trips, such as: 1) accessibility to learners with all types of abilities and socioeconomic backgrounds, 2) accessibility from any part of the world with an Internet connection, 3) suppression of logistics of in-person field trips such as time, transportation and high costs, 4) availability when sites cannot be visited due to safety conditions, time, weather, or health reasons, and 5) the ability for the audience to move through the content at their own pace (Carabajal et al., 2017; Cliffe, 2017; Evelpidou et al., 2021; Pugsley et al., 2022).

EFTs in ES-related topics have been created for formal education at the college level, collecting and processing visual, spatial, and informational data of a geological site of interest with which the user can interact to varying degrees (Barth et al., 2022; Dolphin et al., 2019). Some of these virtual field trips have been created to substitute classic field guides (e.g., Streetcar to Subduction to the San Francisco Bay Area) or to provide remote alternatives to real, in-person field trips in formal ES field education (e.g., virtual field trips during the COVID-19 pandemic) (Bond et al., 2022). These virtual experiences combine digital narratives with geological fieldwork observations, introduce information about a geologic field site, and provide an authentic sense of being at real geological sites (Cliffe, 2017; Dolphin et al., 2019; Granshaw & Duggan-Haas, 2012). Nevertheless, most of these EFTs have been used as an alternative education in ES majors, but they have not been designed with outreach in K-12 environments in mind. Thus, EFTs have the potential to become a widely used outreach strategy in both informal and formal learning environments, following pre-established models for K-12 outreach through EFTs, such as the Streaming Science model (Beattie et al., 2020; Loizzo et al., 2019).

This study examined the development, implementation, and assessment of an EFT called Rocks Really Rock: An Electronic Field Trip across Geologic Time. The EFT followed the Streaming Science EFT model (Loizzo et al., 2019) and a quantitative design to assess the impact of the program on K-12 school students through a post-survey in three main areas: a) attitudes towards geology, b) attitudes towards geology careers, and c) perceptions of geology literacy. The collaboration between scientists and K-12 environments, which this model has successfully tested in several contexts (Aenlle et al., 2022; Barry et al., 2022), provided a platform to positively impact students' attitudes and perceptions toward ES and ES careers using EFTs. In the next section, we describe the development of the EFT and the survey data collection in detail.

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3. Methods

3.1 EFT context and content development

This study developed, implemented, and assessed an EFT called Rocks Really Rock: An Electronic Field Trip across Geologic Time whose target audience was middle and high school students. The EFT consisted of six single-presenter explanatory videos (recorded in Idaho-US in Summer 2021) embedded in a Web Google Earth project, an open-access tool that allows project creators to geotag locations around the Earth and embed multimedia content. Each of the videos was linked to a specific geographical stop with geological significance within the context of the EFT content (Figure 1). The lead author used a storytelling approach to present the content at each of the stops, following a chronological order to tell the story of geological changes on Earth that can be observable in the rocks found in the field. The entire EFT took approximately 40 to 45 minutes and was publicly available online (See supplement link).

The expertise of the subject matter expert (this article's lead author) in the field of geology of Idaho was instrumental in developing the EFT. Ortiz-Guerrero has an academic background in geology and was in the process of finalizing her Ph.D. when she developed the program and assessment. This academic pursuit allowed her to acquire in-depth knowledge and expertise in the subject of the EFT. Furthermore, the EFT content featured her rock research and field sites in Idaho , thus she had familiarity with the regional geological features and their history, which allowed the authors to create a targeted and engaging learning experience for the K-12 students.

The EFT geology content was designed to align with the Next Generation Science Standards (NGSS) learning objectives in the Middle School Earth Sciences (MSESS) disciplinary core ideas, from three subcategories: 1) The History of Planet Earth, 2) Earth's Material and Systems, and 3) Plate Tectonic and Large-Scale System Interactions (National Research Council, 2012; NGSS Lead States, 2013). These NGSS standards also intersect with several of the Big Ideas listed in the National Science Foundation's (NSF) Earth Sciences Literacy Principles (ESLP) (Wysession et al., 2012). Table 1 summarizes the integration of these educational and Big Idea standards, which resulted in the design of the EFT to incorporate four key Big Ideas from the ESLP. The characteristics of each video, the recording location, and the associated ESLP and NGSS objectives are summarized in Table 2. A unique sub-website for the EFT was created on the Streaming Science platform, which included a description of the program, links to a registration form, and the teacher's guide. The teacher's guide was designed as a stand-alone document that included instructions for K-12 educators to go implement the EFT in their classrooms.

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3.2 Research Design

3.2.1 Participant Recruitment

Teacher and student recruitment was conducted after approval by the Institutional Review Board for Human Subjects Research at the University of Florida. Teachers in K-12 schools in the U.S. were recruited to participate in the EFT using the following methods: 1) direct email invitation through the Streaming Science educators' listserv in MailChimp, 2) direct email invitation to educators through the Scientist in Every Florida School program of the Thompson Earth Systems Institute at the Florida Museum of Natural History, 3) Streaming Science social media accounts, and 4) word of mouth through the lead author's personal contacts.

After teachers registered their classrooms for the EFT and indicated their interest in participating in the research, they were emailed a link to the website, teacher's guide, and EFT content. Approved opt-out consent forms were sent home to parents informing them of their child's participation in the EFT and in the anonymous research. Parents who did not want their child to participate had the option of signing and returning the forms to the school. After the forms were returned, teachers implemented the EFT and completed the post-surveys as part of their normal classroom instruction.

3.2.2 Survey Design

The assessment followed a quantitative design to evaluate the impact of the program on K-12 school students through a post-survey in three main areas: a) attitudes toward geology, b) attitude towards Geology careers, and c) perceptions of geology literacy. We used a post-retrospective survey design approach which consisted of a questionnaire completed by the students after completing the program. Students were asked to use a rating scale to indicate a favorable or unfavorable opinion about a statement (also known as Likert-scale items). The ability to use these responses in statistical analysis has made them a widely used and reliable tool for measuring attitudes toward science in outreach research (Adedokun et al., 2011; Aenlle et al., 2022; Barry et al., 2022; Lyon et al., 2020; Osborne et al., 2003).

Several questions and statements for the post-retrospective assessment were adapted from previous ES' education studies and EFT studies related to The Streaming Science Project (Adedokun et al., 2011; Lyon et al., 2020; Tillinghast et al., 2019). The survey is available as Supplementary Material (SM1). Surveys were implemented using Qualtrics, an online survey platform. The survey link was distributed via email to teachers who had registered to participate. Teachers had their students complete the survey electronically or through paper copies that were scanned and sent to the researchers.

3.2.3 Data Analysis

Descriptive statistics were used to analyze the survey data. Paired T-tests with means and p-values were calculated to compare the before and after student responses to the same question. The t-test compares the means between two related groups on the same continuous dependent variable. The greater the magnitude of the t-value, the greater the difference between the means. Conversely, the closer the t-value to 0, the more likely it is that there isn't a significant difference between the means 1. Each

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t-value has an associated p-value that indicates the statistical significance of the t, with $p<0.05$ being a statistically significant analysis. The selected valid responses were coded as a data set and analyzed in the SPSS (Statistical Package for the Social Sciences) software to calculate means, standard deviations, t-tests, and p-values.

Several limitations were identified in this study. First, the sample size of participating schools. Although forty-one teachers/classrooms expressed interest in the program, only six classrooms completed the program. Second, some of the students did not complete the entire survey nor did they answer all the questions, which reduced the amount of useful data. Third, there were problems with the audio quality in some of the pre-recorded videos in the EFT due to the wind interfering with the microphones during the field recording portion. The noise, which interfered with the presenters' voice, could have made it difficult for subjects to understand certain parts of the EFT. However, this difficulty was present in less than 10% of the materials. Fourth, the limitation of having only one presenter. Although the presenter had experience with outreach and scicomm, this may have led to audience fatigue. Finally, there was no detailed demographic assessment which prevented us from distinguishing results between individuals from different backgrounds.

4. Results

The first pilot of the Rocks Really Rock program took place in April and May 2022. Forty-one teachers initially responded to the Google Form recruitment survey expressing interest in participating in the program. Six teachers/classrooms participated in the entire program, from EFT presentation to post-survey distribution and completion. Three classrooms were located in Florida, one classroom in New York City (homeschool), one classroom in North Dakota, and one classroom in Virginia. A total of 120 students participated in the EFT, and 120 surveys were completed via Qualtrics and paper-copies, which were distributed by teachers after completion of the EFT to students who did not opt-out of the program.

All the responses were downloaded from Qualtrics and coded as one data set for analysis in SPSS (Statistical Package for the Social Sciences) software. Surveys with less than 90% of complete responses were not used for the data analysis. A total of 83 usable surveys were included in the data analysis. The survey responses are included as a spreadsheet in Supplementary Materials (SM2). Figure 3 shows the classroom-grade distribution of participants who completed the post-survey as well as the gender distribution. Most of the participating students were female. The grade range was 5th-12th grade. All fifth-grade subjects were from the homeschool participant class. As observed, most of the participants were middle-school students (6th-8th grade), and they made up 82% of the sample.

4.1 Assessing EFT impact on students' attitudes toward geology.

The first part of the survey attempted to determine how students' attitudes toward geology changed over the course of the EFT. Students were asked about their attitudes toward geology before and after the EFT on a scale of 1-6, where 1=unexciting,

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mundane, and unappealing, and 6 =exciting, fascinating, and appealing. Table 3 shows the means (M) for the responses to each of the statements for N valid responses, and the standard deviation (SD) from each mean. The results of the paired t-tests for the statements are reported for N-t valid responses. Overall, the results show a significant change in students toward more positive attitudes toward geology after the EFT, as indicated by t-tests and p-values <0.05. The statement that showed the greatest (and significant) change toward a more positive attitude was Geology is appealing/unappealing (t-test: -5.58, p=0.00). The statement that showed the least change toward a more positive attitude was Geology is exciting/unexciting (t-test: -5.02, p=0.00).

4.2 Assessing EFT impact on students' attitudes toward geology careers.

The second part of the survey attempted to determine how the students' attitudes toward geology careers changed due to their participation in the EFT. Students were asked about their attitudes toward geology careers before and after the EFT via a post-retrospective survey using a 5-point Likert-scale with the following range: 1.00=Strongly disagree, 2.00 =somewhat disagree, 3.00=neither agree nor disagree, 4.00 somewhat agree, and 5.00=strongly agree. Table 4 shows the means (M) for the responses to each of the statements for N valid responses, and the standard deviation (SD) from each mean. The results of the paired t-tests for the statements are reported for N-t valid responses, which are the number of answers that can be paired and compared through the test. Statements 2, 3, and 4 showed a statistically significant change in perception, all having p-values <0.05. On the contrary, the t-test for statement 1 is not statistically significant according to the p-value >0.05. The statement that showed the greatest (and significant) change toward a more positive attitude was Geology is important (t-test=-5.31, p=0.00). The statement that showed the least change toward a most positive attitude was Geology is a science (t-test=-2.47, p=0.02).

4.3 Assessing impact of the EFT on students' perceptions of geology literacy.

The third part of the survey attempted to determine how the students' perceptions of geology literacy changed due to the EFT. Students were asked about their attitudes toward geology careers before and after the EFT using a 5-point Likert-scale with the following range: 1.00=Strongly disagree, 2.00 =somewhat disagree, 3.00=neither agree nor disagree, 4.00 somewhat agree, 5.00=strongly agree Table 5 shows the means (M) for the responses to each of the statements for "N" valid responses. The results of the paired t-tests for the statements are reported for N-t valid responses. All results showed a statistically significant positive change with p-values <0.05. The statement that showed the greatest) change was I have a great deal of knowledge about geology (t=-8.36, p=0.00).

In addition, students were asked about their knowledge of rocks before and after the EFT on a 5-point Likert-scale with the following range: 1.00=nothing, 2.00=not much, 3.00=a little, 4.00=a lot, and 5.00=everything. Table 6 shows the means (M) for the responses for one question for "N=82" valid responses. The mean score for the question Before the electronic field trip how much did you know about rocks? was M=2.93 (SD=0.80), which is between "not much" and "a little," and the mean score for the question After the electronic field trip, how much do you know about rocks? was M=3.62 (SD=0.75) which is between "a little" and "a lot." The results of a paired t-test for this statement, for N-t valid responses, showed a positive change in attitude with statistical significance.

5. Discussion

According to the Council of Advisors on Science and Technology of the President of the United States, there will be a shortage of nearly one million STEM professionals in the coming years. Their projections show that STEM fields will need to increase their recruitment by 34% (Crawford et al., 2021; Olson & Riordan, 2012). As noted previously, this situation may be more challenging for ES careers given the lack of exposure/awareness of ES disciplines among K-12 students, in addition to the low ES literacy of the general population. For this reason, given that high-quality education in K-12 school settings have the potential to reinforce positive attitudes toward STEM content and careers, the role of these environments is very important in building an ES-literate society and increasing ES career awareness (Locke et al., 2018). Furthermore, science educators can effectively support these formal educational settings through outreach activities, which have the potential to increase students' positive attitudes toward STEM and related careers and increase the motivation to engage in STEM activities (Vennix et al., 2017, 2018).

The purpose of this study was to determine the impact of an EFT in web Google-Earth on ES topics for K-12 students. To do so, we built a web Google-Earth EFT using pre-recorded videos called Rocks Really Rock: An Electronic Field Trip across Geological Time and assessed it with students from seven middle and high Schools in the United States. Our results showed that EFTs in ES are effective tools that can be created by Earth scientists to develop outreach projects and support K-12 science educators to: 1) generate positive attitudes toward the ES, 2) positively impact interest in ES careers, and 3) reinforce positive perceptions in ES literacy. In the following section we present our considerations of this type of EFT and discuss the findings in relation to our research objectives.

5. 1 Changes in students' attitudes towards Earth sciences using EFT

The results of this study, in light of the existing literature on STEM and ES outreach, support the following factors that we believe determine a positive change in K-12 students' attitudes toward ES using EFTs: 1) the use of pre-recorded videos in the Web Google-Earth platform, 2) the two-way asynchronous interactions between teacher-student-scientist, and 3) the use of storytelling to design the content of the EFT. Here, we lay out the main considerations that led us to propose these factors.

5. 1.1 Use of pre-recorded videos in Web Google-Earth.

There are several advantages (for both creators and users) of Web Google-Earth as a platform for creating virtual field trips in the ES, such as: the effective and user-friendly format and interface of the platform, the easy way to distribute via direct web link, the ability to geotag the different field trip stops in one single project, the 3D view navigation of the locations providing opportunities for independent exploration, among others (Barth et al., 2022; Evelpidou et al., 2021; Mahan et al., 2021; Wyatt & Werner, 2019). In addition, EFTs through Web Google-Earth do not limit the experience to the geotagged locations, but also allow the creator to include links to supporting materials (e.g., links to publications, maps, field guides, among others) and display multimedia content (photos, videos, satellite images, slides) that allow the user to further explore the studied area (Evelpidou et al., 2021).

One of the more powerful outreach benefits of Web Google Earth is the use of multimedia, particularly video. Several studies have shown that multimedia in both science education and outreach can present science materials effectively, efficiently, and more interestingly, which helps students engage with science content and achieve learning outcomes (Morris & Lambe, 2017; Syawaludin et al., 2019; Wang et al., 2022). For example, pre-recorded videos in ES are known to increase interest in STEM because they provide a way to present content knowledge to the public using images, text, multimedia, etc., which can also create a different pedagogical experience (Wang et al., 2022). We suggest that ES outreach programs through Web Google Earth can benefit from the possibility of combining two tools: pre-recorded ES videos and geotagged locations. This allows students to follow the presenter's explanations, experience the presenter's field observations at each site, and explore the geotagged locations where the videos were filmed. The pre-recorded videos also allowed us to embed explanatory graphics and videos from other creators. Our videos can be easily found by other ES educators on YouTube and can be used in various teaching and learning environments, as accessible support materials for other ES educators around the world (Maynard, 2021; Welbourne & Grant, 2016).

5.1.2 Asynchronous interactions between teacher-student-scientist.

The benefits of interactions between students, teachers, and scientists have been previously evaluated and found to be an essential part of science outreach by positively changing students' perceptions of science and science-related careers (Barry et al., 2022; Painter et al., 2006). Science organizations and K-12 science educators believe that there is a need for scientists to be involved in science education (GSA Position Statement- Promoting Earth Science Literacy for Public Decision Making, 2013; King, 2013; Levine et al., 2007). Currently, several ES K-12 outreach strategies for students and teachers focus on in-person visits from professional scientists, visits to science fairs, visits to science museums, and field trips (Abramowitz et al., 2021; Onstad, 2021; Tillinghast et al., 2019). However, many of these outreach strategies have limitations, including lack of funding for in-person visits, time-consuming transportation, or accessibility.

Our results showed that outreach through EFTs in Web Google Earth is an asynchronous alternative for interactive learning experiences in formal educational environments (K-12 classrooms). This mode of EFT has the potential to create positive attitudes toward ES and ES careers, similar to previous synchronous interactions through EFTs via the Streaming Science model (Barry et al., 2022; Loizzo et al., 2019). Because the core of the EFT activity is asynchronous, it has the advantage of being used multiple times by students and teachers after the class activity, and it allows the teacher to view it prior to the class activity. Additionally, the asynchronous, pre-recorded nature of the EFT reduces barriers for students and teachers who may face barriers to accessing field-based outreach events due to financial limitations or physical disabilities (among others), allowing for inclusive participation in outreach activities.

5.1.3 The use of storytelling to craft the content of the EFT.

Several studies have highlighted that ES is a challenging set of sciences to communicate to non-expert audiences (Scherer et al., 2017; Sell et al., 2006). Wang et al. (2022) proposed three categories to explain the challenges of communicating ES topics: 1) Earth processes operate at unobservable locations and nonhuman "deep timescales," 2) ES information is more relevant to some locations than others, and 3) ES topics involve complex and dynamic systems. Therefore, regardless of the accuracy of the content of an ES outreach strategy, it may not always be effective in positively impacting the learning experience of non-expert audiences or in engaging them with scientific content. However, there are several science communication tools that geoscientists can use to effectively communicate ES to the public, such as storytelling (McNeal et al., 2014; Stewart & Hurth, 2021).

Our research indicated that storytelling is an effective strategy for achieving positive impacts through ES outreach initiatives (Dahlstrom, 2014; Joubert et al., 2019; Martinez-Conde & Macknik, 2017). In this study, the presenter used a storytelling approach using narrative to go present facts and evidence about Earth's history, allowing students to go through the science content as if they were being told the story of Earth through time. Our results show overall that the pre-recorded videos were effective in promoting interest with the ES and ES careers, suggesting that storytelling may contribute significantly when developing asynchronous science outreach material for K-12 students.

5.2 Addressing the challenges in ES education and ES careers through outreach

The study discussed in this article focused on the evaluation of attitudes toward geology and Earth sciences (ES) education using an Earth Field Trip (EFT) intervention. The results of t-tests indicated a statistically significant positive change in attitudes toward geology, suggesting that participating in the EFT increased students' positive attitudes toward ES. These findings demonstrate the potential of expanding EFT to other ES fields and reaching middle/high school students. These findings align with previous research on STEM education and outreach, emphasizing the significance of positive attitudes and well-informed perceptions in fostering interest in ES learning and pursuit of ES careers. In the following section we discuss the following topics. 1) the role of EFTs in students' attitudes toward Earth sciences, and 2) The role of EFT in Earth sciences in the perception of ES literacy.

5.2.1 The role of EFTs in students' attitudes toward Earth sciences.

The t-tests in the evaluation regarding attitudes toward geology (e.g., Geology is unexciting/exciting, Geology is mundane/fascinating, and Geology is appealing/unappealing) showed a statistically significant positive change, indicating that attitudes toward ES increased after students participated in EFT. These findings demonstrate the feasibility of expanding EFT

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to other ES fields (not just geology) and to middle/high school (and home) students. Thus, EFT may help science educators change negative or neutral attitudes toward ES to positive attitudes. In addition, EFT may address teacher unpreparedness for ES content and the paucity of available interactive ES instructional resources that prevent and limit ES instruction in various K-12 settings (King, 2013).

Based on our findings, the lack of awareness of ES may not be as much of a challenge for ES education (as reported in the literature) as the lack of enthusiasm for ES among K-12 students. Our results showed that there was no statistically significant change when we measured awareness, as most students were aware of geology as a science and where geologists might work before the EFT. However, the t-tests related to the statements measuring attitudes toward geology and geology careers all showed significant positive results.

Research has shown that students considering geology careers do so as early as middle school (Lyon et al., 2020). Thus, the use of EFT in this stage can become a powerful intervention strategy to influence ES career choices in a positive way. Based on our findings, there was a significant positive change after following the EFT, on attitudinal statements about geology careers (A job as a geologist would be interesting, I would consider geology as a major, and Geology is important). Such EFTs can combine K-12 ES topics (linking learning goals to ESLPs or NGSS) with real-world career scenarios to increase students' interest in ES careers. These EFTs can address students' difficulties connecting science content to career pathways, as well as educators' lack of knowledge about realistic role models in these careers (Jahn & Myers, 2015; Levine et al., 2007; Lyon et al., 2020; McNeal et al., 2014; Petcovic et al., 2018). We recognize that the implementation of this EFT in the science classroom did not necessarily indicate successful recruitment of students into an ES major, but the data demonstrated that the EFT was successful in positively impacting students' thoughts about choosing a geology major.

All findings discussed in this article support previous STEM education and outreach research in ES and other STEM fields. Prior research has shown that an EFT as outreach strategy can support STEM education by fostering positive attitudes toward science, which tends to encourage youth to pursue STEM careers and build a skilled STEM workforce (Barry et al., 2022; Loizzo et al., 2019). Similarly, several studies in ES education remind us that positive attitudes and well-informed perceptions about the field of geology and other ES fields influence middle and high school students' interest in ES learning and desire to pursue ES careers (Kurtis, Kimberly, 2009; Lyon et al., 2020; McNeal et al., 2014).

5.2.2 The role of EFT in Earth sciences in the perception of ES literacy.

Our study found that an EFT built in web Google Earth covering ES topics had a positive impact on students' perceptions of geology literacy and their interest in learning geology topics. After students completed the retrospective self-assessment of their knowledge of ES, there was a statistically significant positive difference in the pre-post statements. The change in the statement I have a great deal of knowledge about geology indicated that the EFT had a positive impact on the students' perception of their knowledge of ES, and that this perception improved. Similarly, the change in the statement I would like to

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learn more about geology showed that students had an increased desire to learn and an increased interest in geology after the EFT.

Our study contrasts to other studies that have assessed students' perceptions and interest in ES literacy by exposing K-12 students to ES content but have not necessarily obtained positive attitudinal changes after the programs. For example, Lyon et al. (2020) used the statement I would like to learn more about geology in an attitudinal survey program in ninth graders who had been exposed to a Geosciences course with content aligned to the NGSS. Their data showed a decrease in interest in geology on the post-survey after had taken the course. The authors considered that one of the main challenges may have been in "translating material covered in class into something they (the students) value" (Lyon et al., 2020). The difference in results between an ES course and an ES outreach program such as our EFT supports our previously mentioned premise about how ES topics are communicated (using storytelling and multimedia) and supports the idea that in K-12 settings, ES outreach using multimedia and science communication tools may be more effective in generating positive attitudes toward geology than exposing students to ES courses.

5.3 Recommendations: How can the implementation of Earth Sciences electronic field trips be improved?

Based on this pilot study using web Google-Earth for ES outreach in K-12 environments we consider a number of recommendations for EFT creators, users, as well as for further research. Creators, especially scientists with no experience multimedia creation, may find it useful to allocate funding to work with expert multimedia editors to improve the video and audio quality of the delivered content. In addition, more content can be added to each site between longer-form videos if there is an opportunity to explore more sites in the area. By making more content available at multiple geo-tagged locations, students and teachers will be able to engage with the application in a more interactive way. We also suggest that the teachers first go through the Google Earth web program on their own before presenting it in their classrooms, and if deemed appropriate, design exercises using the concepts learned in the EFT that can complement the activity before, during, or after the EFT is presented to students. Teachers can also network with the creators and participate in annual research to assess the impact of these EFTs at different K-12 levels to determine which groups of students are more or less impacted.

6. Conclusions

Earth Sciences are relevant to society and its relationship to the Earth system. However, ES education in U.S. K-12 environments faces multiple challenges such as 1) limited exposure to ES, 2) lack of awareness of ES careers, and 3) low ES literacy. Interactions between science educators, students, and scientists are an essential part of science outreach. Previous studies have shown that successful outreach programs leading to positive attitudinal changes toward STEM in students can help students understand how science can explain the natural world around them.

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This study found that outreach through EFTs in Web Google Earth is an asynchronous alternative to synchronous interactive learning experiences in formal education environments (K-12 classrooms.) Our study showed that web Google-Earth EFTs have the potential to increase positive attitudes toward ES (specifically geology), interest in ES careers, and perceptions of ES-literacy, providing several advantages for ES K-12 outreach. It presents a unique opportunity for Earth Scientists to network with K-12 educators and address these challenges, creating interactions between scientists and K-12 classrooms. Our findings indicated that one of the major problems in ES education is not a lack of awareness but a lack of excitement among K-12 students about ES topics, and therefore scicomm tools such as storytelling and use of multimedia in platforms such as web Google Earth, provide an effective strategy for creating outreach content that generates engagement with science topics and increases positive attitudes toward science.

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Figures:

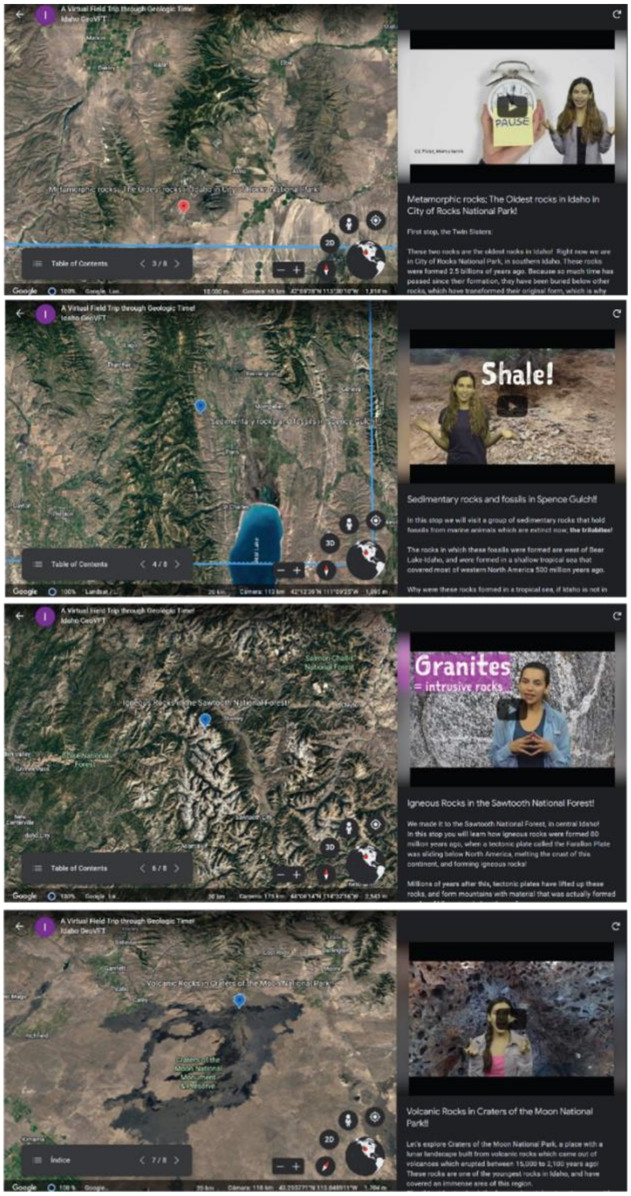

Figure 1. Screenshots from the EFT "Rocks Really Rock, and EFT Across Geological Time". Adapted from: https://earth.google.com/earth/d/1btfkYpOkcsqQktfky-t0pYJLT1e2lJSP?usp=sharing © Google Earth 2023. Recovered: September 19, 2023

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Figure 2. Screenshot from Streaming Science web page for "Rocks Really Rock EFT". Adapted from: https://streamingscience.com/rocks-really-rock-an-electronic-field-trip-across-geologic-time/ Recovered: September 19, 2023

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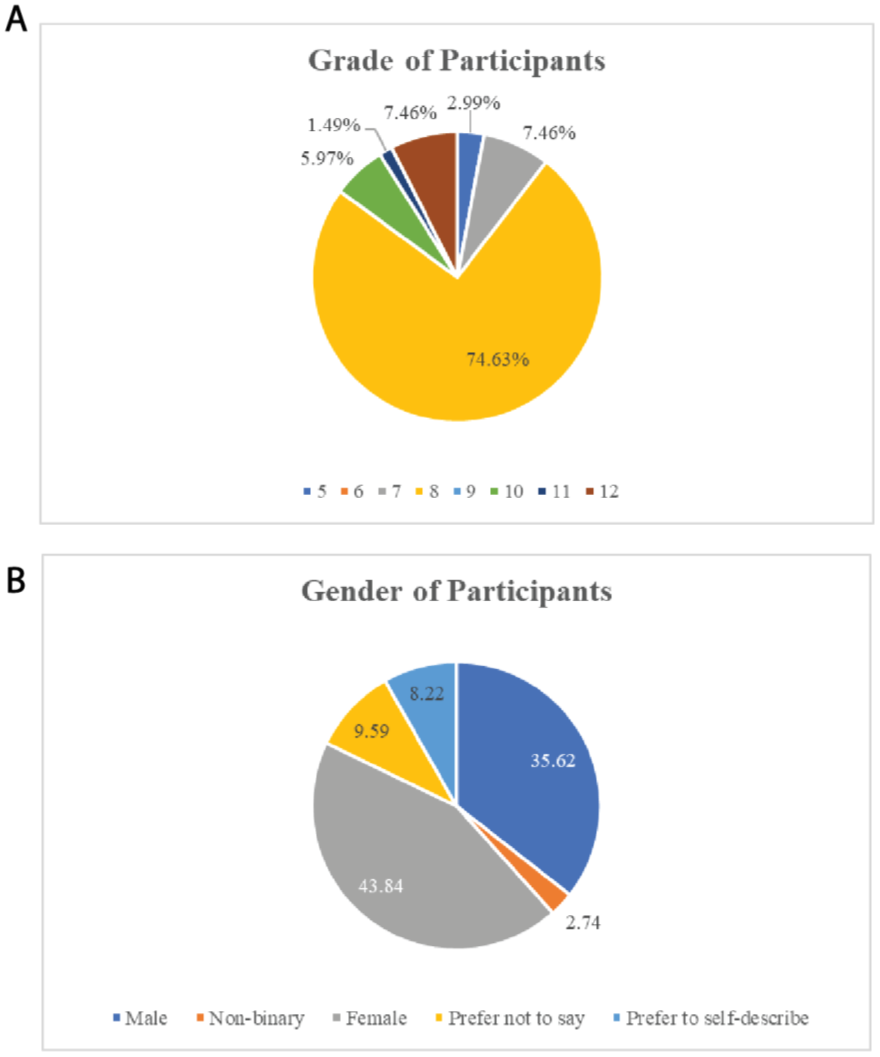

Figure 3. A) Grade distribution from participant students. B) Gender distribution from participant students.

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Tables

Table 1. List of *Earth Sciences Literacy Principles* (ESLP) and *Next Generation Science Standards* (NGSS) used for content literacy in "Rocks Really Rock" EFT

ESLP	Middle School Earth Sciences (MS-ESS) NGSS standards used in content creation
Big Idea 2 (Earth is 4.6 billion years old)	MS-ESS1.C - The History of Planet Earth. MS-ESS2.A - Earth's Material and Systems MS-ESS2.B - Plate Tectonic and Large-Scale System Interactions
Big Idea 3 (Earth is a complex system of interacting rock, water, air, and life).	MS- ESS1.C - The History of Planet Earth. MS-ESS2.A - Earth's Material and Systems MS-ESS2.B - Plate Tectonic and Large-Scale System Interactions
Big Idea 4 (Earth is continuously changing)	MS- ESS1.C - The History of Planet Earth. MS-ESS2.B - Plate Tectonic and Large-Scale System Interactions
Big Idea 6 (Life evolves on a dynamic Earth and continuously modifies Earth).	MS- ESS1.C - The History of Planet Earth.

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458 Table 2. Structure of "Rocks Really Rock" EFT

Video/ Duration (mins/secs)	Recording Location	Covered Topics, Earth Science Literacy Principle (ESLP), and Next Generation Science Standard (NGSS)	Learning Objectives
1. Intro (2m 24s)	Studio	This module is an introduction into the program and to the concepts of geologic time, and plate tectonics. ESLP=Big Idea 2 (Earth is 4.6 billion years old), and Big Idea 3 (Earth is a complex system of interacting rock, water, air, and life). NGSS=MS- ESS1.C, The History of Planet Earth.	1. Recall what is the geologic timescale.

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460 Table 2. Continued

Video/ Duration (mins/secs)	Recording Location	Covered Topics, Earth Science Literacy Principle (ESLP), and Next Generation Science Standard (NGSS)	Learning Objectives
2. Stop 1 "City of Rocks, Looking for the oldest rocks in Idaho" (5m 29s)	Twin Sisters rocks at City of Rocks National Park (Idaho-US) +Studio	This module covers three different topics: 1) The age of the oldest rocks in Idaho, 2) The differences between today's Earth and Earth 2-billion years ago, and 3) the concept of metamorphism. ESLP=Big Idea 2 (Earth is 4.6 billion years old), and Big Idea 4 (Earth is continuously changing) . NGSS= MS- ESS1.C, The History of Planet Earth., and MS-ESS2.A-Earth's Material and Systems	1.Recall what is a metamorphic rock. 2.Recall how old are the oldest rocks in Idaho.

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Table 2. Continued

Video/ Duration (mins/secs)	Recording Location	Covered Topics, Earth Science Literacy Principle (ESLP), and Next Generation Science Standard (NGSS)	Learning Objectives
3. Stop 2 "Cambrian Fossils". (5m 21s)	Spence Gulch (Idaho-US) +Studio	This module covers four different topics: 1) Changes in Earth from 2000-500 Ma, 2) The Cambrian Earth and the Cambrian explosion 3) Formation of sedimentary rocks, and 4) Formation of fossils, and ichno-fossils. ESLP=Big Idea 2 (Earth is 4.6 billion years old), Big Idea 4 (Earth is continuously changing), and Big Idea 6: Life evolves on a dynamic Earth and continuously modifies Earth. NGSS= MS- ESS1.C, The History of Planet Earth., and MS-ESS2.A-Earth's Material and Systems. and MS-ESS2.B Plate Tectonic and Large-Scale System Interactions .	1. Recall what is a sedimentary rock 2. Recall what is a fossil, and what is a trilobite. 3. Recall what was the Cambrian explosion.

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466 Table 2. Continued

Video/ Duration (mins/secs)	Recording Location	Covered Topics, Earth Science Literacy Principle (ESLP), and Next Generation Science Standard (NGSS)	Learning Objectives
4. Subduction Zone and Plate Tectonics (2m57s)	Studio	This module explains the formation of subduction zones, and the occurrence of a subduction zone in the Cretaceous in western North America. ESLP=Big Idea 2 (Earth is 4.6 billion years old), and Big Idea 4 (Earth is continuously changing) NGSS= MS- ESS1.C, The History of Planet Earth., and MS-ESS2.A-Earth's Material and Systems. and MS-ESS2.B Plate Tectonic and Large-Scale System Interactions	1.Recall the effect of the movement of plate tectonics, in changing the shape of continents.

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Table 2. Continued

Video/ Duration (mins/secs)	Recording Location	Covered Topics, Earth Science Literacy Principle (ESLP), and Next Generation Science Standard (NGSS)	Learning Objectives
5. Stop 3 "Igneous Rocks in the Sawtooth Moutain" (6m13s)	Sawtooth Lake at the Sawtooth National Forest (Idaho-US) +Studio	This module covers three topics: 1) Plate tectonics 80 million years ago in The Cretaceous, 2) Formation of igneous rocks in subduction zones, 3) Minerals forming granitic rocks, and 4) geology methods for outcrop rock observation. ESLP=Big Idea 2 (Earth is 4.6 billion years old), and Big Idea 4 (Earth is continuously changing) NGSS= MS- ESS1.C, The History of Planet Earth., and MS-ESS2.A-Earth's Material and Systems. and MS-ESS2.B Plate Tectonic and Large-Scale System Interactions	1.Recall what is a subduction zone, and the effects on mountain formation. 2. Recall what an igneous rock is.
6. Stop 4 "Origin of volcanic rocks" (6m14s)	Craters of the Moon National Park (Idaho-US) +Studio.	This module covers two topics: 1) Formation of volcanic extrusive rocks, and 2) Formation of lava tubes. ESLP= Big Idea 4 (Earth is continuously changing). NGSS= MS- ESS1.C, The History of Planet Earth.,	1.Recall what type of rock a basalt is. 2.Recall what are lava tubes.

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472 Table 3. Survey results about attitudes towards geology before and after EFT. Ranking Scale: 1 = unexciting, mundane,
473 unappealing /// 6=exciting, fascinating, appealing.

Statements	Mean score (Standard Deviation) BEFORE the 'Rocks really rock' electronic field trip, I thought Geology was	AFTER the 'Rocks really rock' electronic field trip, I now think Geology is	N	T-test before & after	P-value (Sig. 2-tailed)	N-t
unexciting-exciting	2.99 (1.27)	3.72 (1.36)	83	-5.02	0.000	82
mundane-fascinating	3.33 (1.35)	4.00 (1.36)	83	-5.08	0.000	82
unappealing-appealing	3.23 (1.43)	4.01 (1.38)	83	-5.58	0.000	82

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Table 4. Survey results about attitudes about geology careers. Scale: 1 = Strongly disagree, 2=Somewhat disagree, 3=Neither agree nor disagree, 4=Somewhat agree, 5=Strongly Agree

Statements	Mean score (Standard Deviation) BEFORE participating in the Rocks really Rock EFT, I thought	AFTER participating in the Rocks really Rock EFT, I now think	N	T before & after	P-value (Sig. 2-tailed)	N-t
1.Geologists can work outdoors	4.49 (0.79)	4.61 (0.71)	83	-1.32	0.19	82
2.Geology is a science	4.26 (0.89)	4.49 (0.77)	82	-2.47	0.02	81
3.Geology is important	3.71 (1.02)	4.23 (0.85)	83	-5.31	0.00	82
4.A job as a geologist would be interesting	2.66 (1.07)	3.12 (1.14)	82	-3.93	0.00	81
5.I would consider geology as a major	2.09 (1.06)	2.43 (1.17)	81	-3.64	0.00	80

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Table 5. Survey results about perceived literacy in geology Pt1. Scale: 1 = Strongly disagree, 2=Somewhat disagree, 3=Neither agree nor disagree, 4=Somewhat agree, 5=Strongly Agree

Student's attitudes	Mean scores (Standard Deviation)		N	T before & after	P-value (Sig. 2-tailed)	N-t
	BEFORE participating in the Rocks really Rock EFT, I thought	AFTER participating in the Rocks really Rock EFT, I now think				
I have a great deal of knowledge about geology.	2.66 (1.00)	3.46 (0.89)	83	-8.36	0.00	82
I would like to learn more about geology	2.84 (1.07)	3.40 (1.20)	82	-5.54	0.00	81

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Table 6. Survey results about attitudes about perceived literacy in geology before and after the EFT Pt2. Scale: 1= Nothing, 2= Not much,3=A little, 4=A lot, 5=Everything

	Mean score (Standard Deviation) Students' attitudes	N
Before the Electronic Field Trip how much did you know about rocks?	2.92 (0.80)	82
After the Electronic Field Trip how much do you know about rocks?	3.62 (0.75)	82
T-test	-9.53	
P-value	0.00	
N-t	81	

Video Supplement

The following link contains the public web-address to the electronic field trip "Rocks Really Rock" which take viewers to the web-Google Earth application https://earth.google.com/earth/d/1btfkYpOkcsqQktfky-t0pYJLT1e2lJSP?usp=sharing

Author contribution

COG and JL: concept, data collection, research, writing, edition and manuscript revision.

Competing interests: The authors declare that they have no conflict of interest.

Ethical statement

The data used in this study was collected on a voluntary and anonymous basis. Identification of individual participants in the questionnaire is impossible. Ethics approval was obtained through the University of Florida's Institutional Review Board (IRB).

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Data Availability

The authors confirm that the data supporting the findings of this study are available within the article and its supplementary materials.

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