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Graphing Literacy in a Seventh Grade Science Classroom

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Abstract

Graphing literacy is an essential skill in processing and developing scientific understanding; however, students graduating from secondary science education do not exhibit the proper skills to be graphing literate. Because graphing is linked to scientific literacy, this deficiency translates into lower science performance. This study focused on the connection between science and graphing through a quasi-experimental investigation on science literacy improvement of two seventh-grade science classes. Science literacy was assessed through a pre and posttest multiple-choice assessment derived from the online science program, STEMscopes. The intervention administered to the treatment group contained five lessons on specific isolated skills for building graphing literacy, while the control group carried on with regular science instruction. Independent and dependent t-tests were conducted to determine differences and growth in science literacy both across and within groups. No statistically significant difference was found on test scores between the control and treatment after the intervention. Further investigation is recommended with larger sample sizes and a longer integrated graphing literacy intervention with middle-school science students is warranted.

Keywords: Graphs, Graphing Literacy, Science, Science Literacy, Middle-School

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Literature Review

Within today's society, knowing how to read a graph is a necessity (National Research Council, 1996). This was highlighted in 2020 when the global pandemic COVID-19 hit the United States, and vast amounts of information and data from the science community were generated and reported to the public. With the barrage of data, graphs, and tables that tallied daily cases and deaths, research has shown that the public lacked adequate graphing literacy skills that would aid in processing these media posts, articles, and journals correctly (Holder, 2020; Romano et al., 2020). Graphing literacy, the ability to read and interpret graphs, has been linked to the ability to read and understand science, as it is one of the main tools to conduct and communicate new information.

Graphs are a mainstay component of everyday news and media literature as well as academic articles and textbooks (National Research Council, 2012) because of their ability to influence, persuade, and explain (Lai et al., 2016; Matuk et al., 2019). By converting quantitative data into a visual that conveys meaning between variables, graphs provide evidence with the power to support or refute a claim (Wong, 2017). Seen often in modern publications, graphs can explain the workings of politics, cultural preferences, or historical events. This information is generated by science, where the body of knowledge grows through mounting evidence from investigation to investigation. Thus the skill of graphing literacy is essential (National Research Council, 2012).

Graphing and science are intertwined, where graphs are the essential tool for science to process countless amounts of data taken from investigating scientific phenomena, while communicating it in an effective and efficient way. Data that is organized in a graph allows for the interpretation of salient trends or patterns between the subjects studied (Fry, 1981). Taking it a step further, analysis is where conjectures can be made with data points that were not originally recorded in the study through the processes of interpolation and extrapolation (Bertin, 1983). These graphing applications of interpretation, analysis and communication make it possible for fellow scientists and researchers to continue the process of science with the goal that as hypotheses are tested and supported, science knowledge is gained.

One arena where graph literacy is not emphasized enough but must be a priority is in the science classroom (Harsh & Schmitt-Harsh, 2016; National Research Council, 2012). Lai et al. (2016) studied graph comprehension in science classrooms and noted that insufficient graph literacy skills have been linked to poorer understanding of science, or science literacy. Today, graphing literacy remains a difficult skill for students and adults alike (Boote, 2014; Harsh & Schmitt-Harsh, 2016), and many middle school and high school students have difficulties in using, interpreting, and understanding graphical interpretations of data (Glazer, 2011) making superficial conclusions instead of using evidence from graphs (Matuk et al., 2019). Two research studies found that as students were entering college and the workforce, there was an “overestimation” of graphing literacy, necessitating more class time to include a review on graphing (Harsh & Schmitt-Harsh, 2016; Picone et al., 2007). Another example of the lack of graphing preparation leading to an incomplete grasp of how the science process works has been seen in pre-service teachers who were being trained to teach in the science field. Bowen and Roth (2005) found these individuals were inadequately knowledgeable in comprehending graphs as they proceeded to earn their teaching degrees.

To be scientifically literate, an individual must have the ability to read and understand scientific concepts and grasp how science builds knowledge through the scientific process. This is delineated within the state of California's adopted science standards, called the Next Generation Science Standards (NGSS). Scientific literacy is outlined as the combination of building knowledge about scientific phenomena and the action of students engaging in the processes of scientific investigation (Committee on Science Literacy and Public Perception of Science, 2016). The target of the NGSS is for students to achieve a level of scientific literacy through their primary and secondary education that yields sufficient knowledge to make informed decisions and competitively participate in an evolving world (National Research Council, 1996).

To gain progress in these goals, Lai et al. (2016) argue that graphing literacy must be better addressed within middle school science classrooms, playing a more dominant role in science education. The National Research Council (2012), described the progression of educational science standards, noting that middle school is where students should have the opportunities to learn how to display and interpret graphs. Middle school science differs from elementary science topics, where there is an exposure to more complex scientific systems resulting in complex data sets that can be applied to graphing. Beginning with diagrams and pictorial representations of abstract concepts such as the variety of forces on a particular object, students use these graphical interpretations as a way to show their understanding of underlying scientific ideas. Graphing expands further to more traditional graphing models such as the use of scatter plots and line graphs that highlight the relationship between variables mapped out on x and y axes.

In order to align to science standards, educators purposely build a science curriculum that explicitly teaches scientific concepts progressively integrated into every grade level, as well as perform science by exposing students to scientific investigations. These investigations involve data collection through observations and utilize graphing as the instrument that organizes data points, displaying them in a way that can reveal trends or patterns not otherwise seen (Shah & Hoeffner, 2002; Zucker et al., 2014). However, many researchers agree that graphing literacy in science classrooms is not adequately covered in middle school science classrooms to the detriment of students and their resulting science literacy skills (Boote, 2014; Lai et al., 2016).

Graphing Literacy in Science

Graphs are the evidence that scientists use as the foundation of their arguments. Two powerful ways that graphing aids in this endeavor are through data analysis and data communication. Harsh and Schmitt-Harsh (2016) state that as a tool to analyze information, graphs frame data visually, illuminating trends such as patterns, highs, lows, averages, rates, and so on. Further, Wong (2017) discusses how graphs make it possible to potentially forecast the future, displaying information that would not have been seen, through extrapolation. This can lead researchers to further understand the underpinnings of the relationship between variables observed and inspire more in-depth questioning that can be researched to result in better answers.

The second essential use of graphs in science is to relay and communicate results to other scientists and to the public (National Research Council, 1996; NGSS Lead States, 2013). This is done through journals, lectures, classes, and seminars, where scientists challenge and validate each other's work by looking at presented evidence, which can cause ideas to fall away or be integrated with current knowledge (Bertin, 1983; Matuk et al., 2019; National Research Council, 2012). Graphs in these articles provide evidence to the reader that has the power to confirm relationships that the study has been testing or refute it (National Research Council, 2012).

Because scientists do more than interpret and analyze graphs, an essential skill to graphing literacy in science is the ability to construct them (Zucker et al., 2015). The National

Academy of Science along with the California Department of Education Science Standards clearly list constructing graphs as a necessary skill for science literacy (National Research Council, 2012). Scientists must choose the most effective type of graph to present their scientific data, since different graphs highlight different types of data in different ways. For example, a line graph represents the relationship between two or more variables and a pie graph represents the size of different portions compared to the whole. Graph construction demonstrates the link of the graph maker to their scientific knowledge and their use of graphs in scientific explanations (Bowen & Roth, 2005).

Problems with Graphing Literacy in Education

Galesic & Garcia-Retamero (2011) noted that time allotted to teach graphing literacy is inconsistent within middle school science classrooms. Secondary educational science teachers tend to focus on addressing more scientific content versus spending time teaching graphing literacy. Harris and Zwiep (2013) indicated this is possibly due to the pressure of teaching rigorous standards that can be entirely new concepts for students. This shifts mental attention for both teacher and student away from comprehensive teaching of the fundamentals of graphing and learning while simultaneously trying to grasp new abstract scientific concepts.

Wong (2017) notes that science educators reason not to teach graphing due to a misplaced reliance on coinciding math classrooms covering the topic, but argues that problems arise because math and science have different perspectives of graphs. In math, graphs are a visual representative of a mathematical function or model, where points fall neatly in place. In science, graphs highlight relationships and trends observed in scientific investigations where graphs can be "messy" with outliers. Due to the complexity of graphing in the two different contexts, the transfer of graphing skills and knowledge from math do not translate well into science. This has created a disconnect where students struggle to look at graphs in different ways depending on the classroom they are in.

Teaching Graphing Literacy in Science Classrooms

To gain graphing literacy students must develop the skills of reading, analyzing, and constructing graphs (Shah & Freedman, 2011). Graphs are one of the oldest tools to organize and communicate information (Bertin, 1983). They utilize visual markings that denote qualitative meaning through pattern, increasing order of size, color, or complexity, and can represent geography or mathematical equations. Graphs also provide an intuitive understanding of the diagram itself, in which the images have their own meaning, akin to a new language (Bowen & Roth, 2005). The quantitative information provided through the title, labels, intervals, and other readable notations provide the context in which these visual markings are set.

One approach to teaching graphing literacy was proposed by Edward Fry (1981), who recommended that graphing be analogous to teaching reading literacy. Similar to identifying letters which are combined to create words, sentences, and paragraphs, learning how to read a graph should proceed in this similar hierarchical progression. By learning graph markings and inscriptions, then understanding what they represent, can be combined to piece together the details of the relationship between the variables displayed. Curcio (1987) categorized these graph reading skills into three stages: reading the data, reading between the data, and reading beyond the data.

Bertin (1983) was a French statistician who wrote in detail on how to decipher graphs. With respect to reading the data, he separated the markings of a graph as external and internal, imagining that the graph is contained within a box with a prominent inside and outside. The inside markings are categorized by the Variable Visible Marks that encompass the 2D plane, size, value, shape, color, texture, and orientation, which are represented with data points, curve or straight changes in line shape, height of bars, pie section sizes, and so on. The symbols outside of the axes are the axes' labels, legend, title, and caption which comprise the conventional information of a graph. Here, students make the connection of the two axes as number lines, and gain practice in understanding how intervals and ranges can change the visual representation of a graph. The combination of the inside and outside markings is what makes up a graph and can be categorized into different types– such as bar graphs, pie graphs, and line graphs.

Reading between the data is similar to understanding that in addition to the idea that letters form words, those words when strung together have meaning. Reading a graph's visual features are the first step. To read between the data, the second step is to evaluate what is visible in a graph and then interpret greater meaning on how the variables shown are associated (Matuk et al., 2019). Bertin (1983) stated that variables can range as qualitative, sometimes further dividing into different categories such as schools and types of schools, to quantitative or sequential (ranking of order) represented numerically. Reading between the data also involves the removal of noise in a graph containing outliers that can possibly skew trends, and recognizing how the data points are trending. These inferences are what add understanding to the visual markings inside and outside of the graph.

To further read beyond the data, the idea of interpolation (surmising data points not collected in an investigation but falling within the range of points) and extrapolation (surmising data points not collected in an investigation but falling outside of the range of points) is key (McKenzie & Padilla, 1986). These two tools of graphing involve drawing a best-fit-line that represents the general trends being seen and pinpointing points that were not collected within the data. This can for example predict future outcomes if time is one of the variables in the graph

(McKenzie & Padilla, 1986; Wong, 2017). Reading beyond the data is also having the skill of compiling pieces of a story that the graph is communicating by combining all the clues that have been deciphered, akin to understanding how paragraphs work together to make a story. This adds additional nuance to a scientific inquiry which can lead into stronger evidence or inspire further inquiries that can be tested in a scientific problem. It also strengthens a student's understanding of graphs and science (Matuk et al., 2019).

The last isolated skill is graph construction. The construction of graphs can be viewed as an extension of reading beyond the data which involves the interpretation of a graph, because one must possess the knowledge of how a viewer regards a graph to make the best design decisions on how to purposefully portray the data (Lai et al., 2016; Shah & Hoeffner, 2002). Scientists must have knowledge of which type of graph to use with their specific data, transforming information that has been interpreted, to create something new (Shah & Hoeffner, 2002). Graph construction can be analogous to the "writing" portion of literacy, where the reader has determined what information they would like to communicate, using the skills of graph design and graph display to make it understandable to the public. Science students need to be adept at a range of different types of graphs, understanding how to create them electronically utilizing Imagery Theory. Bertin (1983) defines Imagery Theory as using attributes that communicate ideas in the most efficient and direct way possible. Graph construction is also an exercise that demonstrates students' understanding of how their data reflects scientific concepts when accompanied by written evaluations.

In an effort to link graphing to scientific content, Harsh and Schmitt-Harsh (2016) recommend that the type of data presented or collected by students should grow toward more realistic data sets that are deemed "messy", reflecting more authentic data collection in the science field. Students must then learn to convert this raw data into purposefully designed graphs through sketching with pen and paper, then be trained in the use of technological graphing devices. Shah and Hoeffner (2002) state that when students practice the translation of one representation of data to another, links are made clearer between visual and quantitative values. This leads to a better grasp on graph translation and scientific understanding. In Picone and colleagues' (2007) graphing interventions, students were given exercises specifically to connect the data and graphs with science course content and used those interpretations of trends to test hypotheses.

Methods

Graphing literacy is a concept not adequately being taught across the curriculum as many studies suggest (Connery, 2007; McKenzie & Padilla, 1986; Zucker et al., 2015). In the science classroom, students are falling short in standardized science assessments such as the Program for International Student Assessment (PISA) in 2015 where the United States ranked 24th among other countries (DeSilver, 2017). The purpose of this study was to study the role of graphing instruction apart from seventh grade science content in a middle school setting, and test whether science literacy improves. The graphing intervention was guided by *A Framework for Graph Literacy Goals and Objectives* from Zucker and colleagues (2015). Scientific literacy was assessed via questions from the science program, STEMscopes, to build a 24 question multiple-choice pre and posttest at the beginning and end of the study. Two seventh grade science classes were used, one as the control group and the other the treatment group. The entirety of the study was conducted during distance learning.

Research Question

Does a five lesson graphing intervention outside of normal science instruction, integrated into a seventh grade science classroom during distance learning, increase science literacy as measured by scores from STEMscopes science literacy assessments?

Hypothesis

With the inseparable relationship between the practice of using graphs in science research (Bowen & Roth, 2005), middle-school science students who receive graphing-specific intervention in their science curriculum will see a larger increase in science literacy as assessed by STEMscopes science literacy tests before and after the intervention, when compared to students who do not receive the graphing specific instruction.

Research Design

This study utilized a quantitative quasi-experimental nonequivalent two-group pretest posttest design. One seventh grade integrated science period served as the experimental group, and another seventh grade integrated science period located at the same school was the control group. Before the study began, both groups took the pretest as a baseline assessment. Then, the experimental group received a five lesson graphing intervention delivered on synchronous distance learning days for approximately 50 minutes per session, while the control group continued its science curriculum without the graphing intervention. The difference between groups was that the researcher administered the graphing intervention to only the experimental treatment group. Data analysis occurred after the posttest to determine if there was a change in science performance with the added separate instruction of reading, understanding, and learning how to construct graphs.

Independent Variable

The independent variable in the study was the intervention of teaching graphing literacy to the experimental group of a seventh grade science classroom period via distance learning. Graphing literacy combines the skills of literacy (to read), with graphing, which is compartmentalized by the three goals of the intervention: reading the data, reading between the data and reading beyond the data (Fry, 1981). Lesson plans aligned with the progression of *Teaching Graph Literacy Across the Curriculum*, called the *Framework of Graph Literacy Goals and Objectives* (Zucker et al., 2015; Appendix A).

Within the intervention, only graphing literacy was taught, and no new science concepts were introduced to differentiate that the cause of any change in science literacy would be due to the separate graphing intervention. Another reason for this separation was that based on assertions from some researchers, introducing the complex task of graphing in addition to new scientific concepts does not provide ample space and time to learn both at once (Roth & Bowen, 2001; Shah & Freedman, 2011).

Dependent Variable

Scientific literacy was the dependent variable in this study and included not only a foundational understanding of subject matter that is associated with the world around us and within us but an emphasis on the act of science that involved the investigation process and its role in society (National Research Council, 1996). Scientific literacy was measured by comparing data derived from a 24 multiple-choice question, norm-referenced pretest and posttest focused on assessing the graphing skills of reading, interpreting, and constructing graphs (Appendix B). These questions were pulled from NGSS aligned science questions published in the online curriculum created by Accelerate Learning Inc., called STEMscopes (STEMscopes, n.d.).

Setting and Participants

The middle school selected for this study maintained a student body of 1221 students during the 2020-2021 school year (California Department of Education, 2020). The student population was 87% Hispanic, 7% White, 3% Asian or Filipino, and 3% African American, American Indian, Pacific Islander or two or more races. This compared to the state average of 55% Hispanic, 22% White, 12% Asian or Filipino, and 10% other (California Department of Education, 2020). Twenty one percent of students at the school were English Learners (ELs) compared to the state average of 19%, and 76% of students were categorized as socioeconomically disadvantaged, whereas 61% of students were so categorized in California (California Department of Education, 2020).

Purposeful convenience sampling was used to decide what school to work with, as well as to sample the classes that will represent the experiment and the control. The sample was purposeful as the two classes were both studying the same science content, but also convenient as the sample was readily available to the researcher. The total number of participants was 29 ($n = 29$), with 16 students in the treatment group and 13 in the control group. The treatment group was chosen due to having higher participation numbers and fewer transitional ELs and Students with Disabilities (SWDs).

Treatment Group

In the treatment group, the chosen period contained 16 students, with eight males and eight females. Out of the 16, 93.8% were Hispanic and 6.3% of the group was White. Two students were categorized as ELs.

Control Group

For the control group in the same middle school, the chosen period contained 13 students, with nine males and four females. One hundred percent of the group were Hispanic, with five of the students categorized as ELs, and within this group two were SWDs.

Measures

Criteria used to select and frame the questions for the assessments were based on the sample's demographics where EL participants encompassed 38% of the control group and 13% of the treatment group. Considering the need for ease in reading literacy to address the possible complications that arise from students who were English Learners, each assessment question was translated into Spanish and an audio link was provided with the question read in Spanish (Gándara & Hopkins, 2010).

The test questions, listed in Appendix B, were sourced from the K-12 online science platform by Accelerate Learning Inc., STEMscopes (n.d.), with questions ranging from levels third grade to fifth grade covering various science "scopes" that include weather, ecology, physics, genetics, natural hazards, and astronomy. This curriculum was developed to align with the California Next Generation Science Standards (CA NGSS) and California Science Framework (STEMscopes, 2020). The assessments contained 24 multiple-choice questions, worth one point each, and were administered on a Google Form to fit with the current situation of state mandated school distance learning during the COVID-19 pandemic. Analysis of the difference in scores compared the pre and posttest data for both control and experimental groups determined if there had been a change in scientific literacy due to the added instruction of graphing literacy in the experimental group that exceeded that of the control group.

Validity

The developers of STEMscopes indicated that content validity was established by experts who hold doctorate degrees in the science field, scrutinizing content for accurate scientific meaning and scientific skills (STEMscopes, 2019). In addition, under the Every Student Succeeds Act (ESSA), the Department of Education of California delineated a four-tier system that represented the level of Evidence Based Interventions, where STEMscopes qualified for tier two (STEMscopes, 2019; California Department of Education, n.d.). This tier claimed, “moderate evidence”, meaning that at least one quasi-experimental study was conducted with large and multi-site samples that concluded that the use of STEMscopes made a statistically significant positive change in student scores, including its assessments, in a science classroom (California Department of Education., n.d.). One such study on the effectiveness of STEMscopes conducted by Rice University, found an increase in science achievement in 5th grade science classes in a large urban school district when comparing STAAR science scores between those districts that had active STEMscopes accounts and those who did not (Snodgrass Rangel et al., 2014). A veteran science teacher with over 20 years of experience aided to verify that the questions indeed measured science literacy.

Reliability

The questions chosen in the finalized pre and posttest STEMscopes science literacy assessments addressed varying science topics that center around the use of graph literacy which included reading tables, reading graphs, and interpreting graphs. The questions were pulled from STEMscopes, grades 3rd-5th online from the “Evaluation” menu and the other in-class activity sections “Elaborate” and “Explore” (STEMscopes, n.d.). Simpler assessment questions were purposely chosen to increase measured reliability, accounting for the lower English language proficiency of participants in both the treatment and the control groups. Multiple choice questions were the only type of assessment question used, (another strategy to lower literacy challenges), tabulated as one point each, and delivered online through a Google Form that the students were comfortable with. Answer keys were already established by STEMscopes, therefore scoring was determined by alignment with the answer key by the researcher, resulting in high reliability. A content-based expert reviewed the results of the researcher's marks to verify that at least 20% of the answers were correctly marked for both the pretest and posttest.

Intervention

The intervention on graphing literacy (Appendix A) was conducted in five lessons through distance learning in the 7th grade integrated science class. Before the intervention began, a pretest executed through Google Forms was given with 24 multiple-choice questions chosen from STEMscopes. After the pretest, the graphing literacy intervention lessons that were aligned with the *Graphing Framework Objectives and Goals* authored by Zucker et al. (2015), delineated in Appendix A, Table 1 were given. The four goals within the intervention were Reading a Graph (identify and encode prominent visual graph features), Interpreting a Graph (link superficial graph features to quantitative facts), Analyzing a Graph (discover trends or other relationships and integrate the features and relationships with the context of the graph) and finally Constructing a Graph (graph design and construction) (Zucker et al., 2015). Lesson one of reading graphs focused on overall graph features by identifying the visuals of a graph. In lesson two, interpreting a graph dealt with reading the axes as number lines that can change in range and intervals, which can create changes to the resulting graph. Plotting and finding coordinate points was also covered. In lesson three, analyzing graphs, students learned to use a best-fit-line and extrapolate or interpolate data points that were not noted in the preliminary data collection.

Lastly, these pieces came together to aid students in recognizing the full story that the graph has conveyed. And in lesson five, students learned to design and construct graphs.

The table in Appendix A reflected a few deletions and augmentations from Zucker's framework based on knowledge gained during the research portion of this study, as well changes to better suit the science classroom's needs. For example, Goal 3 and Goal 7 were eliminated because of limited student exposure to mathematical functions as well as objective 1.4 which was removed due to insufficient instruction in independent and dependent variables at the time of delivering the intervention. After the lessons the STEMscopes science literacy posttest was given to the treatment and control groups for data collection to be analyzed.

Procedures

Within the first week of this research study, both the treatment and control group participated in taking a STEMscopes science literacy pretest online through the distance learning format Google Classroom. The assessments collected only the students school identification number to match the pre and posttest scores and provided no other identifiers to the researcher. Measures were collected from a spreadsheet furnished by Google Form that consisted of a total of 24 questions, both available in English and Spanish.

The five lessons of the intervention were taught, working within the school's distance learning schedule for the treatment group which included synchronous teaching four days per week. The intervention was applied to the treatment group on Thursday of week 1, Tuesday-Friday of week 2, and completed on Tuesday of week 3.

Students in both the treatment and control group were given 50 minutes to complete the pretest during class. After the intervention both the treatment and control group had again 50 minutes in class to complete the posttest. Each of the days of intervention between pre and posttest contained a 50-minute graphing lesson delivered by the researcher online to the treatment group. The lessons spanned the bulk of the 70-minute period, with the remaining time spent on class activities such as attendance or announcements. The control group received 50-minute lessons related to an engineering project that did not involve graphing. After assessments and instruction were completed, the scores of both pretest and posttest were matched according to the student identifier and statistically analyzed.

Data Collection

Data from both pretest and posttest were collected through the Google Forms application, that compiled each submitted exam score and displayed a set of analytics such as questions that were answered most incorrectly, the mean test scores, and the standard deviation. The maximum score for each assessment was 24 points and both were blindly analyzed for grading accuracy by the researcher and one other science educator. Data from students who did not complete both the pretest and the posttest was removed as well as data from students who had not completed district required parental permission forms to be included in the study.

Fidelity

To guarantee fidelity, a fellow science teacher watched 20% of the 50-minute teaching sessions in both the control group and the treatment group. Guided by a fidelity checklist (Appendix C), the fellow seventh grade science teacher guaranteed 95% agreement that the interventions were followed on the checklist. This checklist and the Intervention Lesson Planning Guide in Appendix A were also reviewed by a veteran science teacher prior to the start of the intervention to confirm at least 90% adherence to the *Graphing Framework Goals and Objectives* used to guide the study's instruction piece. Lastly, intervention lessons were conducted by the same research teacher to eliminate any confounding variables that multiple teachers may add.

Ethical Considerations

Ethical considerations in this study involved seventh grade science participants in both the treatment and control groups. With respect to individuals, no identifying information was collected during the STEMscopes science literacy pre and posttest beyond the district provided Google account identifier, which served the purpose of matching the results of the STEMscopes science literacy pretest and posttest for each student. Parental consent forms were also collected for each participating student, as requested by the school district. At the end of the data analysis of the study, if there had been a significant change in scientific literacy in the treatment group, it would have been recommended that the control group receive the same graphing intervention.

Validity Threats

Validity threats, both internal and external, were managed through various avenues depending on the threat. The most significant internal validity threat involved the cancelation of in-person education within the state due to the COVID-19 pandemic for the school year of 2020-2021. Because of this, the research study was conducted entirely online during distance learning. This included class instruction through the Google Meet software, with all work required occurred on Google Slides, Google Forms, and Google Docs.

Additional internal threats included participant attrition, pretest learning, and diffusion of treatment. Participant attrition such as illness or technical issues like disruption of Internet service was handled by removing from the data collection results of students who did not complete both the pretest and posttest. Pretest learning threats were lowered by the high number of test questions and a randomized shuffling to remove any memorization of questions and answers. Lastly, diffusion of treatment was addressed by only providing the graphing literacy intervention in the treatment science period, and not addressed in the control.

The external validity threat that had the highest chance of skewing data came from the 38% of the control and 13% of the treatment group were categorized as ELs. Because they are still developing English within their education, translating results of this study to the public may be difficult due to differences in population dynamics. Gándara & Hopkins (2010) described how ELs struggle in education more than any other group (except for those who are recommended for special education). In the setting of science classes, this dilemma is exacerbated by the fact that some ELs are busy overcoming the obstacle of learning academic English through extra language classes with less time devoted to learning science. When they do arrive in science class, obstacles are two-fold. The first is to learn academic English used in science, and the second is to learn science literacy which includes graphing literacy. Therefore, scores on both measured assessments most likely differed from native English speakers and may also shed light on how this population responded to this intervention treatment.

Data Analysis

All data were entered into the Statistical Package for the Social Sciences® (SPSS®) for Windows, version 25.0.0 (SPSS, 2017). No names or identifying information was included in the data analysis. Before analyses were conducted, all data were cleaned to ensure no outliers were present (Dimitrov, 2012). After cleaning the data, independent sample t-tests and dependent sample t-tests (pretest and posttest) were conducted to determine the significant difference in scientific literacy between the two mean scores (i.e., treatment and control) on the STEMscopes assessments. Further, before interpreting the analytical output, Levene's Homogeneity of Variance was examined to see if the assumption of equivalence has been violated (Levene, 1960). If Levene's Homogeneity of Variance was not violated (i.e., the variances were equal across groups), data were interpreted for the assumption of equivalence; however, if the variances were not equal across groups, the corrected output was used for interpretation.

Results

Two independent samples t-tests were conducted on the whole sample ($n = 29$) for both the pre and post assessment scores. Results for the pretest were: Levene's Homogeneity of Variance was not violated ($p > .05$), meaning the variance between groups was not statistically different and no correction was needed, and the t-test showed significant differences between the mean scores on the pretests between the two groups $t(27) = -2.54$, $p < .05$. The initial science literacy of the treatment and control group as measured with the pretest were statistically different before the intervention period (see Table 1). Results for the posttest were: Levene's Homogeneity of Variance was not violated ($p > .05$), meaning the variance between groups was not statistically different and no correction was needed, and the t-test showed non-significant differences between the mean scores on the posttests between the two groups $t(27) = -1.97$, $p > .05$. This means there was not a significant difference in posttest scores between the control and treatment group (see Table 1).

Table 1

Results of Independent Samples T-Tests

	Mean	SD
Pretest*		
Treatment	13.38	4.66
Control	9.54	3.13
Posttest		
Treatment	14.75	4.27
Control	11.23	5.34

Note. SD = Standard Deviation. * = $p < .05$.

After determining the differences between pre and post assessment scores between groups, two paired t-tests were conducted for both groups (i.e., treatment and control) to determine if participants mean scores from pre to post were significantly different within each group (See Table 2). Results for each group were as follows: treatment group, $t(15)$ -1.70, $p >$ .05; control group, $t(12) = -1.58$, $p > .05$. Both the pre & posttests within the treatment and within the control group resulted in p values higher than .05, therefore they did not show a statistically significant difference. Additionally, the negative t-value for each group indicates an increase in scores from pre to post assessment, meaning improvement has occurred for both groups; however, neither group had statistical significance.

Table 2

Results of Paired T-Tests

	Mean	SD
Treatment Group		
Pre	13.38	4.66
Post	14.75	4.27
Control Group		
Pre	9.54	3.13
Post	11.23	5.34

Note. SD = Standard Deviation.

Discussion

Based on research linking graphing literacy with scientific knowledge, this study developed a five lesson graphing intervention plan focusing on the skills of graphing without the inclusion of new science material for seventh grade science students. The aim was to test the hypothesis that if graphing literacy improved, science literacy would improve as well. Results from a 24 question multiple-choice pre and posttest proved to be inconclusive, given that there was no statistically significant increase in science literacy after the planned graphing intervention in the treatment group compared to the control group.

Scores for the treatment group had a higher mean and lower standard deviation on the posttest when compared to the pretest. This indicated that the treatment group was not only scoring higher, but more students were performing consistently with less variance across scores. The control group displayed the opposite, with an increase in standard deviation from pretest to posttest making their results more variable than the treatment group. Therefore, although the intervention did not provide statically significant results, the treatment group was able to score higher and more consistently than the control.

Within the results, it is not clear whether unlinking graphing literacy from science literacy was helpful in the graphing intervention used in this study. If the goal is to teach graphing literacy to aid in scientific literacy, then increasing the frequency of teaching graphing throughout the school year in conjunction with science content may be more valuable. Graphs are a bridge between data and scientific concepts as Shah and Hoeffner (2002) suggest, where active practice of relating a graph to the scientific hypothesis, theory or explanation strengthens a student's link of graphing to scientific literacy. Teaching graphing literacy in hand with science solidifies their importance to one another, and when complexity increases within data sets graphing skills progress simultaneously (Zucker et al., 2015). Researchers such as Shah and Hoeffner (2002) have found that among important factors that influence graphing literacy, prior knowledge of science and graph conventions play a role. This study recommends that introducing science students to graphing skills in the beginning of the year before science content is beneficial but developing these skills throughout the year along with science will further students' handle on how graphing supports and adds to science.

The independent t-test comparing the means of science literacy in the posttest between the treatment and control group showed no significant statistical difference, however both groups did improve with increased mean scores. This occurred in the control group despite the lack of intervention and the lack of additional relevant scientific instruction related to the assessment questions. Future studies should ensure the tests can be completed by all subjects to avoid improvement based on familiarity with questions leading to increased speed of test taking and more questions being attempted as well as decreased test fatigue.

Limitations and Future Directions

Convenience factors likely played a large role in the investigation's outcome. Two seventh-grade science periods were available during the study, with the final sample sizes (n = 29) containing 13 students in the control versus 16 in the treatment group. This was significantly less than the number of students in the classes, as many were removed from the final results because they took only one of the two tests (pre or post) or lacked parental consent allowing scores to be used in the data. Another major limitation in this study was the large discrepancy between the control and treatment group, demonstrated by the results from the independent sample t-tests with the control versus treatment group on the pretest. Demographics may also be a contributing factor to this discrepancy, as the make-up of the control contained five EL students and three SWD, versus four ELs and no SWD students in the treatment group.

The two groups were taught through distance learning on Google Classroom, and were sourced from a lower income community where English was not the first language of many students. This may have also obscured any learning effect because ELs have exhibited lower performance than their peers due to the doubled effort of learning English on top of science (Gándara & Hopkins, 2010). The higher count of SWD students in the control also added to this difference as this group has even more difficulty with science concepts than ELs. Because this study was conducted through distance learning, students had lower accountability when not in a face-to-face classroom, and the gap between ELs and SWDs with their peers may have been widened as reflected in their pretest scores.

The idea that teaching graphing skills in the science classroom separate from how graphs are used in math should increase science literacy remains a viable hypothesis. However, the results here did not provide evidence in that favor. More research is recommended with emphasis on larger, more balanced sample groups and reduction of confounding factors without the environment of distance learning. Educating science students with the goal of achieving graphing literacy is still an essential task for science educators. The benefits extend beyond the borders of science, aiding students as they progress through their educational career into adulthood as part of greater society. More research and pedagogy development must be done to find the most effective graphing programs utilized in science classrooms, and in the meantime science educators must plan and implement their own strategies to integrate graphing and science instruction.

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Appendix A

Lesson Planning Guide for Graph Interventions:
Framework of graph literacy goals and objectives (Zucker et al., 2015)

Date	Goals & Objectives:	
DAY 1	Administer science literacy pretest to experimental period- with half the class taking Test A, and other half Test B. Time: 20 min	
I. Reading the Data: Identify and Encode Visual Graph Features.		
DAY 2 Time: 30 min	Goal 1: Identify general graph features	Visually process the "whole" graph shape. This includes relating shapes and meanings.
	Objective 1.1:	Identify the overall shape and direction of a line graph and connect the shape with the real-world meaning.
	Objective 1.2:	Identify the maxima and minima of a graph and interpret their meaning.
DAY 3 Time: 30 min	Goal 2: Identify and use scales	Focus on the scales and correctly interpreting the quantity graphed, the units (if any), and the numerical range.
	Objective 2.1:	Understand zooming, panning, stretching and shrinking do NOT change the data on the graph
	Objective 2.2:	Name correctly the coordinate values of any point on any single line graph or scatter plot, including units if any.
II. Reading Between the Data: Link Graph Features to Quantitative Facts, Trends or other Relationships		
DAY 4 Time: 30 min	Goal 3: Identify trends in noise	Two important graph skills in science are perceiving the trend of the data by *ignoring* the fluctuations and then estimating the extent of the noise.
	Objective 3.1	Interpolate between points on a graph.
III. Reading Beyond the Data: Integrate the Features and Relationships with the Context of the graph		
DAY 5	Goal 4: Graph	This goal focuses on more complex data, where changes in

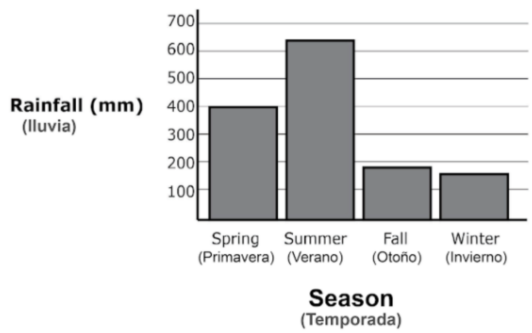
Time: 30 min	Extrapolation Link stories and graphs–piece wise linear	the trends can occur that represent changes in the research study.
	Objective 4.1:	Connect specific sections of a graph with specific portions of a story.
	Objective 4.2:	Connect multiple representations–including the graph, table function and animation–to specific portions of a story
IV. Graph Design and Construction		
DAY 6 Time: 50 min	Goal 5: Construct Graph	Designing a graph *before* constructing it *Graphing creates visuals (marks) for the purpose of conveying information and processing it.*
	Objective 5.1:	Transfer data from a table, know what kind of graph to use, label x- & y-axes, set intervals, and be able to convert data to points on a graph.
	Objective 5.2:	Tell the story
DAY 7 Time: 50 min	Administer science literacy posttest to experimental period- with half the class taking B form of the test, and other half taking A. Time: 20 min	

Appendix B

STEMscopes Questions:

1. Which season gets the most rain?

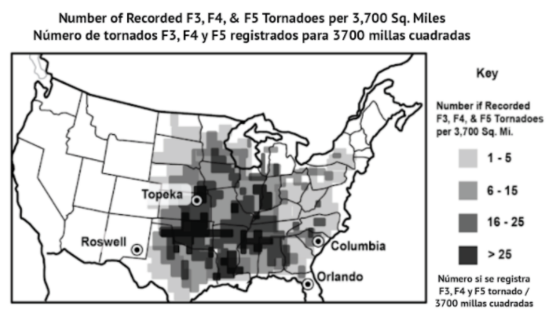
Español: ¿En cuál estación/temporada llueve más?
Enlace de audio en español:
https://drive.google.com/file/d/1PSN55SF6T5PQzaPTm89HKq_6A8mmi5U_/view?usp=sharing



- Spring (Primavera)
- Summer (Verano)
- Fall (Otoño)
- Winter (Invierno)

2. Based on the data provided by this map, which of the following cities would be most likely to experience a tornado with a rating of F3 or greater in the next year?

Español: Según los datos proveidos por este mapa, ¿cuál de las siguientes ciudades sería más probable que experimente un tornado con una calificación de F3 o superior durante el próximo año?
Enlace de audio en español:
https://drive.google.com/file/d/1tmlPscO2x_qwejQk2gLwmPt5cnyNiotO/view?usp=sharing

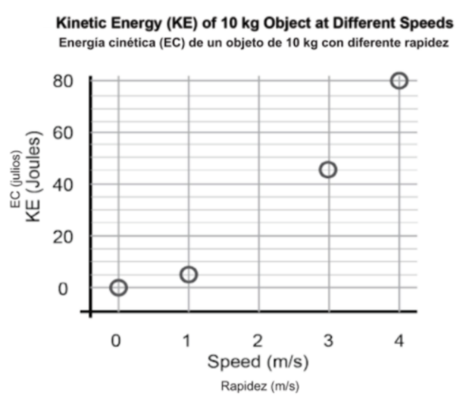


- Roswell, New Mexico
- Topeka, Kansas
- Orlando, Florida
- Columbia, South Carolina

3. Based on the information in the graph, we can predict that the kinetic energy of the object at 2 m/s would be-

Español: Basado en la información del gráfico, podemos predecir que la energía cinética del objeto a 2 m / s sería:
Enlace de audio en español:
https://drive.google.com/file/d/16JYigIYDAQ6LVQPEOPaNUxwloJ7YMqST/view?usp=sharing

A graph showing the kinetic energy of a 10 kg object at different speeds is provided.
Se provea un gráfico que muestra la energía cinética de un objeto de 10 kg a diferentes velocidades.



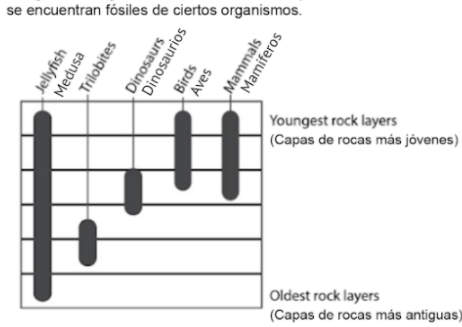
- 12 Joules (12 julios)
- 20 Joules (20 julios)
- 38 Joules (38 julios)
- 44 Joules (44 julios)

4. The information in the diagram supports which of the following conclusions?

Español: ¿Cuál de las siguientes conclusiones respalda la información del diagrama?
Enlace de audio en español:
https://drive.google.com/file/d/1SvGt30SuPBFNZ46JSmlh2zPWkcXoMyB9/view?usp=sharing

The following diagram shows where, in layers of rock, fossils of certain organisms are found.

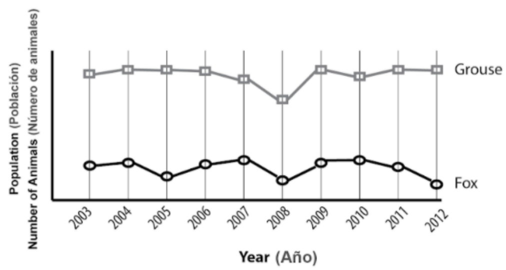
El siguiente diagrama muestra dónde, en capas de roca, se encuentran fósiles de ciertos organismos.



- Birds descended directly from trilobites and dinosaurs. (Las aves descienden directamente de trilobites y dinosaurios.)
- Trilobites became extinct before dinosaurs appeared on Earth. (Los trilobites se extinguieron antes de que aparecieran los dinosaurios en la Tierra.)
- Jellyfish live longer than any other organisms on Earth. (Las medusas viven más que cualquier otro organismo de la Tierra.)
- Mammals did not appear on Earth until after the dinosaurs went extinct. (Los mamíferos no aparecieron en la Tierra hasta después de que los dinosaurios se extinguieron.)

5. An increase in population of an organism would most likely be associated with which of the following?

Español: ¿Un aumento en la población de un organismo probablemente estaría asociado con cuál de los siguientes?
Enlace de audio en español:
https://drive.google.com/file/d/1Tgc9KrZFMmSdIXlpvNx1uby6t3mDXi2A/view?usp=sharing



The graph here shows the populations, over several years, for two animals that share a habitat. Foxes are mammals that hunt for food, and grouse are birds, a common prey animal of foxes. (El gráfico aquí muestra las poblaciones, durante varios años, de dos animales que comparten un hábitat. Los zorros son mamíferos que cazan para alimentarse, y los urogallos son aves, una presa común de los zorros.)

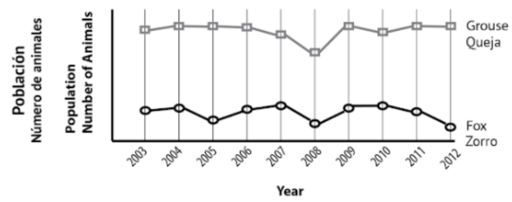
- A series of severe weather events in the habitat (Una serie de eventos climáticos severos en el hábitat.)
- A decrease in necessary resources available (Disminución de los recursos necesarios disponibles)
- An expansion of suitable living space (Una expansión del espacio habitable adecuado)
- An increase in animals that prey on the organism (Un aumento de animales que se alimentan del organismo.)

6. According to the data, in which year did the population of foxes show a decrease that is most likely the result of a decrease in the availability of a source of food?

Español: Según los datos, ¿en qué año la población de zorros mostró una disminución que probablemente sea el resultado de una disminución en la disponibilidad de una fuente de alimento?
Enlace de audio en español: https://drive.google.com/file/d/1fr_OVNVGyCT98j1ul1N0sYG-5KDZ5raN/view?usp=sharing

The graph here shows the populations, over several years, for two animals that share a habitat. Foxes are mammals that hunt for food, and grouse are birds, a common prey animal of foxes.

El gráfico aquí muestra las poblaciones, durante varios años, de dos animales que comparten un hábitat. Los zorros son mamíferos que cazan para alimentarse, y los urogallos son aves, una presa común de los zorros.

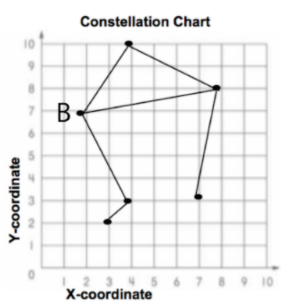


- 2003
- 2005
- 2008
- 2012

7. The location of the Sun determines the different constellations that can be seen from Earth. During the month of May, you may see a constellation like the one shown here. Use the picture to answer the question: Label point B with the x- and y- coordinates. (Hint: To get the x-coordinate, look from the dot down. To get the y-coordinate, look left to the y-coordinate axis.)

Untitled Title
Enlace de audio en español:
https://drive.google.com/file/d/1oQb1Hn2XHkgWKkrfvhHPuqwwJsNQ905f/view?usp=sharing

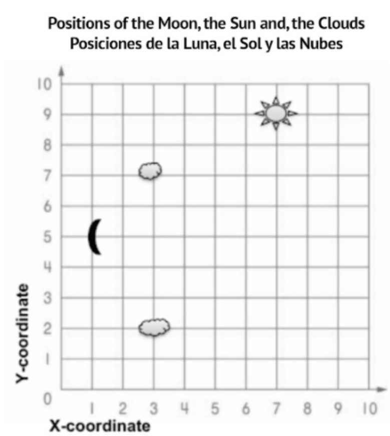
12: La ubicación del Sol determina las diferentes constelaciones que se pueden ver desde la Tierra. Durante el mes de mayo, es posible que vea una constelación como la que se muestra aquí. Usa la imagen para responder la pregunta: Etiqueta el punto B con las coordenadas x- e y-. (Sugerencia: para obtener la coordenada x, mire desde el punto hacia abajo. Para obtener la coordenada y, mire hacia la izquierda en el eje de la coordenada y).



- 4, 10
- 4, 8
- 3, 2
- 10, 3

8. During the day, objects such as the Sun, the Moon, and clouds can be seen easily with the naked eye. What are the coordinates of the Moon? Write them in the (x, y) format.

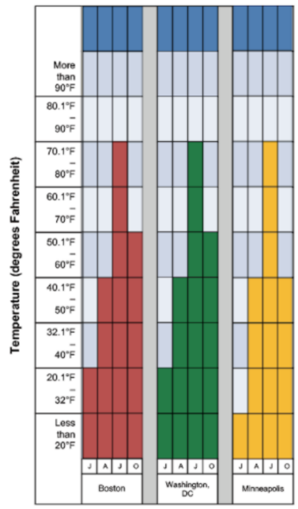
Español: Durante el día, objetos como el Sol, la Luna y las nubes se pueden ver fácilmente a simple vista. ¿Cuáles son las coordenadas de la Luna? Escríbalos en formato (x, y).
Enlace de audio en español:
https://drive.google.com/file/d/1jZa6QUUC6EnUF0ZLnsbUw4KW2yq6Zwfp/view?usp=sharing



- 2, 5
- 1, 5
- 3, 5
- 3, 2

9. How would you compare the conditions in Boston and the conditions in Washington DC?

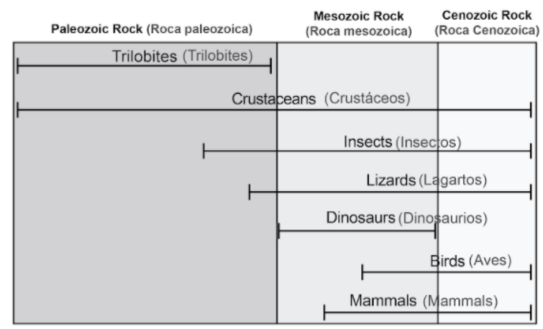
Español: ¿Cómo compararías las condiciones en Boston y las condiciones en Washington DC?
Enlace de audio en español:
https://drive.google.com/file/d/1jkvdXXlMQNKF0Z5P7azZ5sdvOsdAGQRa/view?usp=sharing



- Very much the same (Muy parecidas)
- Very different (Muy diferente)
- Kind of the same (Un poco parecidas)
- Kind of the different (un poco diferente)

10. The data in this diagram supports which of the following conclusions?

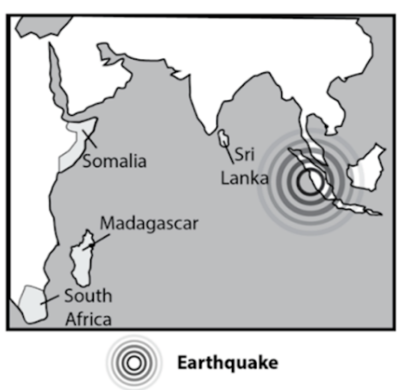
Español: ¿Cuál de las siguientes conclusiones apoya los datos de este diagrama?
Enlace de audio en español:
https://drive.google.com/file/d/17tczDO2GzRLqs7QT43vxISJWtydGWQvg/view?usp=sharing



- Birds appeared before trilobites had gone extinct. (Las aves aparecieron antes de que los trilobites se extinguieran.)
- Insects appeared only after dinosaurs had gone extinct. (Los insectos aparecieron solo después de que los dinosaurios se extinguieron.)
- Mammals did not appear until after trilobites had gone extinct. (Los mamíferos no aparecieron hasta después de que los trilobites se extinguieron.)
- Crustaceans had gone extinct at about the same time as trilobites. (Los crustáceos se habían extinguido casi al mismo tiempo que los trilobites.)

11. The data on the map would best support a prediction of which of the following events?

Español: ¿Los datos del mapa apoyarían mejor una predicción de cuál de los siguientes eventos?
Enlace de audio en español: https://drive.google.com/file/d/1EWiJ6H3hSQBvoH-I1eXMasSQWZIodB2D/view?usp=sharing

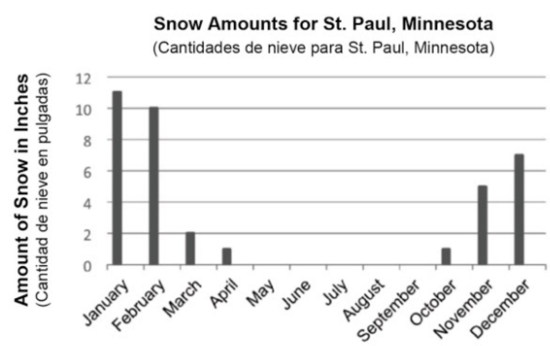


The provided map shows the location of an earthquake under the ocean.
El mapa provisto muestra la ubicación de un terremoto bajo el océano.

- A tsunami in Sri Lanka (Un tsunami en Sri Lanka)
- An earthquake in South Africa (Un terremoto en Sudáfrica)
- A hurricane in Somalia (Un huracán en Somalia)
- Flash floods in Madagascar (Inundaciones repentinas en Madagascar)

12. What was the total amount of snowfall for the entire year? (Hint: 4 inches of snow fell in March, April and October.)

Español: ¿Cuál fue la cantidad total de nieve durante todo el año? (Sugerencia: cayeron 4 pulgadas de nieve en marzo, abril y octubre)
Enlace de audio en español: https://drive.google.com/file/d/1TQWb3Em6Lw-BOB1V-J66OdZioO15dnFQ/view?usp=sharing



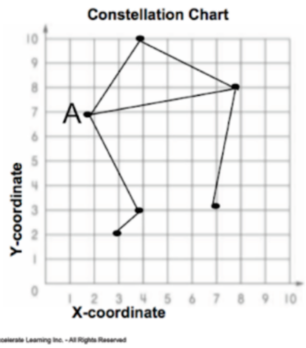
- 20 inches
- 50 inches
- 37 inches
- 12 inches

13. The location of the Sun determines the different constellations that can be seen from Earth. During the month of May, you may see a constellation like the one shown here. Use the picture to answer the question: Label point A with the x- and y- coordinates. (Hint: To get the x-coordinate, look from the dot down. To get the y-coordinate, look left to the y-coordinate axis.)

Untitled Title

Enlace de audio en español: https://drive.google.com/file/d/11TWIK-A0LMEDzHMvPKKoWIT7ACdKvivg/view?usp=sharing

La ubicación del Sol determina las diferentes constelaciones que se pueden ver desde la Tierra. Durante el mes de mayo, es posible que vea una constelación como la que se muestra aquí. Usa la imagen para responder la pregunta: Rotula el punto A con las coordenadas x e y. (Sugerencia: para obtener la coordenada x, mire desde el punto hacia abajo. Para obtener la coordenada y, mire hacia la izquierda en el eje de la coordenada y).

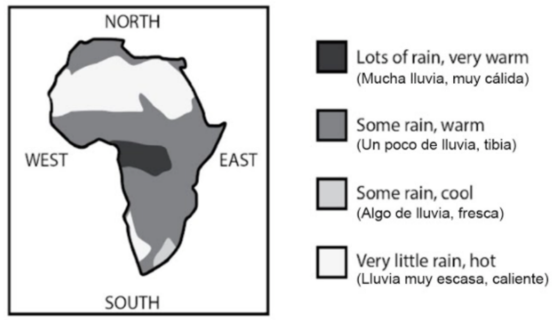


- 2, 10
- 3, 7
- 7, 2
- 2, 7

14. A rainforest is a place with a warm climate that gets lots of rain. Where are the rainforests in Africa?

Español: Una selva tropical es un lugar con un clima cálido que recibe mucha lluvia. ¿Dónde está la selva tropical en África?

Enlace de audio en español: https://drive.google.com/file/d/1DavCx1RaCpEMMy3lBiOnjMtytZ6kSFBs/view?usp=sharing



- In the middle of the west side (En el medio del lado oeste)
- At the very end of the tip in the south (Al final de la punta en el sur)
- Almost everywhere on the East side (Casi en todas partes en el lado este)
- In the widest part to the North (En la parte más ancha al norte)

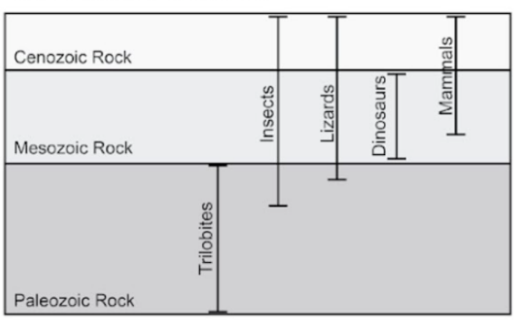
15. According to the data in this diagram, which groups of animals appeared before trilobites were extinct?

Español: Según los datos de este diagrama, ¿qué grupos de animales aparecieron antes de que se extinguieran los trilobites?

Enlace de audio en español: https://drive.google.com/file/d/1ATZIpmpZN7otXkTdh0qpgxkjpWWWIWVh/view?usp=sharing

The diagram shows the rock layers, based on relative age, in which the fossils of major groups of animals are found.

El diagrama muestra las capas de rocas, según la edad relativa, en las que se encuentran los fósiles de los principales grupos de animales.



- Insects and lizards (Insectos y lagartijas)
- Lizards and dinosaurs (Lagartos y dinosaurios)
- Dinosaurs and mammals (Dinosaurios y mamíferos)
- Insects and dinosaurs (Insectos y dinosaurios)

16. Which seed will grow into a plant that is 30 centimeters tall, has blue flowers, and has long, pointed leaves?

Español: ¿Qué semilla crecerá en una planta de 30 centímetros de altura, con flores azules y hojas largas y puntiagudas?

Enlace de audio en español: https://drive.google.com/file/d/1JRHMBBaOcfUmWeK7FrYHxpYpec-kGJ2B/view?usp=sharing

Plant	Height of Adult (cm)	Leaf Shape	Flower color
Buttercup Botón de oro	30	3 lobes, pointed	Yellow
Nightshade Hierba mora/belladona	20	Long, pointed	Purple
Asters Margaritas	30	Long, pointed	Blue
Chinaberry Chinaberry	900	Rounded with point	Blue

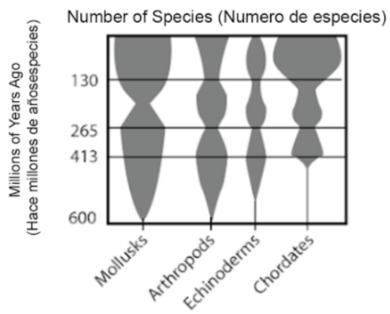
- Buttercup (Botón de oro)
- Nightshade (Hierba mora/belladona)
- Aster (margaritas)
- Chinaberry

17. What is the only group that experienced an increase of diversity between 413 million years age and 265 years ago?

Español: ¿Cuál es el único grupo que experimentó un aumento de la diversidad entre 413 millones de años y hace 265 años?
Enlace de audio en español:
https://drive.google.com/file/d/140BfHtMJ_dOkEALnVlNqNObIVBaR3KRU/view?usp=sharing

This diagram provides information on the diversity, in number of species, for four major groups of animals over time.

Este diagrama proporciona información sobre la diversidad, en número de especies, de cuatro grupos principales de animales a lo largo del tiempo.



- Mollusks (Moluscos)
- Arthropods (Artrópodos)
- Echinoderms (Equinodermos)
- Chordates (Cordados)

18. When we move a species to a new location, it is sometimes called an invasive species because it did not naturally live there. This is a table that represents the number of Kudzu plants and Native plants after each round of growth. What do you notice about the numbers of the invasive species, Kudzu plants after each round?

Español: Cuando trasladamos una especie a una nueva ubicación, a veces se la denomina especie invasora porque no vivió allí de forma natural. Esta es una tabla que representa el número de plantas Kudzu y plantas nativas después de cada ronda de crecimiento. ¿Qué notas sobre el número de especies invasoras, plantas Kudzu después de cada ronda?
Enlace de audio en español:
https://drive.google.com/file/d/1LBm8KsZIc0XmJQjK3XI7BO6sfiMix0vC/view?usp=sharing

Round	Number of Kudzu	Number of Native Plants
1	5	16
2	7	14
3	9	12
4	11	10
5	13	8
6	15	6

- As there are more rounds, the number of Kudzu plants are staying the same. (A medida que hay más rondas, la cantidad de plantas de Kudzu se mantiene igual.)
- As there are more rounds, the number of Kudzu plants are increasing. (A medida que hay más rondas, aumenta el número de plantas de Kudzu.)
- As there are more rounds, the number of Kudzu plants are decreasing. (A medida que hay más rondas, la cantidad de plantas de Kudzu está disminuyendo.)
- As there are more rounds, the number of native plants are increasing. (A medida que hay más rondas, aumenta el número de plantas nativas.)

19. Assuming the data indicates patterns that will continue, which city will most likely experience an earthquake of a magnitude of 5.0 or higher in the next year or two?

Español: Suponiendo que los datos indiquen patrones que continuarán, ¿qué ciudad probablemente experimentará un terremoto de magnitud 5.0 o superior en los próximos dos años?
Enlace de audio en español:
https://drive.google.com/file/d/116Ulue0FTslyqp0QF6TsfQ2bXggzar47/view?usp=sharing

City	Earthquakes (Magnitude)									
	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
W	2.1	1.8	1.6	1.5	3.1	1.1	1.4	2.0	2.5	1.5
X	7.9	-	-	-	-	-	-	-	5.5	-
Y	4.8	5.2	5.5	6.1	4.5	5.8	-	5.1	5.3	6.1
Z	-	-	-	1.4	-	-	1.5	-	-	2.5

The table provides data on the earthquakes recorded for four different cities over a ten year period.

La tabla proporciona datos sobre los terremotos registrados en cuatro ciudades diferentes durante un período de 10 años.

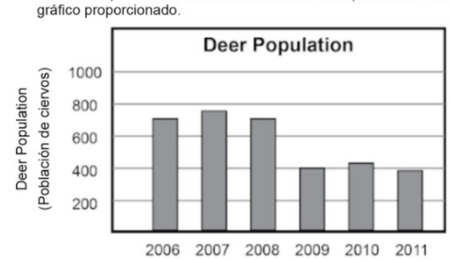
- City W
- City X
- City Y
- City Z

20. Which of the following is the most likely explanation for the change in population in 2009?

Español: ¿Cuál de las siguientes es la explicación más probable del cambio de población en 2009?
Enlace de audio en español:
https://drive.google.com/file/d/1TnCoAfGHSBw_5_1VA3ctxQjltPvuYG2-/view?usp=sharing

The population of deer in a certain area is monitored over a period of six years. The data is represented in the graph provided.

La población de ciervos en un área determinada se monitorea durante un período de seis años. Los datos se representan en el gráfico proporcionado.



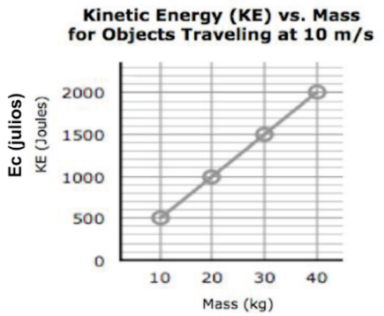
- Wolves, which prey on deer, were being hunted more than usual. (Los lobos, que se alimentan de ciervos, eran cazados más de lo habitual.)
- Rainfall in the previous spring was higher than the yearly average. (Las precipitaciones de la primavera anterior fueron superiores a la media anual.)
- Humans introduced grazing animals that feed on the same plants as the deer. (Los humanos introdujeron animales de pastoreo que se alimentan de las mismas plantas que los ciervos.)
- More insects that pollinate flowering plants move into the habitat. (Más insectos que polinizan las plantas con flores se trasladan al hábitat.)

21. In order for an object moving at 10 m/s to have a kinetic energy of 1800 Joules, the object must have a mass in the range of–

Español: Para que un objeto que se mueve a 10 m / s tenga una energía cinética de 1800 Joules, el objeto debe tener una masa en el rango de–
Enlace de audio en español: https://drive.google.com/file/d/1BNWMRNM-sQ3moH1PFAuLK_jE4PPylqgd/view?usp=sharing

A graph showing the kinetic energy and mass of objects traveling at 10 m/s is shown.

Se muestra una gráfica que muestra la energía cinética y la masa de los objetos que viajan a 10 m/s.



- 0–10 kg.
- 10–21 kg.
- 20-30 kg.
- 30-40 kg.

22. By looking at this data, we can see that -

Español: Al observar estos datos, podemos ver que:
Enlace de audio en español: https://drive.google.com/file/d/1-HF5H4J-YZHHGtwvpEWe0Hfo_4sxClSk/view?usp=sharing

The length of the giraffes' necks in one group of 14 giraffes was measured. The number of giraffes with different neck lengths was recorded.

Se midió la longitud del cuello de las jirafas en un grupo de 14 jirafas. Se registró el número de jirafas con diferentes longitudes de cuello.

Neck Length (cm) Longitud del Cuello	Number of Giraffes Numero de jirafas
176	1
178	4
180	6
182	2
184	1

- the necks of giraffes are much longer now than in the past. (los cuellos de las jirafas son mucho más largos ahora que en el pasado.)
- not all the giraffes have the same neck length. (no todas las jirafas tienen el mismo largo de cuello.)
- giraffes can never have necks longer than 184 centimeters. (las jirafas nunca pueden tener cuellos de más de 184 centímetros.)
- the necks of giraffes are the longest of any animal. (Los cuellos de las jirafas son las más largas de cualquier animal.)

23. Which two cities have a cooler climate?

Español: ¿Qué dos ciudades tienen un clima más fresco?
Enlace de audio en español:
https://drive.google.com/file/d/1d50CheNZSTjs4N9BW32_ULaaPj69coL7/view?usp=sharing

The temperature on July 5, 2015, in Karachi, Pakistan was near 117°F. People were trying to stay cool by swimming in the cool ocean water. See the data below for the temperature in different cities on that same day.

City	Temperature on July 5, 2015
Karachi, Pakistan	117°F
Anchorage, Alaska	67°F
Phoenix, Arizona	93°F
Dikson, Russia	36°F

La temperatura el 5 de julio de 2015 en Karachi, Pakistán, estaba cerca de los 117° grados Fahrenheit. La gente intentaba mantenerse fresca nadando en el agua fría del océano. Consulte los datos a continuación para conocer la temperatura en diferentes ciudades ese mismo día.

- Karachi, Pakistan and Dikson, Russia
- Anchorage, Alaska and Phoenix, Arizona
- Anchorage, Alaska and Dikson, Russia
- Karachi, Pakistan and Phoenix, Arizona

24. Which two months have more than 150 millimeters of snow?

Español: ¿Cuáles dos meses tienen más de 150 milímitros de nieve?
Enlace de audio en español: https://drive.google.com/file/d/1d3SILgcomiVS3VBk-7hQ8CQKQn1gf6_g/view?usp=sharing

Month (Mes)	Average Snowfall (mm) (Nevadas promedio)
July (julio)	0
August (agosto)	0
September (septiembre)	0
October (octubre)	0
November (noviembre)	19
December (diciembre)	140
January (enero)	191
February (febrero)	218
March (marzo)	127
April (abril)	20
May (Mayo)	0
June (junio)	0

- September and October (Septiembre y octubre)
- November and December (Noviembre y diciembre)
- January and February (enero y febrero)
- March and April (Marzo y abril)

Appendix C

Table 2.0: Sample Fidelity Checklist for Graphing Intervention

<table>
<tr><th>Date</th><th colspan="2">Goals & Objectives:</th></tr>
<tr><td>DAY 1</td><td colspan="2">Administer science literacy pretest to experimental period and control period.
Time: 50 min</td></tr>
<tr><td colspan="3">I. Reading the Data: Identify and Encode Visual Graph Features.</td></tr>
<tr><td rowspan="3">DAY 2

Time:
50 min</td><td colspan="2">Goal 1: Identify general graph features
Visually process the “whole” graph shape. This includes relating shapes and meanings.</td></tr>
<tr><td colspan="2">Objective 1.1:
Identify the overall shape and direction of a line graph and connect the shape with the real-world meaning.</td></tr>
<tr><td colspan="2">Objective 1.2:
Identify the maxima and minima of a graph and interpret their meaning.</td></tr>
<tr><td>CHECK</td><td>Fidelity Check:</td><td>Notes:</td></tr>
<tr><td></td><td>Introduction of graphing skill through:
- Real-world example or polls taken in class</td><td></td></tr>
<tr><td></td><td>Display prepared slide deck to present in class on the graphing skill of the day</td><td></td></tr>
<tr><td></td><td>Include a student Graphing Handbook that students will fill in, and after each accomplished skill, can collect at badge</td><td></td></tr>
<tr><td></td><td>Include Formative Assessment during or end of class on graphing</td><td></td></tr>
<tr><td></td><td>Build in time for graphing practice</td><td></td></tr>
<tr><td>DAY 3
to
DAY 6</td><td colspan="2">Goals for the day specified and same list is used for each intervention day.</td></tr>
</table>

Table 3.0: Sample Fidelity Checklist for Control Group

Date	Goals & Objectives:	
DAY 1	Administer science literacy pretest to experimental period and control period. Time: 50 min	
CHECK Day	**Fidelity Check:**	**Notes:**
	NO introduction of graphing skill through: - Real-world example or polls taken in class	
	NO prepared slide deck to present in class on the graphing skill of the day	
	NO student Graphing Handbook used	
	NO formative assessment during or end of class on graphing	
	NO time built in for graphing practice	