

IMPACTS OF THE IDENTIFY AND INTERPRET STRATEGY IN A SUMMER SCHOOL
PROGRAM ON IMPROVING STUDENTS' SCIENTIFIC EXPLANATIONS

by

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ABSTRACT

During the pandemic, students did not have as many opportunities to engage in authentic experiences using critical science and engineering practices (SEPs). At-risk students were enrolled in a summer school program designed to give students experiences to practice using and improving the SEPs of planning and carrying out investigations, analyzing and interpreting data, and constructing scientific explanations. The purpose of this study was to look at whether the Identify and Interpret (I^2) strategy students were taught to analyze and interpret qualitative and quantitative data would also help improve students' scientific explanations, specifically in the areas of evidence and reasoning. After receiving initial instruction on both the claim, evidence, reasoning (CER) framework and I^2 strategy, students engaged in multiple investigations that gave them opportunities to practice gathering data, making graphs, and using the I^2 strategy. Students wrote six scientific explanations using the CER framework, and rubrics were used to score student explanations in claim, evidence, and reasoning. Graphs and data tables where students used the I^2 strategy were reviewed to see how relevant the students' "what I see" (WIS) or "what it means" (WIM) statements were and if the students used the WIS or WIM statements in their scientific explanations. The results suggest that when students thoughtfully engaged in the Identify and Interpret strategy, students typically scored higher in their evidence and reasoning scores, especially in the evidence score, than students that did not. By making connections between the "what I see" statements as evidence and the "what it means" statements as reasoning and encouraging students to use them in writing explanations, the I^2 strategy has the potential to increase student scores for evidence and reasoning. The study also showed the strategy was not as impactful as it could have been for all students, which could be attributed to poor graphing skills, not explaining the relationship between variables in their WIM statements, and lack of content knowledge to help provide appropriate reasoning in the WIM statements and explanations.

INTRODUCTION & BACKGROUND

Context of the Study

During the pandemic, students did not have as many opportunities to engage in authentic experiences using critical science and engineering practices (SEPs), such as analyzing and interpreting data from student-led investigations and constructing explanations of phenomena based on their investigations' data. Engaging students in these science and engineering practices is essential in developing their understanding of the crosscutting concepts and disciplinary core ideas in a more meaningful way (NRC, 2012). The loss of continued exposure to authentic science learning experiences created multiple gaps in students' knowledge across all dimensions of the Next Generation Science Standards (NGSS), particularly in the science and engineering practices. These gaps were especially harmful to the most vulnerable student populations at the school where the study was conducted, where 63% are students of color and 70% are socioeconomically disadvantaged (Clark Intermediate, 2022). When practices are emphasized in educational settings, they have the "potential to shift science education toward more equitable, active, and engaged learning for all students" (Schwartz et al., 2017, p. 33), which is especially important for students of color and students that come from socioeconomically disadvantaged communities. Historically, these students have limited access to meaningful learning opportunities in science.

To help address some gaps in the science and engineering practices (SEPs) created from the pandemic, the two science teachers I worked with in this study created a summer school program that would give students multiple opportunities to engage in the SEPs most crucial for student success in their future science education. As the district science teacher on special

assignment (TOSA), I worked alongside them as a consultant for the program they developed. The SEPs we selected to focus on were Planning and Carrying Out Investigations (SEP-3), Analyzing and Interpreting Data (SEP-4), and Constructing Explanations (SEP-6). One reason SEP-3 was selected was so students could conduct science investigations that utilized some standard tools and equipment they would be expected to know how to use in future science courses. Investigations would allow students to engage in qualitative and quantitative data collection and analysis (SEP-4), including learning graphing skills and interpretation from visual representations of data. Finally, students would practice writing scientific explanations (SEP-6) using the data collected as evidence to answer questions posed for each investigation.

In addition to creating opportunities to engage students in the SEPs selected, it was important to the teachers to create a fun and engaging environment for the students enrolled in the summer school program. The students recommended for the program were primarily students with D and F grades in two or more core academic courses during the 2020-21 school year. Many of the activities selected not only re-taught or introduced students to science concepts essential for future learning but were highly engaging and motivating to students in previous school years. According to A Framework for K-12 Science Education, the “doing of science or engineering can pique students’ curiosity, capture their interest, and motivate their continued study” (NRC, 2012, p. 42). By selecting high-interest activities, students would hopefully stay enrolled for the entire six-week summer school program, potentially allowing for more growth in the science and engineering practices focused on during the program.

Purpose of the Study

Students typically struggle to write high-quality science explanations, especially with selecting and including appropriate and sufficient evidence (McNeill & Krajcik, 2007; Sandoval, 2003; Sandoval & Millwood, 2005) and providing reasoning to link their evidence to their claims (McNeill et al., 2006). To help address these issues, the summer school curriculum included re-teaching the claim, evidence, and reasoning (CER) framework students had used during the school year. A variety of scaffolds were embedded throughout the curriculum, some of which faded over the five weeks of instruction, to try and improve students' use of appropriate and sufficient evidence and reasoning when writing scientific explanations.

Conducting science investigations during summer school would provide students with opportunities to collect and interact with various types of data to improve their ability to analyze and interpret data (SEP-4). To make meaning from the data, students would organize it into tables to help recognize variables, conduct simple statistical analyses like calculating the mean or average for multiple trials, and create graphs to help recognize potential patterns in the data. Students were taught the Identify and Interpret (I^2) strategy from BSCS Science Learning to help students make sense of their graphs and observational data. The strategy helps students break down the graph or information into smaller parts by first identifying what they see in the graph, such as trends, changes, or differences, and then interpreting the meaning of their observations (BSCS, 2012a, b). These scientific tools or analyses help to “bring out the meaning of data-and their relevance-so that they may be used as evidence” (NGSS Lead States, 2013, p. 56).

As I consulted with the teachers to design the summer school curriculum, I started to see a possible connection with the I^2 strategy helping students identify potential evidence that could be used in the explanations they would have to write following most of the investigations. The

strategy also has students interpret, or make sense of, what they see in the graph, which often requires the use of scientific knowledge or principles. The ability to link evidence, or data, to a claim using scientific knowledge or principles is a key feature in the reasoning portion of scientific explanations (McNeill et al., 2006). Since students would be working on their writing of scientific explanations using the claim, evidence, and reasoning framework and their ability to analyze and interpret data using the I² strategy, this led to my question of whether the I² strategy could also help improve students' scientific explanations.

Focus Statement/Question

My focus question was, What is the impact of using the Identify and Interpret strategy in a summer school program on improving students' ability to write scientific explanations?

My sub-questions include the following:

1. How effective is the Identify and Interpret strategy in improving students' use of appropriate and sufficient evidence when writing scientific explanations?
2. How effective is the Identify and Interpret strategy in improving students' reasoning when writing scientific explanations?
3. What impact does using the Identify and Interpret strategy have on students' confidence in writing scientific explanations?

CONCEPTUAL FRAMEWORK

Importance of Science and Engineering Practices

With the implementation of the Next Generation Science Standards (NGSS), there is a need to shift science instruction to an inquiry-based instructional model where students are figuring out aspects of our natural world. The vision laid out in A Framework for K-12 Science Education (NRC, 2012), from which NGSS was built, calls for the integration of knowledge along with the necessary practices to engage students in scientific inquiry and engineering design. At the heart of inquiry in the NGSS are the science and engineering practices. The science and engineering practices (SEPs) allow students to become active participants in generating knowledge and making sense of the world. By engaging students in the practices of science alongside the development of content knowledge, we are showing students a more accurate representation of what science is and how scientific knowledge is developed.

Constructing Explanations

Constructing explanations is a key practice of science, as scientists use this process to build knowledge to answer questions about why or how something occurs in the natural world (Schwartz et al., 2017). As students engage in constructing scientific explanations around phenomena, they are working to make sense of the world around them. This sense-making process often involves the sharing of ideas, discussing the merits of each other's explanations, which should be rooted in evidence and scientific knowledge, and the reconciliation of those ideas based on the evidence presented. Over the last several decades, studies have shown that “students understand more deeply and remember longer when they actively construct explanations about the world around them” (Schwartz et al., 2017, p. 208).

Claim, Evidence, Reasoning Framework

Early forms of constructing and defending scientific explanations in curriculum and instructional design stemmed from Toulmin's model of argumentation, which consisted of a claim, data, warrant, and backing (Berland & Reiser, 2009). To align Toulmin's model more closely with the science standards of the time and make the process more accessible to middle school students, McNeill et al. (2006) devised the claim, evidence, reasoning (CER) framework as an entry point to help students learn how to construct scientific explanations. They defined each component as follows, "the claim is an assertion or conclusion that answers an original question. The evidence is the scientific data that supports the claim...The reasoning is a justification that shows why the data count as evidence to support the claim" (p. 158).

The framework was designed as a scaffold to try and make the structure and essential components of a scientific explanation clearer to students in hopes that this would encourage deeper thinking about the process and content, which would be visible in their explanations (McNeill et al., 2006). McNeill et al. (2006) found that when students received a focal lesson where they were explicitly taught the CER framework, there was an increase in students' claim, evidence, and reasoning scores. Each mean score for claim, evidence, and reasoning, was at least doubled from the pre-test score. The CER framework has become the standard framework used with students in my district when teaching them how to write scientific explanations. Knowing how to use the framework is a critical skill students need to succeed in future years of their district science education and why it was selected as a focus in the summer school curriculum.

As the framework has been implemented in my district, teachers have seen students struggle with including appropriate and sufficient evidence in their explanations. Students also struggle with using data from their investigations as evidence to support their claims. When

using the CER framework in a chemistry unit of instruction, McNeill and Krajcik (2007) found that while overall student scores in evidence improved from the pre- to the post-test, students were still struggling to use appropriate evidence in their explanations. When students were able to select and use appropriate evidence in their explanations, it led to higher claim and reasoning scores (McNeill & Krajcik, 2007). Further analysis of their data suggested that students' ability to use appropriate data as evidence depends on the wording of the assessment task, students' content knowledge, and their understanding of what counts as evidence (McNeill & Krajcik 2007).

Even with the implementation of the CER framework, teachers have continued to state that students often do not provide appropriate reasoning to support their claims. In a study conducted by McNeill et al. (2006), they found that even though the mean reasoning score improved from the pre-test to the post-test using the CER framework, the post-test reasoning score was only 1.76 with a maximum score of 5.0. In reviewing students' reasoning on the post-test, they found students had difficulty explaining why their data supports their claim and backing up that link using scientific knowledge or principles (McNeill et al., 2006). Students may have had difficulty because the authors were not explicit in the curriculum when they explained reasoning as "a statement that connects your evidence to your claim" (McNeill et al., 2006, p. 182). The study shows the importance of using more precise language in the scaffolds or prompts given to students that reasoning should include scientific principles to connect evidence to a claim.

Analyzing and Interpreting Data

To determine the significance of data collected from an investigation in the context of a question to write a claim, students must first make sense of the data they collected. The data must be presented in a way that helps students see patterns and relationships in the data. Analyzing and interpreting data is a chief practice scientists use to organize and make sense of the raw data they have collected (NRC, 2012). Scientists use a range of tools to aid in analyzing and interpreting data, such as tables, charts, graphs, and mathematics. Tables can help organize the data in a more accessible form and help define independent and dependent variables. Graphs create visual representations of the data, which is better for finding patterns and relationships in the data (Hunter-Thomson, 2021). Learning to interpret graphs helps students explore relationships between variables and develop a deeper understanding of concepts displayed in the data (Schwartz et al., 2017). Mathematics, such as calculating averages, can help express relationships between variables (NRC, 2012). Using these tools, students can reason through the data to create meaning and use that meaning as evidence in explanations (NRC, 2012; Schwartz et al., 2017).

Challenges With Analyzing and Interpreting Data

In the book, *Helping Students Make Sense Of The World Using Next Generation Science And Engineering Practices*, the authors describe the challenges students face when analyzing and interpreting data. Many students make and record observations in a superficial way. For students to identify patterns or relationships in data, we have to help them learn to make and record observations that result in rich data (Schwartz et al., 2017). Because observations are used to try and make sense of a phenomenon, we can help students by asking them what they are looking for and why. Students also need help distinguishing between

observations, or, what they see, and inferences, what they think (Schwartz et al., 2017). The Identify and Interpret strategy discussed later can help students begin to make these distinctions.

In the early stages of learning how to support claims with evidence, another challenge is students who over-analyze or under-analyze their data to support a claim. By teachers demonstrating and students engaging “in the practice [of analyzing data] multiple times, articulating the connections between the data and analysis, and giving meaning to those relationships is one way [to] address these challenges” (Schwartz et al., 2017, p. 176). Students also need support in understanding when to use the various tools and procedures for analyzing data. Instead of selecting the tool most appropriate for the situation, they often pick the first tool they think of, like making a bar graph, regardless of the type of data collected. The lack of mathematical skills can also hinder students’ understanding and engagement with the data (Schwartz et al., 2017).

In a review of the literature on graph interpretation, Glazer (2011) found that “competence is affected by many factors, including aspects of graph characteristics,...the viewer’s expectations about, or familiarity with, the graphs’s content and their prior knowledge” (p. 201). In science, the effect of content knowledge on graph interpretation is incredibly challenging because applying at least some content knowledge to make sense of the data shown in the graph is necessary to answer questions and make claims regarding phenomena (Glazer, 2011). Students tend to focus on trivial features of graphs instead of applying ideas about graphs or the science context (Lai et al., 2016). Lai et al. (2016) found middle school students could interpret simple, straightforward graphs but not complex ones. The researchers also found students “lacked the ability to construct accurate graphs from narrative accounts,...rarely used science knowledge to interpret graphs,...and demonstrated limited understanding of graph ideas

in their interpretations” (p. 679). Making inferences from graphs is an essential graphing skill. Both Glazer and Lai et al. stress the need for instruction that explicitly teaches students graph interpretation skills.

The Identify and Interpret Strategy

As previously stated, the ability to interpret data in the form of graphs, figures, or data tables is an essential skill in science and needs to be explicitly taught. The Identify and Interpret (I^2) strategy is a scaffold developed by BSCS Science Learning to assist students in making sense of information presented in graphs, figures, or tables, by breaking it down into smaller parts (BSCS, 2012a, b). To use the strategy, students first identify any trends or differences they see in the graph (for ease of explanation, I will simplify by using the term graph, but the strategy can be used on other forms of data and figures). For each observation, they draw an arrow to that part of the graph and write a “What I see” (WIS) statement (BSCS, 2012a, b). Statements should only address what the student observes. Once all the WIS statements have been written, students should then interpret the meaning of each observation by writing a “What it means” (WIM) statement (BSCS, 2012a, b). After all WIS and WIM statements have been recorded, students write a caption or summary of the information in the graph.

Teachers should model the I^2 strategy for students, including talking through your thinking, as this helps students see what they should look for on a graph. Other scaffolding ideas include separating the graph into chunks and only writing WIS and WIM statements for one piece at a time (Riley & Biernat, 2018). Teachers can use guiding questions to help students identify patterns from relevant features of the graph, such as variables on the axes, and interpret the patterns (Riley & Biernat, 2018). When students write general or incomplete interpretations,

the teacher can use prompts that encourage the use of scientific knowledge and terms in their WIM statements (Riley & Biernat, 2018). Student discussions around their WIS and WIM statements allow the teacher to facilitate student discourse that fosters learning of scientific practices and content knowledge (Lucci & Cooper, 2019). Using the I² strategy has the potential to help students make better sense of their data that includes connections to scientific concepts (Lucci & Cooper, 2019). Through this type of data analysis, evidence can emerge and be used when students construct explanations. It's possible that the I² strategy could improve students' ability to select and use appropriate and sufficient evidence when constructing scientific explanations.

METHODOLOGY

Introduction

During the pandemic, students did not have as many opportunities to engage in authentic experiences using critical science and engineering practices (SEPs), such as analyzing and interpreting data from student-led investigations and constructing explanations of phenomena based on their investigations' data. At-risk students were enrolled in a summer school program designed to give students experiences to practice using and improving the SEPs of planning and carrying out investigations, analyzing and interpreting data, and constructing scientific explanations. Since students would be working on their writing of scientific explanations using the claim, evidence, and reasoning (CER) framework and their ability to analyze and interpret data using the Identify and Interpret (I²) strategy, the purpose of my study was to look at whether the I² strategy would also help improve students' scientific explanations, specifically in the areas of evidence and reasoning. After receiving initial instruction on both the CER framework and I² strategy, students engaged in multiple investigations that gave them opportunities to practice gathering data, making graphs, and using the I² strategy. Students wrote six scientific explanations using the CER framework, and rubrics were used to score student explanations in claim, evidence, and reasoning. Graphs and data tables where students used the I² strategy were reviewed to see how relevant the students' "what I see" (WIS) or "what it means" (WIM) statements were and if the students used the WIS or WIM statements in their scientific explanations.

Demographics

Initially, the study was to include both seventh and eighth grade students enrolled in the summer school program. The eighth grade students were excluded from the study when it was determined the teacher modified some of the question prompts and provided additional scaffolding or given responses for the students to use on at least half of the explanations students were asked to write. There were 54 seventh grade students enrolled in the summer school program, 11 of which dropped from the program by the time the post-assessment and post-instruction student survey were given at the end of week five. An additional 18 students were removed from the study as nine students didn't complete the pre-assessment, and 11 didn't complete the student pre-instruction survey, leaving a participant number (*N*) of 25 students.

Due to the study being conducted in summer school and my limited access to participants' information, I could only ascertain a few points of demographic information. Of the participants in the study, 52% were females, 72% were students of color, 12% were English learners, 12% had a 504 plan, and 92% were socioeconomically disadvantaged students. For comparison, the school's demographics for the 2020-21 school year were 49% females, 63% students of color, 4% English learners, 9% students with disabilities, and 70% socioeconomically disadvantaged students.

Another demographic of note was that 52% of participants in the study were enrolled in the district Transition program. The Transition program was established to support the district's most vulnerable and at-risk students. Students referred to the program must be from one of the following focus groups due to funding by the state: foster youth, homeless, English learners, low income, or struggling in pivotal grades 5-12 (typically three or more Ds and Fs). The program's goal is to build relationships to support students and their parents or guardians to ensure students

achieve academic success and are college or career ready by connecting them to resources in our schools and community. When reviewing the data, no significant differences were found with this group of students compared to those not enrolled in the Transition program.

This study was a descriptive study and therefore did not have a comparison group. The purpose of the summer school program was to provide all students with opportunities to engage in investigations and develop their skills in analyzing and interpreting data and writing scientific explanations. It was not appropriate to exclude the students from any of the experiences or scaffolding supports provided; therefore, all participants in the study received the same learning opportunities and instructional supports. Pre- and post-assessment data and other data collected during the study would be used to ascertain any impacts of strategies used during summer school. Student participants were made aware that this data, along with a student pre- and post-instruction survey, would be used to determine the effectiveness of the summer school program. Consent forms were not required for this study as the principal deemed the study to be within standard educational practices. Additionally, the research methodology for this classroom research project received an exemption by Montana State University's Institutional Review Board, in which compliance for working with human subjects was maintained (Appendix A).

Treatment

The summer school program and study began on June 14th, 2021. Day one began with a pre-instruction student survey (Appendix B) and pre-assessment (Appendix C). Students also conducted a lab experiment to collect data to practice graphing on day two. On day two, students were taught how to make a graph and included instruction on labeling axes, independent and dependent variables, determining appropriate scales for axes, plotting data, and making a graph

key. Students also participated in a lesson where they were taught the Identify and Interpret (I^2) strategy, which served as the initial treatment (Appendix D). The teacher used the same lesson they had used in previous school years before 2020-21 to teach the strategy. Students had additional opportunities to use the I^2 strategy on graphs created from their lab data on June 22nd, June 23rd, July 1st, and July 13th. Students also practiced using the I^2 strategy on observational data they collected on June 16th, July 7th, and July 8th.

On day four, students received initial instruction on the claim, evidence, and reasoning framework. Students used the framework to write their scientific explanation for the Mystery Powders Lab. Students were encouraged to use their “what I see” (WIS) and “what it means” (WIM) statements in their CER that they had written the day before using the I^2 strategy. The Mystery Powder Lab CER was collected and scored using a rubric to give each student a claim, evidence, and reasoning score. The process of students collecting data from an investigation, using the I^2 strategy on a student-created graph or observational data, and writing a CER using the information from the lab continued throughout the study. Table 1 shows the timeline for the study with the names of the activities and assignments listed. Instruments collected during the study are listed in italics in Table 1. The opportunities students had to use the I^2 strategy, or treatment, are underlined. The summer school program lasted six weeks; however, the study was concluded when students completed their last treatment and CER during week five.

Table 1. Study timeline.

Week	Monday	Tuesday	Wednesday	Thursday
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1	June 14 <i>Pre-Instruction Student Survey</i> <i>Pre-Assessment</i> Coin Lab - data	June 15 Coin Lab - graph <u>Initial instruction - identify & interpret (I²) strategy</u>	June 16 Mystery Powder Lab <u>I² observational lab data</u>	June 17 <i>Mystery Powder Lab CER</i> <u>Initial instruction -CER framework</u>
2	June 21 Tennis Ball Lab - data	June 22 Tennis Ball Lab - graph <u>I² lab graph</u> <u>Write graph summary</u>	June 23 Mass & Motion Lab Force & Motion Lab <u>I² force lab graph</u>	June 24 <i>Force vs. Mass Lab CER</i> CER sentence strip scaffold
3	June 28 Classroom Curling Lab	June 29 Reading - Newton's Third Law <i>Classroom Curling Lab CER</i>	June 30 Mass in Collisions Lab Velocity in Collisions Lab	July 1 <u>I² mass & velocity lab graphs</u> <i>Mass vs. Velocity in Collisions Lab CER</i>
4	July 5 No School	July 6 Reading - Energy in a Roller Coaster Begin rollercoaster design	July 7 Finish rollercoaster design Build & test rollercoaster <u>I² observational rollercoaster trial data</u>	July 8 Rollercoaster testing continued <u>I² observational rollercoaster trial data continued</u> <i>Coaster (Kinetic & Potential Energy) CER</i>
5	July 12 Conservation of Mass Probe Conservation of Mass Lab – data Start graph	July 13 Finish lab graph <u>I² lab graph</u> <i>Conservation of Mass Lab CER</i> <i>Post-Instruction Student Survey</i>	July 14 N/A Study concluded	July 15 N/A Study concluded

Key: *Assignments turned in are italicized*; Treatment is underlined

Data Collection and Analysis Strategies

A mixed-methods approach was used to answer the research questions posed in this study. To first ascertain students' ability to write a scientific explanation, students were given a pre-assessment on day one of the study. The pre-assessment was modified from an existing CER writing prompt by the summer school teacher and myself. The pre-assessment included a question prompt and sample data to mimic what students would be asked to do when writing scientific explanations following lab investigations throughout the study. The teacher provided minimal guidance when introducing the pre-assessment, being careful not to use explicit

language from the CER framework. The pre-assessment was scored using a rubric. Rubrics used to score each CER in the study were developed by starting with a base rubric modeled from the book *Supporting Grade 5-8 Students in Constructing Explanations in Science* (McNeill & Krajcik, 2012). Specific details to score the claim, evidence, and reasoning component for a particular CER were added to the base rubric. Rubrics were reviewed by the teacher and modified if needed. Rubrics used to score each CER identified in the study timeline in Table 1 can be found in Appendix E. The rubric used to score the pre-assessment is shown in Figure 1.

	Claim A statement or conclusion that answers the original question/problem.	Evidence Scientific data that supports the claim. The data needs to be appropriate and sufficient to support the claim.	Reasoning A justification that connects the evidence to the claim. It shows why the data counts as evidence by using appropriate and sufficient scientific principles.
0	Does not make a claim, or makes an inaccurate claim. States that fat and soap are the same substance.	Does not provide evidence, or only provides inappropriate evidence (evidence does not support the claim).	Does not provide reasoning, or only provides inappropriate reasoning.
1	Makes an accurate but incomplete claim. States that they are different, or fat is different, or soap is different (doesn't use both terms fat and soap)	Provides one of the following pieces of evidence: • Fat (0.92 g/cm³) and soap (0.84 g/cm³) have different densities. • Fat (37°C) and soap (100°C) have different melting points. • Fat and soap have different solubilities (fat dissolves in oil, not water. Soap dissolves in water, not oil) • Fat (soft, squishy) and soap (hard) have different hardness's	Provides incomplete reasoning that includes 1 of 2 aspects: • Properties of substances can be used to determine if two substances are the same or not. • Fat and soap have different properties so they cannot be the same substance.
2	Makes an accurate and complete claim. Fat and soap are different substances.	Provides two of the following pieces of evidence: • Fat (0.92 g/cm³) and soap (0.84 g/cm³) have different densities. • Fat (37°C) and soap (100°C) have different melting points. • Fat and soap have different solubilities (fat dissolves in oil, not water. Soap dissolves in water, not oil) • Fat (soft, squishy) and soap (hard) have different hardness's	Provides complete reasoning that includes the following 2 aspects: • Properties of substances can be used to determine if two substances are the same or not. • Fat and soap have different properties so they cannot be the same substance.
3	N/A	Provides three of the following pieces of evidence: • Fat (0.92 g/cm³) and soap (0.84 g/cm³) have different densities. • Fat (37°C) and soap (100°C) have different melting points. • Fat and soap have different solubilities (fat dissolves in oil, not water. Soap dissolves in water, not oil) • Fat (soft, squishy) and soap (hard) have different hardness's	N/A

Other Notes:

Figure 1. Rubric used to score pre-assessment scientific explanation.

On day two of the study, students received initial instruction in the I² strategy (the treatment). Students continued to practice using the I² strategy throughout the study. Following each use of the I² strategy, students wrote a scientific explanation to answer a question that required the use of evidence and reasoning from the data they analyzed and interpreted from their investigations. Students wrote their explanations using the CER framework. Each CER was

scored using the rubric developed for that specific explanation. For most rubrics, the maximum score for the claim was two, and the evidence was three. In some CER scaffolds provided to students, the reasoning component asked for a specific number of statements to support their evidence. This caused the reasoning component to sometimes be scored at a maximum of three points and other times at a maximum of two points.

The average was calculated for the claim, evidence, reasoning, and total score for each CER in order to compare the scores due to the varying nature in point value between the components. The averages were compared for each CER component and the total score across each explanation the students wrote. Average scores were also compared between the pre-assessment CER and post-assessment CER (Appendix F) to determine if there was any growth in student scores. The Coaster CER was used as the post-assessment comparison instead of the final CER students wrote for the Conservation of Mass Lab. This was due to the summer school teacher leaving the program early for medical reasons. Students were left with a substitute that did not follow the study's protocols, so the Conservation of Mass Lab CER was not considered in data comparisons.

To be able to determine if the I^2 strategy had a direct impact on the evidence or reasoning scores in students' explanations, the graphs and observational data tables from student investigations were analyzed. After initial instruction on the I^2 strategy, students were prompted to write "what I see" (WIS) and "what it means" (WIM) statements about their graphs or observational data collected for each investigation. The rubrics used to score student explanations also contained prompts to collect data on students' WIS and WIM statements. The summer school teacher also reviewed these prompts for feedback before using the instrument. Figure 2 shows an example of the prompts used from the Mystery Powders Lab CER rubric.

Wrote WIS statements: All / Some / None	Wrote WIM statements: All / Some / None
Used WIS format correctly: All / Some / None	Used WIM format correctly: All / Some / None
Used WIS statements in CER: Yes / No	Used WIM statements in CER: Yes / No
Other Notes:	Other Notes:

Figure 2. Screenshot of prompts to evaluate “what I see” and “what it means” statements.

Students were asked to write three WIS and three WIM statements for each graph. Students were asked to write a certain number of WIS and WIM statements for the two labs where observational data was collected. For observational data collected, the WIS statement was based on an observation the student made in the lab. The WIM statement should have justified what they saw using scientific information given during the investigation. If students wrote all expected WIS and WIM statements, “all” was marked; if they wrote one or two statements on graphs or one to four statements on observational data, “some” was marked, and if students didn’t write any statements, “none” was marked. These were later turned into numeric values with “all” given a two, “some” given a one, and “none” given a zero. This data was used first to determine how many students engaged in the I^2 strategy across the study.

For the rubric prompt, “Used WIS (or WIM) format correctly,” I looked for whether students correctly used the I^2 WIS and WIM format, i.e., only wrote what they saw and no inference for the WIS statements. I also reviewed and coded whether students wrote relevant observations about their data that could later be used as evidence (WIS) or reasoning (WIM) when they wrote their scientific explanations. The coding method was modified from the method used in a study conducted by Pallant and Lee (2015). They coded evidence in explanations based on the relevance of the evidence and the types of evidence used. The WIS and WIM statements

were coded as relevant, partially relevant, or not relevant. This would help distinguish students who could use the I^2 strategy appropriately to improve their explanations versus those who just used their WIS and WIM statements in their explanations because that is what they were encouraged to do throughout the study. Finally, student explanations were reviewed to see if a student used their WIS or WIM statements in their CER, which was indicated by marking “yes” or “no.” These were later turned into numeric values with “yes” given a one and “no” given a zero.

The data obtained using the post-assessment rubric for both the students’ CER and the I^2 strategy was used to determine whether the I^2 strategy improved students’ ability to use appropriate evidence or reasoning in their explanations. The post-assessment scores for evidence and reasoning were compared to the pre-assessment scores to establish if any student growth occurred in these areas. The post-assessment was also reviewed for appropriate and relevant use of WIS and WIM statements to determine whether any growth in evidence or reasoning scores might have occurred from using the I^2 strategy.

Students’ perceived impact of the strategies selected and used in the summer school program was important to determine from both the teacher’s and researcher’s standpoint. Students completed a pre-instruction survey to ascertain their perceived knowledge and confidence in the areas of analyzing and interpreting data and constructing explanations. The survey included a mix of Likert items and open-response questions. For the Likert items, students were asked to rate whether they strongly agree, agree, neither agree nor disagree, disagree, or strongly disagree with each statement. Open-response items were added as follow-up questions for Likert items that asked students about their confidence in analyzing and interpreting data and constructing explanations to determine what factors may have influenced

their response. The pre-instruction survey, and post-instruction survey, were reviewed by the summer school teacher and my project advisor prior to use with students.

At the conclusion of the study, students completed a post-instruction survey (Appendix G). The post-instruction survey included the same questions as the pre-instruction survey. Additional questions were added to determine if students felt the I^2 strategy improved their confidence in analyzing and interpreting data and writing explanations, including selecting and using appropriate evidence or reasoning. Open-response items were added to questions where students were asked to rate their confidence in analyzing data, constructing explanations, and the I^2 strategy. At the end of the survey, open-response items were included to determine if students felt anything else they did in summer school helped them improve the use of evidence and reasoning in their explanations. This information could be helpful if students rated their confidence in writing explanations higher in the post-survey but didn't attribute it to the I^2 strategy. Pre- and post-instruction survey data were compared to see if students' confidence improved in analyzing and interpreting data and writing explanations. Post-instruction survey data was reviewed to see if the I^2 strategy had a perceived impact on students' confidence in their ability to analyze data, and select and use appropriate evidence and reasoning in their explanations. Informal interviews were conducted with a few students to follow up on some of their open-response items.

The instruments used to determine the impact of each research question in this mixed-methods study are shown in Table 2. Quantitative data measurements are indicated with a number sign (#) and were collected from student surveys, student investigation sheets, pre- and post-assessment CERs, and the additional CERs students wrote during the study. Qualitative data measurements, indicated by an "X" in Table 2, were collected from the open-response items on

student surveys, follow-up student interviews, and the student investigation sheets. To ensure validity and reliability in the instruments used, the student surveys, interview questions, and pre-assessment were peer and professor reviewed. The student investigation sheets, CER rubrics, and CER post-assessment were peer-reviewed.

Table 2. Data Triangulation Matrix.

Research Questions	Data Collection Methods					
	1	2	3	4	5	6
	Student Surveys	Student Interviews	CER Pre-Assessment	Student Investigation Sheets	Student CERs	CER Post-Assessment
Focus Question: What is the impact of using the Identify and Interpret strategy in a summer school program on improving students' ability to write scientific explanations?	# X	X	#	# X	#	#
Sub-Question 1: How effective is the Identify and Interpret strategy in improving students' use of appropriate and sufficient evidence when writing scientific explanations?	# X	X	#	# X	#	#
Sub-Question 2: How effective is the Identify and Interpret strategy in improving students' reasoning when writing scientific explanations?	# X	X	#	# X	#	#
Sub-Question 3: What impact does using the Identify and Interpret strategy have on students' confidence in writing scientific explanations?	# X	X		X		#

Key: # = quantitative data, X = qualitative data

DATA ANALYSIS

Results

When reviewing the overall group data ($N=25$), the results did not show an improvement in students' claim or evidence scores between the pre- and post-assessment. Figure 3 shows the average score for each claim, evidence, and reasoning (CER) component, as well as the overall total score for both the pre- and post-assessment.

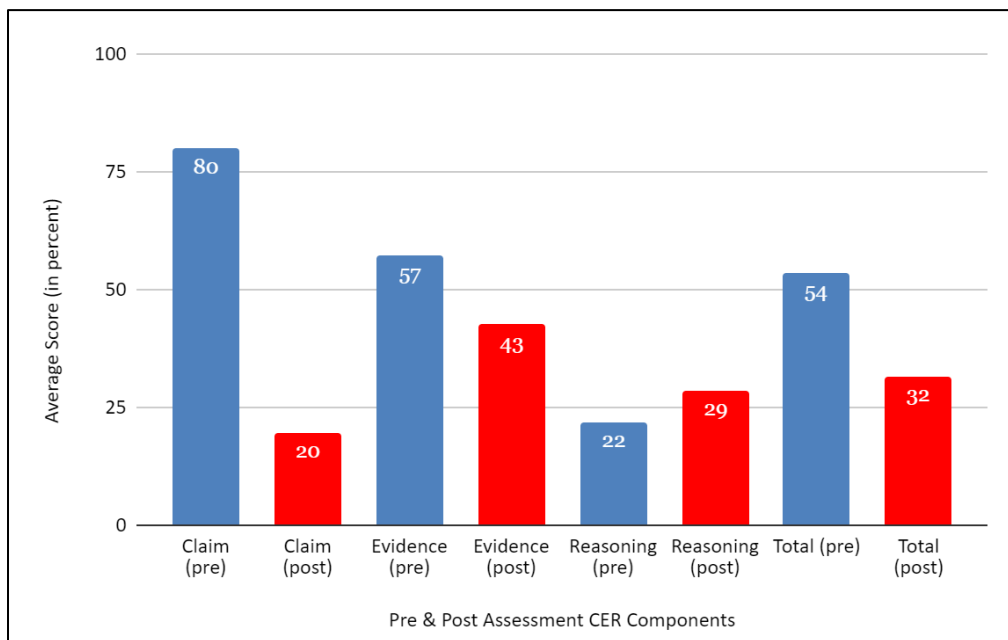


Figure 3. Average pre- and post-assessment scores, ($N=25$).

There was a significant decline in students' claim scores, with the pre-assessment average at 80% and the post-assessment average at 20%. The evidence and total CER score also showed a decline in average scores, although not as significant as the average claim score, with the evidence score dropping from an average of 57% (pre) to 43% (post) and the total score from an average of 54% (pre) to 32% (post). Students did show a slight improvement in their reasoning scores between the pre- and post-assessment, with the average score increasing from 22% (pre)

to 29% (post). One reason the reasoning scores may have improved is that most students did not connect the evidence to a scientific concept or idea on the pre-assessment, which was half of the reasoning score. On the post-assessment, more students were able to connect the evidence of their rollercoaster success or failure to the concept of kinetic or potential energy.

After initial instruction in the Identify and Interpret (I^2) strategy and the claim, evidence, and reasoning framework, average student scores did improve in all aspects of the CER components, with the claim showing the most improvement from 80% on the pre-assessment to 90% on the Mystery Powder CER. Figure 4 shows the average score for each CER component and total score across each explanation students were asked to write. The average scores fluctuated for each component but showed an overall decline (with the exception of reasoning). After the Mystery Powder CER, the question prompts became more complex, often asking students to compare data from two labs to write a claim. The increased complexity of data analysis and CER question prompts could explain the overall decline in most scores over the course of the study.

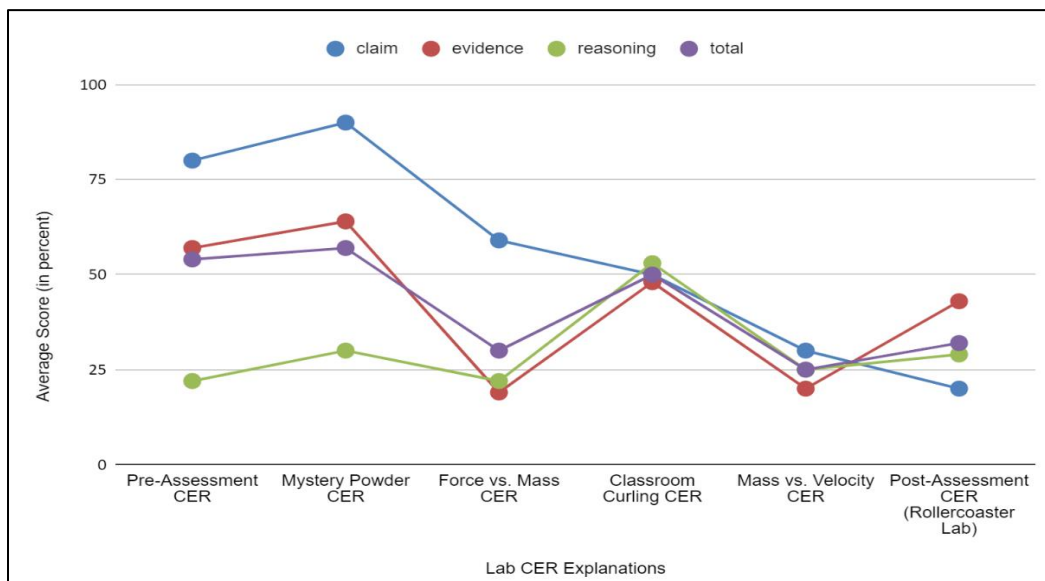


Figure 4. Average CER component and total scores across summer school activities, ($N=25$).

In reviewing student survey responses, 17 of 25 students wrote positive comments that the I² strategy helped them with their CER in some way. Some common themes were the strategy “helped me break things down” and “helped me identify data/evidence.” I dug more into the data to see why students perceived the strategy helped them but didn’t translate to higher overall scores on the post-assessment. The post-assessment did not provide scaffolds or prompts for students to use their WIS and WIM statements in their CER. This could explain why students perceived the I² strategy as helpful to their CER writing but didn’t translate into higher scores on the post-assessment.

When looking at students’ graphs and observational data, most students wrote the “what I see” (WIS) and “what it means” (WIM) statements using the I² strategy for the four labs students collected quantitative and qualitative data. Figure 5 shows the percent usage of the I² strategy across the four labs, including the percent usage of their WIS and WIM statements when writing their CER explanations. The results show higher usage of the strategy for the labs with observational (qualitative) data, Mystery Powder Lab and Rollercoaster Lab, than the labs where students graphed their quantitative data. The students’ WIS and WIM statements were also used more often as evidence or reasoning when writing their explanations for the labs with qualitative data. Simply looking at the usage of the WIS and WIM statements in students’ explanations didn’t provide information on whether the statements improved the use of appropriate evidence or reasoning in their explanations, which were two of my research sub-questions.

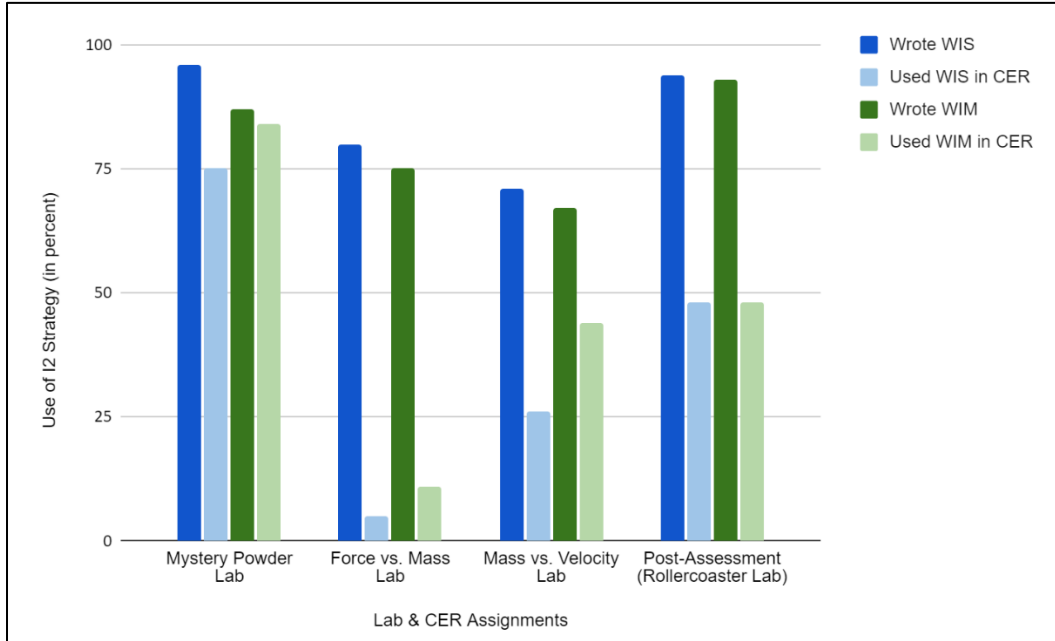


Figure 5. Use of I² strategy in lab and CER assignments, ($N=25$).

Impacts of Identify and Interpret Strategy on Evidence and Reasoning in Explanations

Students' WIS and WIM statements were coded and analyzed to determine the relevance of the statements students wrote. For the Mystery Powder Lab, 83% of students' WIS statements were relevant, and 17% were partially relevant. These were the highest percentages across the four labs for the WIS statements (Appendix H). Relevant WIS statements included wording such as "substance B fizzed when we added vinegar" or "texture was rough for substance C." The average evidence score on the Mystery Powder CER was 64%, the highest average evidence score of the explanations students were asked to write during the study.

Student data from the Mystery Powder activities were then grouped by students who used their WIS and WIM statements in their Mystery Powder CER, group 1 ($n=20$), and those that did not, group 2 ($n=4$). The first graph in Figure 6 shows group 1 and group 2 data for the percent of

relevant, partially relevant, and not relevant WIS and WIM statements written for the Mystery Powder Lab. The second graph shows the CER component and total scores for each group.

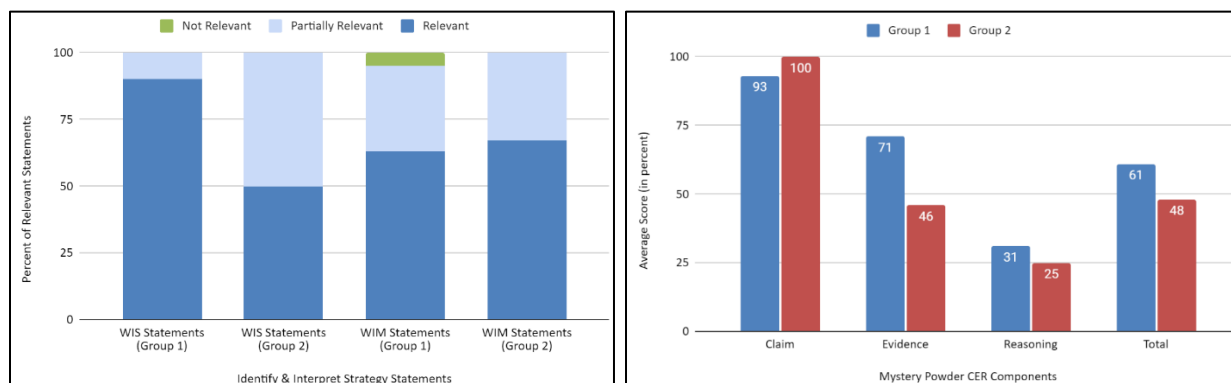


Figure 6. Percent of relevant WIS and WIM statements written and average Mystery Powder CER scores for student groups. Group 1 used WIS and WIM statements in the CER, ($n=20$). Group 2 did not use the statements, ($n=4$).

Group 1 showed significantly higher average scores for the evidence component (71%), with 90% of students writing relevant WIS statements, compared to the average evidence score for group 2 of 46%, with 50% of students writing relevant statements. This data suggests that when students write relevant WIS statements and use them in their CER as evidence, students score higher on the evidence component. Average reasoning scores were only slightly higher at 31% (group 1) than in group 2 (25%). Both groups wrote about the same percentage of relevant WIM statements, which could be why the average reasoning scores were much closer between the two groups.

For the remaining labs, including the post-assessment, student data was grouped by those that used their WIS and WIM statements in their CER, group 1, and those that did not, group 2. Graphs for each group showing the percent of relevant WIS and WIM statements written and average CER scores for the Force vs. Mass Lab and the Mass vs. Velocity Lab can be found in Appendix I. The Force vs. Mass Lab showed no significant difference between the two groups. However, the Mass vs. Velocity Lab showed a significant difference in average scores for all

CER components and total score for group 1 ($n=8$) compared to group 2 ($n=11$). The relevance of the WIS and WIM statements of group 1 were higher, with WIS 50% and WIM 37.5%, compared to group 2, with WIS 18% and WIM 10%. The post-assessment data showed the same trend and is displayed in Figure 7 and Figure 8.

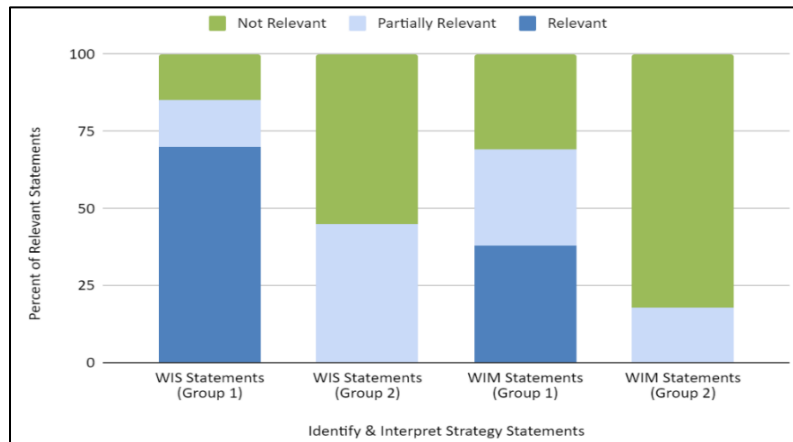


Figure 7. Percent of relevant WIS and WIM statements from post-assessment observational data, group 1, ($n=13$) and group 2, ($n=11$).

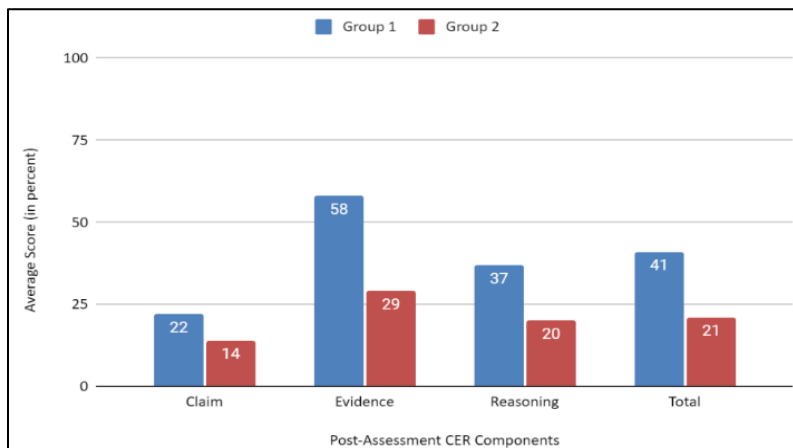


Figure 8. Average post-assessment CER scores for student groups. Group 1 used WIS and WIM statements in the CER, ($n=13$). Group 2 did not use the statements, ($n=11$).

The post-assessment scores show that when students write relevant WIS statements using the I^2 strategy (70% relevant statements from group 1) and use those statements as evidence in their explanations (100% usage), their average evidence score is significantly higher (58%) than

students that do not (29%). Figure 9 shows post-instruction survey items where students were asked if they felt the I^2 strategy, or parts of the strategy, helped improve their explanations. In reviewing student survey data, 64% agreed or strongly agreed that the I^2 strategy improved their use of appropriate and sufficient evidence in their explanations, with 68% agreeing or strongly agreeing that the WIS statements improved their use of evidence in their explanations. On the open-response items, students wrote comments such as “what I see is like identifying evidence” or “the “what I sees” helped me use more evidence to complete the C-E-R.”

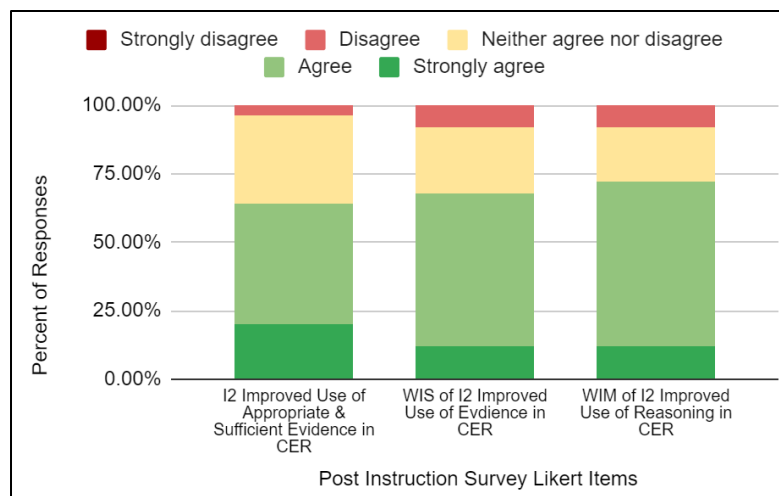


Figure 9. Student post-instruction survey items regarding feelings of I^2 strategy, ($N=25$).

Post-assessment scores also show that when students write relevant WIM statements using the I^2 strategy and use those statements as reasoning in their explanations, their average reasoning score is higher (37%) than students who do not (20%). The students in group 1 wrote 38% relevant and 31% partially relevant WIM statements compared to group 2, with only 18% partially relevant and 82% not relevant WIM statements. Student survey data showed that 72% of students agreed or strongly agreed that writing the WIM statements in the I^2 strategy improved their use of reasoning in their explanations. One student commented that the WIM is “stating in

your own words what the graph means and what's happening and why it's happening.” Another student said, “it helps use the right words to explain.”

Impacts of Identify and Interpret Strategy on Confidence in Writing Explanations

Comparable pre- and post-instruction survey items related to whether the Identify and Interpret strategy impacted students' confidence in writing scientific explanations are shown in Figure 10. Overall, the survey results show that the Identify and Interpret strategy did not have much impact on improving students' confidence in writing explanations. In the pre-instruction survey, 52% of students agreed or strongly agreed they were confident in their ability to select and use evidence in their explanations, compared to 56% of students in the post-survey feeling that the I^2 strategy increased their confidence in selecting evidence. One student commented that “sometimes it's hard writing C-E-R because sometimes the graph or data table don't really have enough information.” Some students struggled with graphing data, which caused WIS and WIM statements to be incorrect or irrelevant or didn't write them. This could have contributed to why more students didn't think the I^2 strategy helped them improve the use of evidence in their CER.

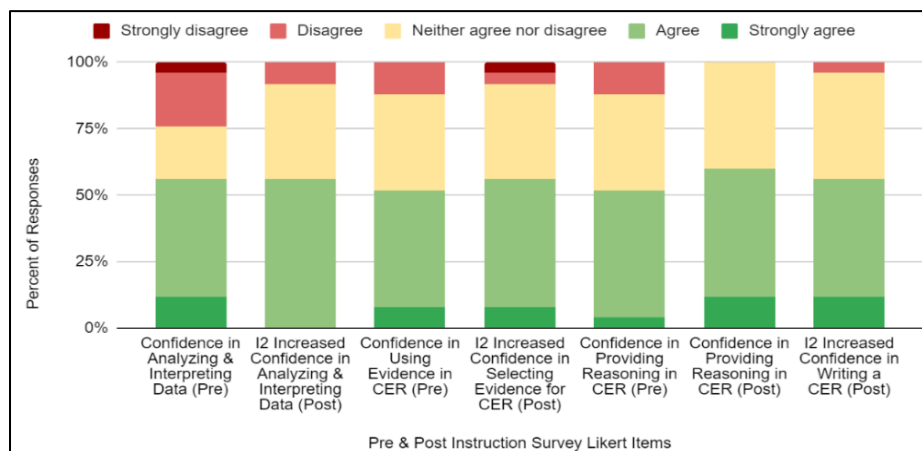


Figure 10. Pre- and post-instruction survey items about student confidence in I^2 strategy, ($N=25$).

When comparing mirrored confidence questions on the pre- and post-instruction survey, shown in Figure 11, students did show an increase in confidence in their ability to analyze data and write a claim, evidence, and reasoning in their explanations. The survey results show that students felt more confident in their ability to analyze data and write explanations at the end of the summer school program but didn't necessarily attribute it specifically to the Identify and Interpret strategy. There also seemed to be some confusion among students about whether what they did in summer school was part of the I² strategy or not. When asked if anything else in summer school improved their use of evidence or reasoning in their CER explanations, some students said things like “the what I see and what it means statements” (helped me) or talked about “what we did with the graphs” (helped me).

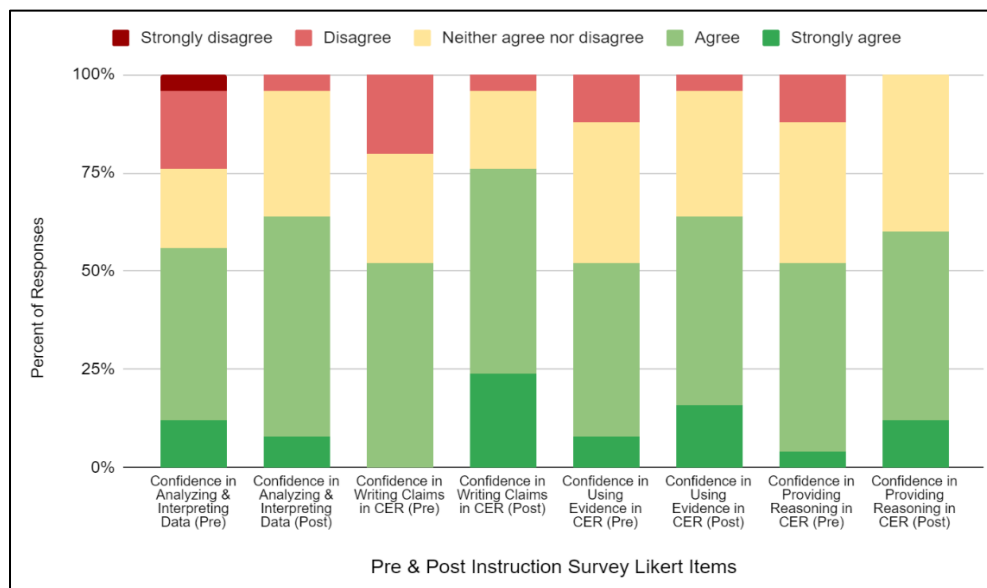


Figure 11. Pre- and post-instruction survey items relating to confidence in analyzing data and writing explanations, ($N=25$).

CLAIM, EVIDENCE, AND REASONING

Claims From the Study

When students thoughtfully engaged in the Identify and Interpret (I^2) strategy, students typically scored higher in their evidence and reasoning scores, especially in the evidence score (see Figure 7 and Figure 8). The I^2 strategy helps students with thoughtful analysis of data, which can “bring out the meaning of data...[to] be used as evidence” (NRC, 2012, p.56). By making connections between the “what I see” (WIS) statements as evidence and the “what it means” (WIM) statements as reasoning and encouraging students to use them in writing explanations, the I^2 strategy has the potential to increase student scores for evidence and reasoning. The study did show the strategy was not as impactful as it could have been for all students for reasons I will explain further.

Students struggled to use the I^2 strategy effectively on the graphs generated using quantitative lab data from the Force vs. Mass Lab and the Mass vs. Velocity Lab. To use the I^2 strategy effectively, students need to have an appropriately created graph to analyze and interpret, which many students did not. Students had difficulty creating appropriate scales for the x and y-axis (especially the y-axis), knowing when to use a bar or line graph, and appropriately plotting data points, which are common issues with creating graphs (Glazer, 2011; Lai et al., 2016). When data was graphed inaccurately, students had difficulty interpreting what they saw, or they misinterpreted what they saw. This often led to students writing WIS and WIM statements that were irrelevant, incomplete, or inaccurate. When students used these types of WIS and WIM statements in their explanations, it resulted in lower evidence and reasoning scores, especially in reasoning. Appendix I shows the relevancy scores for the WIS and WIM

statements students wrote for these labs and the claim, evidence, and reasoning scores for their CER. To make the I² strategy more effective in improving the use of evidence and reasoning, students' graphing skills need to be made stronger. When first teaching the I² strategy, additional graphing scaffolds may need to be provided to students to help them write more relevant WIS and WIM statements.

Another common pattern observed was students' lack of using a scientific concept or principle in their reasoning to connect their evidence to the claim. When reviewing students' WIM statements on their graphs or observational data, I noticed students often didn't connect what they saw to a scientific idea or principle. Students would typically state something similar to the WIS statement or make a connection to one of the variables in the lab, but not the connection between the two variables. Students may have struggled with this because the seventh-grade students had limited content knowledge of physics standards, as this is a concept taught in eighth-grade science. The majority of the labs students engaged in collecting and analyzing data and writing explanations were on physics concepts. Glazer (2011) and Lai et al. (2016) found that graph interpretation can be affected by familiarity with the graph's content and a person's prior knowledge. Lack of content knowledge could have played a role in why students' WIM statements or CER explanations didn't have connections to science concepts in their reasoning. Linking evidence to a science concept or idea accounted for at least 1 point of the reasoning component score, causing most students to earn no more than half of the available points for the reasoning component score. Average reasoning scores for each CER can be found in Figure 4. When students are asked to write a CER, they should have a solid background in the science content they are being asked to write about, particularly to be successful in providing appropriate reasoning.

Lai et al. (2016) also found that middle school students can interpret straightforward graphs but not complex ones. Although the graphs students were asked to create and analyze were not overly complex for the Force vs. Mass Lab and the Mass vs. Velocity Lab, students had to compare two graphs of separate but related data to write a claim for the given question prompt. Students often wrote partial claims or evidence for one of the variables but not both brought up in the question prompt, causing claim and evidence scores to be lower (see Figure 4). Lucci and Cooper (2019) suggest that class discussions where students share what they've found, and express it in the form of their WIS and WIM statements, would give them opportunities to engage in arguing for a particular explanation of the evidence. After the initial lesson in the Identify and Interpret strategy and the Mystery Powder Lab, students mostly engaged in small group discussions regarding their WIS and WIM statements. Whole class discussions around the statements and what students observed specific to the graphs were limited. By engaging students in whole-class discussions, the class can work toward a shared understanding, guided by the teacher, based on relevant evidence and reasoning (Lucci & Cooper, 2019). During class discussions, teachers can ask probing or guiding questions to help students connect how one variable is affecting another variable and why that might be happening (Riley & Biernat, 2018). Teachers can also help students connect text or articles they've read on science concepts to what they see in the lab data during whole-class discussions. Teachers should encourage students to add these connections to their WIM statements, which could potentially help improve students' use of reasoning in their scientific explanations.

In a study conducted by McNeill and Krajcik (2007), the researchers found that students' ability to use appropriate evidence depended on the wording of the assessment task, as well as students' content knowledge and their understanding of what counts as evidence. In retrospect,

the summer school teacher and I realized that the question prompts we gave students to write their explanations were either too open-ended or required a more complex level of understanding that the students enrolled in summer school didn't have. If we had simplified the question prompts and provided students with additional text to read about the scientific concepts seen in the lab, it's possible students could have done better connecting what they saw in the lab data to a science concept to improve their reasoning. On the Classroom Curling CER, students had been given text to read and discuss as a class related to an activity students had done the day before. Students were prompted to use reasoning from the text to link their evidence to their claim in the CER scaffold. Students had their highest reasoning scores in that explanation, with an average score of 53%, which was 23% higher than the second-highest reasoning score on the Mystery Powder CER (see Figure 4).

Value of the Study and Consideration for Future Research

When first comparing pre- and post-assessment data, it was disheartening to see that the Identify and Interpret (I^2) strategy did not have the impact I thought it could have. It was only through analyzing the data more deeply that I was able to see the potential impact the strategy could have on improving students' explanations. A subset of the data in this study shows that the I^2 strategy can be effective at improving students' use of evidence and reasoning in their CER writing when they write relevant WIS and WIM statements. The study also shows that students can be taught to use their "what I see" (WIS) and "what it means" (WIM) statements in their scientific explanations. This data supports the continued use of the I^2 strategy in a science summer program to improve students' ability to write scientific explanations. The data also suggests that the I^2 strategy can be made more effective by incorporating additional instructional

practices into the summer program while students learn and practice the strategy. By investing time to improve the quality of the WIS and WIM statements students write, not only would it help students improve their ability to analyze and interpret data, it has the potential to improve the evidence and reasoning they use in their explanations.

In future research, I would like to try incorporating the class discussion scaffolds and questioning techniques when students write and critique their WIS and WIM statements to see if students can write more relevant statements that could be used in their explanations. I also want to see how providing students with text to read on a concept directly observed from the lab data they collected could improve their ability to select and use appropriate reasoning to connect their evidence to their claim when writing explanations. This seemed to have an impact when students wrote the Classroom Curling CER, but since that was the only lab where direct connections were made from the text to what students wrote, it isn't possible to draw any substantial conclusions from the data collected in the study.

Impact of Action Research on the Author

In reflecting on the action research process, I think one of the most valuable connections I see is using education research to make decisions about what best first-time instructional practices to use with students. When writing the conceptual framework, you get a sense of the success and pitfalls of the instructional practice or practices you are interested in trying with your students. Not everything we read in the literature will apply to every situation we encounter in education. Still, it gives you a grounded place to start before trying to improve your craft as an educator. When we were making decisions about what to include in the summer school curriculum, I was a bit removed from or had forgotten what the research said was the most

appropriate to try. We did incorporate things the summer school teachers had shown to be successful in the past. Still, I can see now that we could have crafted a program with the appropriate level of activities and scaffolding techniques more based on the literature to improve the skills we wanted and still be engaging for students.

Although students struggled with the Identify and Interpret strategy during the study, I am excited about the potential impacts the strategy could have on improving students' analyzing data and writing scientific explanations if the additional scaffolds and techniques discussed previously are applied. As the district science teacher on special assignment, I have the opportunity to share the knowledge gained from this action research study with the teachers I work with and support. I'm excited to be able to mentor teachers in the use of the I² strategy and additional scaffolds to see if this can help us improve students' ability to analyze data and write explanations that have more appropriate evidence and reasoning. Not only would this help us improve as a district in both practices, but we would also be setting students up for success in future science courses and in becoming scientifically literate adults.

REFERENCES CITED

- Berland, L. K., & Reiser, B. J. (2009). Making sense of argumentation and explanation. *Science Education*, 93(1), 26-55. <https://doi.org/10.1002/sce.20286>
- BSCS (2012a). Identify and Interpret (I²) strategy [student edition]. https://media.bsccs.org/icans/Icans_I2_SE.pdf
- BSCS (2012b). Identify and Interpret (I²) strategy [teacher edition]. https://media.bsccs.org/icans/Icans_I2_TE.pdf
- Clark Intermediate. Ed-Data Education Data Partnership. (2022). <https://www.ed-data.org/school/Fresno/Clovis-Unified/Clark-Intermediate>
- Glazer, N. (2011). Challenges with graph interpretation: A review of the literature. *Studies in Science Education*, 47(2), 665-681. <https://doi.org/10.1080/03057267.2011.605307>
- Hunter-Thomson, K. (2021). How can we use and interact with graphs better? (Data literacy 101). *Science Scope*, 44(6), 8-14. <https://www.nsta.org/science-scope/science-scope-julyaugust-2021/how-can-we-use-and-interact-graphs-better-data-literacy>
- Lai, K., Cabrera, J., Vitale, J. M., Madhok, J., Tinker, R., & Linn, M. (2016). Measuring graph comprehension, critique, and construction in science. *Journal of Science Education and Technology*, 25, 665–681. <https://doi.org/10.1007/s10956-016-9621-9>
- Lucci, K., & Cooper, R. A. (2019). Using the I2 strategy to help students think like biologists about natural selection. *The American Biology Teacher*, 81(2), 88-95. <https://doi.org/10.1525/abt.2019.81.2.88>
- McNeill, K. L., & Krajcik, J. (2007). Middle school students' use of appropriate and inappropriate evidence in writing scientific explanations. In Lovett, M & Shah, P (Eds.) *Thinking with data: The proceedings of the 33rd Carnegie Symposium on Cognition*. Lawrence Erlbaum Associates, Inc.
- McNeill, K. L., & Krajcik, J. S. (2012). *Supporting grade 5-8 students in constructing explanations in science the claim, evidence, and reasoning framework for talk and writing*. Pearson.
- McNeill, K. L., Lizotte, D. J., Krajcik, J., & Marx, R. W. (2006). Supporting students construction of scientific explanations by fading scaffolds in instructional materials. *Journal of the Learning Sciences*, 15(2), 153-191. https://doi.org/10.1207/s15327809jls1502_1
- National Research Council. (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. National Academies Press.
- NGSS Lead States. (2013). *Next generation science standards: For states, by states*. National Academies Press.

- Pallant, A., & Lee, H. S. (2015). Constructing scientific arguments using evidence from dynamic computational climate models. *Journal of Science Education and Technology*, 24(2), 378-395. <https://doi.org/10.1007/s10956-014-9499-3>
- Riley, L., & Biernat, K. (2018). Classroom strategies for analyzing and interpreting graph data. *Science Scope*, 42(4), 32-35. <https://www.jstor.org/stable/26611887>
- Sandoval, W. A. (2003). Conceptual and epistemic aspects of students' scientific explanations. *The Journal of the Learning Sciences*, 12(1), 5-51. <http://www.jstor.org/stable/1466633>
- Sandoval, W. A., & Millwood, K. A. (2005). The quality of students' use of evidence in written scientific explanations. *Cognition and Instruction*, 23(1), 23-55. https://doi.org/10.1207/s1532690xc2301_2
- Schwarz, C. V., Passmore, C., & Reiser, B. J. (2017). *Helping students make sense of the world using next generation science and engineering practices*. NSTA Press, National Science Teachers Association.

APPENDICES

APPENDIX A

IRB EXEMPTION

Mary Nelson

From: Beiswanger, Kelly <kelly.beiswanger@montana.edu>
Sent: Tuesday, November 30, 2021 4:46 PM
To: Mary Nelson
Cc: Woolbaugh, Walter
Subject: RE: IRB Exemption Form for MSSE Program
Attachments: Nelson-Woolbaugh MN113021-EX.pdf



EXTERNAL MESSAGE - Think Before You Click

Dear Mary,

Thank you for your application. This email acknowledges receipt of the request for IRB Review and serves as the Approval Letter for your research. Your new **IRB Exempt Protocol # is MN113021-EX**.

Study Title: Impacts of the Identify and Interpret Strategy in a Summer Intensive Program to Improve Students' Scientific Explanations

As the PI, it is your responsibility to facilitate subject understanding by informing subjects of all aspects of the project, providing an opportunity to ask questions, and describing risks and benefits of participation. Submit any new changes to the research protocol to the IRB via [Amendment Form](#) prior to implementing.

The research described in your submission is exempt from the requirement of additional review by the Institutional Review Board in accordance with 45 CFR 690.104(d). The specific paragraph which applies to your research is:

- (1) Research, conducted in established or commonly accepted educational settings, that specifically involves normal educational practices that are not likely to adversely impact students' opportunity to learn required educational content or the assessment of educators who provide instruction. This includes most research on regular and special education instructional strategies, and research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.

Thank you,
 Kelly Beiswanger

IRB Administrator & Program Manager
 Office of Research Compliance
 Hamilton Hall 114
 Montana State University
 kelly.beiswanger@montana.edu
 406-994-4706
<https://www.montana.edu/orc/irb>

APPENDIX B

STUDENT PRE-INSTRUCTION SURVEY

Student Pre-Instruction Survey

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

The purpose of this questionnaire is for your teachers to understand what your confidence in and current level of understanding in some of the skills and strategies we will work on during summer school. This will not be graded and will not affect your standing in this class.

* 1. What is your first name?

* 2. What is your last name?

* 3. During the 2020-21 school year, I was in

☐ 7th Grade

☐ 8th Grade

Student Pre-Instruction Survey

Analyzing Data

* 4. When asked to "analyze data" from a data table or graph, I understand what that means.

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

* 5. I feel confident in my ability to analyze and interpret data from various sources (data tables, graphs, diagrams, written observations, etc.).

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

Explain why you selected your response:

* 6. In 7th or 8th grade, I was shown how to use the Identify and Interpret (I2) strategy to analyze and interpret data.

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

* 7. I know how to use the Identify and Interpret (I2) strategy to analyze and interpret data.

- ☐ Strongly agree
 ☐ Agree
 ☐ Neither agree nor disagree
 ☐ Disagree
 ☐ Strongly disagree
☐ Not Applicable (I've never been taught or shown this strategy before)

Student Pre-Instruction Survey

Constructing Explanations (C-E-R: Claim, Evidence, Reasoning)

* 8. When asked to write a scientific explanation, or C-E-R, I understand what that means.

- ☐ Strongly agree
 ☐ Agree
 ☐ Neither agree nor disagree
 ☐ Disagree
 ☐ Strongly disagree

* 9. I feel confident in my ability to write a claim in a scientific explanation, or C-E-R.

- ☐ Strongly agree
 ☐ Agree
 ☐ Neither agree nor disagree
 ☐ Disagree
 ☐ Strongly disagree

Explain why you selected your response:

* 10. I feel confident in my ability to select and use appropriate (correct/accurate) and sufficient (enough) evidence when writing a scientific explanation, or C-E-R.

- ☐ Strongly agree
 ☐ Agree
 ☐ Neither agree nor disagree
 ☐ Disagree
 ☐ Strongly disagree

Explain why you selected your response:

* 11. I feel confident in my ability to provide reasoning when writing a scientific explanation, or C-E-R. Reasoning is using a science concept or principle to justify why the evidence connects to the claim.

- ☐ Strongly agree
 ☐ Agree
 ☐ Neither agree nor disagree
 ☐ Disagree
 ☐ Strongly disagree

Explain why you selected your response:

APPENDIX C

PRE-ASSESSMENT CER

How to Write a Scientific Explanation

C-Claim E-Evidence R-Reasoning

Students were conducting an investigation to try and determine if fat and soap are the same substance or if they are different substances. In order to decide, they tested various properties of fat and soap to compare. The data they collected is shown below:

1. *Examine the data table below.*

Student Data Collection for Fat and Soap					
	Color	Hardness	Solubility (dissolve in water/oil)	Melting Point	Density
Fat	Off-white or slightly yellow	Soft, squishy	Water - no Oil - yes	37°C	0.92 g/cm ³
Soap	Milky white	Hard	Water -yes Oil - no	Above 100 °C	0.84 g/cm ³

2. *Write a scientific explanation stating whether **fat** and **soap** are the same substance or different substances.*

APPENDIX D

IDENTIFY AND INTERPRET STRATEGY LESSON

Identify and Interpret (I²) Strategy

STEP 1

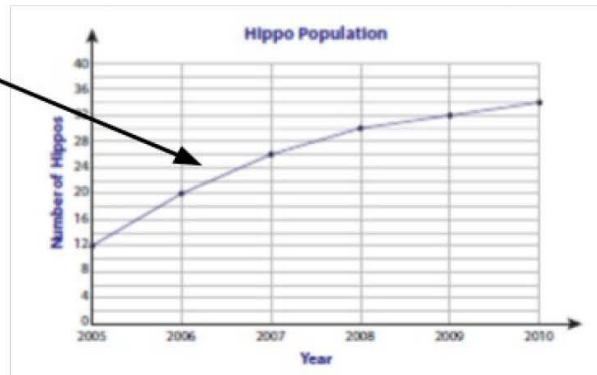
What I see:

An upward slope
from 2005 - 2010

STEP 2

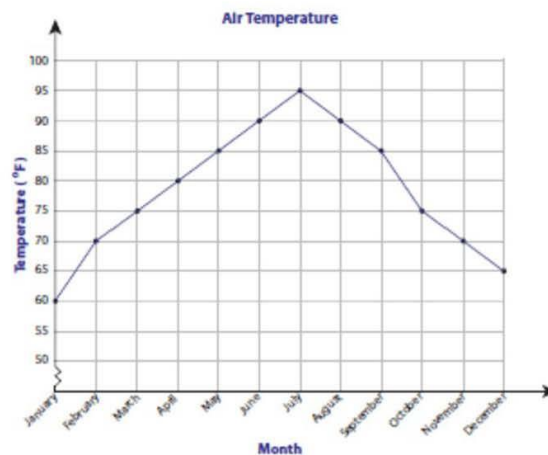
What it means:

The # of hippos
increased from
2005 - 2010

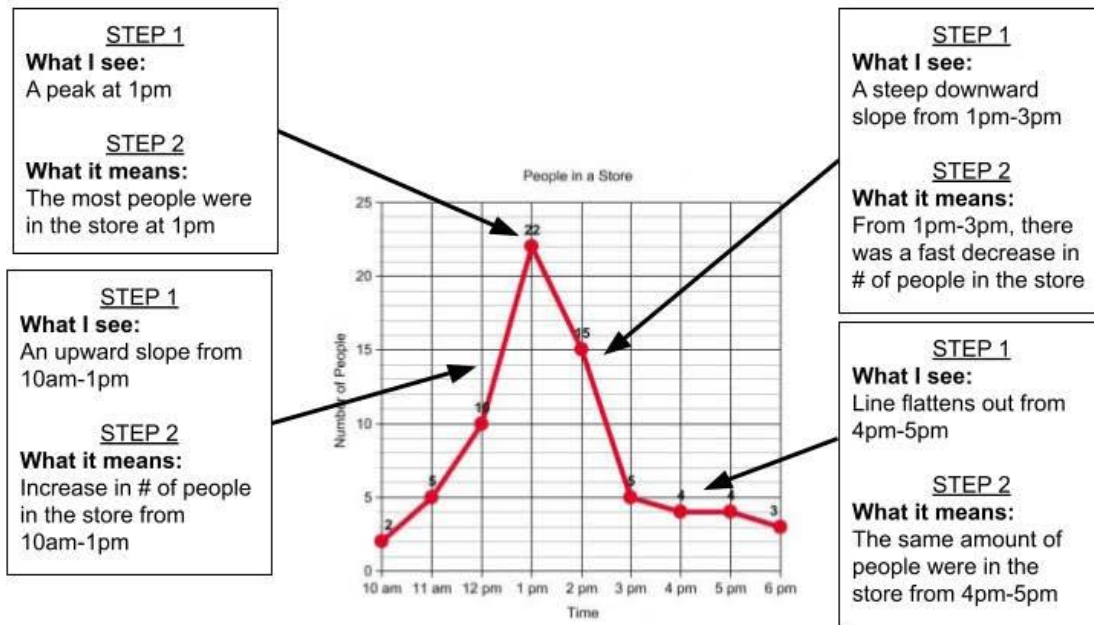


For each graph, complete Steps 1 and 2. Help has been provided for you on the first graph to get you started (you still need to do Steps 1-2 at least one more time):

- Step 1. Make 2-3 "What I see" comments on the graph. Only comment on what you can observe, not what you interpret the graph to mean (i.e. you can observe a downward slope of a line, but you interpret a decrease in hippo population).
- Step 2. For each "What I see" comment you made, make a "What it means" comment.



Here is an example of how to do Steps 1-3. Notice how for each "What I see" comment (Step 1), there is a "What it means" comment (Step 2). Then for Step 3, a logical caption is written that discusses each "What I see" comment and ties it together with its matching "What it means" comment. The paragraph begins with a topic sentence that summarizes what the graph is about and ends with a possible reasoning as to why the graph looks the way it does.

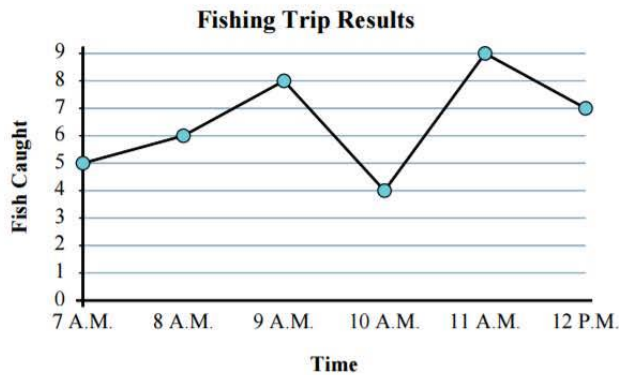


STEP 3

This graph shows the number of people in a store over a time period of 8 hours. There is an upward slope from 10am to 1pm, showing that there was an increase in people shopping in the store during this time frame. Then from 1pm to 3pm, there is a steep downward slope, which means the number of people in the store quickly declined during those 2 hours. From 4pm to 5pm, the line plateaus, showing that there was the same amount of people in the store during that hour. At 1pm, there is a peak, which means that at that time there was the most people in the store. This peak occurred during lunchtime, which likely is the cause to the high volume of shoppers.

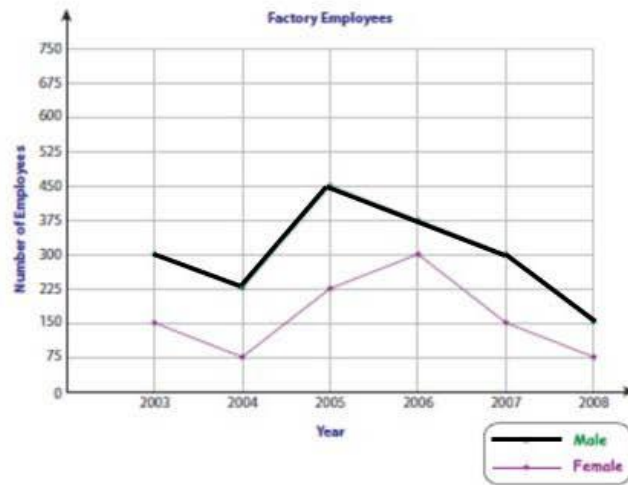
For the next 2 graphs, complete Steps 1-2 (like you did on Page 1), then complete Step 3 (follow the example provided to you on Page 2).

Step 3. Step 3 of the I^2 strategy is to write a caption. A paragraph with sentence frames have been provided for you below the graph to help guide your thinking.



This graph shows _____
 over the course of 5 _____. There is an _____ slope from 7am to _____, which means that the fishermen caught _____ fish. The downward slope from _____ to _____ means that the fishermen caught less fish. There is another _____ slope from _____ to _____ then a _____ slope from _____ to _____, which means _____ fish were caught, before the number of fish caught _____.
 There is a peak at _____, which means this is the best time to catch fish, while the lowest point is at _____, which means this is not a good time to catch fish.

Can you add anything else?



This graph compares _____ to _____ employees who work in a factory over the course of _____ years. Both genders show an _____ slope from 2003-2004, which means that there was a _____ in male and female employees during that year. The slope for male employees has an upward slope until _____ then a _____ slope until 2008, which means the number of male employees increased until _____, then _____ until _____. Studying the female line, there is an upward slope until _____ before it drops from _____ to _____. This shows that the factory gained more female employees from _____ to _____, but then they _____ from _____ to _____. While the number of male employees peak in _____, female employees peaked in _____, which means _____.

Can you add anything else?

APPENDIX E

CLAIM EVIDENCE REASONING (CER) RUBRICS

Pre-Assessment CER Rubric

Student Name: _____

	Claim	Evidence	Reasoning
0	Does not make a claim, or makes an inaccurate claim. States that fat and soap are the same substance.	Does not provide evidence, or only provides inappropriate evidence (evidence does not support the claim or is inaccurate).	Does not provide reasoning, or only provides inappropriate reasoning.
1	Makes an accurate but incomplete claim. States that they are different, or fat or soap is different (doesn't use both terms fat and soap)	Provides one of the following pieces of evidence: - Fat (0.92 g/cm³) & soap (0.84 g/cm³) have different densities. - Fat (37°C) and soap (100°C) have different melting points. - Fat and soap have different solubilities (fat dissolves in oil, not water. Soap dissolves in water, not oil) - Fat (soft, squishy) and soap (hard) have different hardness's	Provides incomplete reasoning that includes 1 of 2 aspects: - Properties of substances can be used to determine if two substances are the same or not. - Fat and soap have different properties so they cannot be the same substance.
2	Makes an accurate and complete claim. Fat and soap are different substances.	Provides two of the following pieces of evidence: - Fat (0.92 g/cm³) & soap (0.84 g/cm³) have different densities. - Fat (37°C) and soap (100°C) have different melting points. - Fat and soap have different solubilities (fat dissolves in oil, not water. Soap dissolves in water, not oil) - Fat (soft, squishy) and soap (hard) have different hardness's	Provides complete reasoning that includes the following 2 aspects: - Properties of substances can be used to determine if two substances are the same or not. - Fat and soap have different properties so they cannot be the same substance.
3	N/A	Provides three of the following pieces of evidence: - Fat (0.92 g/cm³) & soap (0.84 g/cm³) have different densities. - Fat (37°C) and soap (100°C) have different melting points. - Fat and soap have different solubilities (fat dissolves in oil, not water. Soap dissolves in water, not oil) - Fat (soft, squishy) and soap (hard) have different hardness's	N/A

Other Notes:

Powder CER Rubric**Student Name:** _____

	Claim	Evidence	Reasoning
0	Does not make a claim, or makes an inaccurate claim. Incorrectly identifies the mystery substance.	Does not provide evidence, or only provides inappropriate evidence (evidence does not support the claim or is inaccurate).	Does not provide reasoning, or only provides reasoning that does not link evidence to claim.
1	Makes an accurate and complete claim. Correctly identifies the mystery substance.	Provides one of the following pieces of evidence for the mystery substance the student was assigned to write about: • A = Detergent ○ Substance's texture is rough so it's a crystal, cabbage juice turned green so it's a base, & uses another test result (brown w/iodine or fizzed w/vinegar). • B = Baking Soda ○ Substance's texture is smooth so it's a powder, fizzed w/vinegar, and turned brown w/iodine so no starch. • C = Salt ○ Substance's texture is rough so it's a crystal, cabbage juice turned purple so it's neutral, & uses another test result (brown w/iodine or no fizz w/vinegar). • D = Baking Powder ○ Substance's texture is smooth so it's a powder, fizzed w/vinegar, & turned black w/iodine so it has starch. • E = Cornstarch ○ Substance's texture is smooth so it's a powder, no fizz w/vinegar, & turned black w/iodine so it has starch. May also include inappropriate evidence.	Provides 1 of the following 2 reasoning components: • A = Detergent ○ Connects evidence from a test to result in flow chart ○ States only detergent is a crystal and a base • B = Baking Soda ○ Connects evidence from a test to result in flow chart ○ States only baking soda is a powder, fizzed w/vinegar, & has no starch • C = Salt ○ Connects evidence from a test to result in flow chart ○ States only salt is a crystal and neutral (pH) • D = Baking Powder ○ Connects evidence from a test to result in flow chart ○ States only baking powder is a powder, fizzed w/vinegar, & has starch. • E = Cornstarch ○ Connects evidence from a test to result in flow chart ○ States only cornstarch is a powder, doesn't fizz in vinegar, & has starch. May also include inappropriate reasoning.
2	N/A	Provides two pieces of evidence (listed above) for mystery substance the student was assigned to write about. May also include inappropriate evidence.	Provides both reasoning components (listed above) for the mystery substance. Does not include any inappropriate reasoning.
3	N/A	Provides three pieces of evidence (listed above) for mystery substance the student was assigned to write about. Does not include any inappropriate evidence.	N/A

Wrote WIS statements: All / Some / None**Wrote WIM statements:** All / Some / None**Used WIS format correctly:** All / Some / None**Used WIM format correctly:** All / Some / None**Used WIS statements in CER:** Yes / No**Used WIM statements in CER:** Yes / No**Other Notes:****Other Notes:**

Force vs Mass - CER Rubric

Student Name: _____

	Claim	Evidence	Reasoning
0	Does not make a claim, or makes an inaccurate claim. States that mass had a bigger impact on the motion of the object/car.	Does not provide evidence, or only provides inappropriate evidence (evidence does not support the claim or is inaccurate).	Does not provide reasoning, or only provides inappropriate reasoning that does not link evidence to claim.
1	Makes an accurate but incomplete claim. States that force (ramp height) had a bigger impact. (doesn't connect to motion of the object/car).	Provides at least 1 piece of evidence from the force <u>OR</u> mass lab data that supports the claim that force (ramp height) has a bigger impact on the car's motion than mass. • Force Lab: Uses data from force lab that shows the highest ramp height had the shortest time. (for additional evidence, could use any ramp height data if it's a shorter time than the shortest mass lab data) ○ Ex: When the height of the ramp was 40 cm (highest ramp height) the time the car took to reach the finish line was 0.58 seconds (shortest time). • Mass Lab: Uses data from mass lab that shows no matter what the mass of the car was, the time the car took to reach the finish line was longer than the shortest time from the force lab. ○ Ex: When the mass of the car was 38.3 g (most mass) the car took 1.27 seconds to reach the finish line (time longer than force lab). May also include inappropriate evidence from their data.	Provides incomplete reasoning that includes 1 of 2 aspects linking evidence to the claim from the force <u>OR</u> mass lab data. • Force Lab Example: ○ Car traveled the fastest at highest ramp height ○ Faster car traveled (shorter car took to reach the finish line), the bigger the impact force had on the car's motion. • Mass Lab Example: ○ More mass the car had, still reached finish line with more time (longer time) ○ Slower the car traveled (longer car took to reach the finish line), the less impact mass had on the car's motion. May also include inappropriate reasoning for other pieces of evidence.
2	Makes an accurate and complete claim. States that force (ramp height) had a bigger impact on the motion of the object/car.	Provides at least 2 pieces of evidence from the force <u>AND/OR</u> mass lab data that supports the claim that force (ramp height) has a bigger impact on the car's motion than mass. May also include inappropriate evidence from their data.	Provides incomplete reasoning that includes 1-2 aspects listed above which links the evidence to the claim from the force <u>AND</u> mass lab data. May also include inappropriate reasoning for 1 piece of evidence.
3	N/A	Provides 3 pieces of evidence from the force <u>AND</u> mass lab data that supports the claim that force (ramp height) has a bigger impact on the car's motion than mass. Does not include any inappropriate evidence	Provides complete reasoning that includes both aspects listed above which links the evidence to the claim from the force <u>AND</u> mass lab data.

Wrote WIS statements:

Mass: All / Some / None

Force: All / Some / None

Used WIS format correctly:

Mass: All / Some / None

Force: All / Some / None

Used WIS statements in CER:

Mass: Yes / No

Force: Yes / No

Other Notes:

Wrote WIM statements:

Mass: All / Some / None

Force: All / Some / None

Used WIM format correctly:

Mass: All / Some / None

Force: All / Some / None

Used WIM statements in CER:

Mass: Yes / No

Force: Yes / No

Other Notes:

Classroom Curling CER Rubric

Student Name: _____

	Claim	Evidence	Reasoning
0	Does not make a claim, or makes an inaccurate claim. States the lab demonstrates Newton's 3 rd Law when a puck is at rest, or when the puck is pushed.	Does not provide evidence, or only provides inappropriate evidence (evidence does not support the claim or doesn't come from lab observations).	Does not provide reasoning, or only provides inappropriate reasoning.
1	Makes an accurate but incomplete claim. States the lab demonstrates Newton's 3 rd Law when objects collide.	Provides at least 1 piece of evidence from the curling lab observations that demonstrates Newton's 3 rd Law of Motion. Ex: When the two pucks collide, they went in opposite directions. May also include inappropriate evidence from lab observations.	Provides incomplete reasoning that includes 1 of 2 aspects: - Includes information about Newton's 3rd law from the reading - Connects Newton's 3rd law to lab observations
2	Makes an accurate and complete claim. States the lab demonstrates Newton's 3 rd Law when a puck collides with another object (i.e., a bumper or another puck)	Provides 2 pieces of evidence from the curling lab observations that demonstrates Newton's 3 rd Law of Motion. May also include inappropriate evidence from their data.	Provides complete reasoning that includes the following 2 aspects: - Includes information about Newton's 3rd law from the reading - Connects Newton's 3rd law to lab observations
3	N/A	Provides 3 pieces of evidence from the curling lab observations that demonstrates Newton's 3 rd Law of Motion. Does not include any inappropriate evidence	N/A

Used Reasoning from Text: All / Some / None

Other Notes:

Collision Lab (Mass & Velocity) CER Rubric**Student Name:** _____

	Claim	Evidence	Reasoning
0	Does not make a claim, or makes an inaccurate claim. States the car with less mass has more force in a collision than the car with more mass. OR States the car with less velocity (lower ramp height) has more force in a collision than the car with more velocity (higher ramp height).	Does not provide evidence, or only provides inappropriate evidence (evidence does not support the claim or is inaccurate).	Does not provide reasoning, or only provides inappropriate reasoning.
1	Makes an accurate but incomplete claim. States the car with more mass affects the collision. OR States the car with more velocity (higher ramp height) affects the collision.	Provides at least 1 piece of appropriate evidence from the mass or velocity lab data. Ex's: - When the mass of the car was 41g it knocked over 30 pennies, and when the mass of the car was 35g it knocked over 25 pennies. - The most pennies were knocked over when the mass of the car was 41g. - When the ramp height was 20cm the car knocked over 35 pennies, and when the ramp height was 16cm the car knocked over 29 pennies. - The most pennies were knocked over when the ramp height was 20cm. May also include inappropriate evidence.	Provides incomplete reasoning that includes 1 of 2 aspects: - Mass - More mass the car has, the more pennies it knocked over - The more pennies the car knocked over the more force the car has in a collision - Velocity (ramp height) - More velocity the car has (higher ramp height), the more pennies it knocked over. - The more pennies the car knocked over the more force the car has in a collision
2	Makes an accurate and complete claim. States the car with more mass has more force in a collision than the car with less mass. OR States the car with more velocity (higher ramp height) has more force in a collision than the car with less velocity (lower ramp height).	Provides 2 pieces of appropriate evidence from the mass or velocity lab data. May also include inappropriate evidence from their data.	Provides complete reasoning that includes both aspects listed above (for mass OR velocity).
3	N/A	Provides 3 pieces of appropriate evidence from the mass or velocity lab data. Does not include any inappropriate evidence	N/A

Wrote WIS statements:**Mass:** All / Some / None**Velocity:** All / Some / None**Wrote WIM statements:****Mass:** All / Some / None**Velocity:** All / Some / None**Used WIS format correctly:****Mass:** All / Some / None**Velocity:** All / Some / None**Used WIM format correctly:****Mass:** All / Some / None**Velocity:** All / Some / None**Used WIS statements in CER:****Mass:** Yes / No**Velocity:** Yes / No**Used WIM statements in CER:****Mass:** Yes / No**Velocity:** Yes / No**Other Notes:****Other Notes:**

Coaster (Kinetic & Potential Energy) CER Rubric

Student Name: _____

	Claim	Evidence	Reasoning
0	Does not make a claim, or makes an inaccurate claim. Claim doesn't include kinetic or potential energy. <u>OR</u> States that kinetic or potential energy affected the coaster.	Does not provide evidence, or only provides inappropriate evidence (evidence does not support the claim or is inaccurate).	Does not provide reasoning, or only provides reasoning that does not link evidence to claim.
1	Makes an accurate but incomplete claim. Claims can vary, but must make an accurate statement about how kinetic energy affected their coaster design. <u>OR</u> Claims can vary, but must make an accurate statement about how potential energy affected their coaster design.	Provides at least 1 piece of evidence from their roller coaster data that supports their claim of how kinetic <u>OR</u> potential energy affected their coaster design. Examples: - The marble flew/launched off the coaster (too much KE). - The marble stayed on the track. - The first hill was too tall/high (too much PE) making the marble go too fast (too much speed/KE). - The first hill wasn't tall enough (not enough PE) so the marble didn't make it to the end of the coaster (not enough KE). - The marble didn't make it through the loop (not enough KE). May also include inappropriate evidence from their data.	Provides appropriate reasoning linking marble behavior or coaster design success/failure to kinetic <u>OR</u> potential energy for at least 1 piece of evidence. Examples: - Connects a failure of the rollercoaster design to too much or too little KE or PE. - Marble didn't go through the loop because it didn't have enough KE/speed to make it through. - Marble flew off the track because it had too much KE/speed. - Connects a success of the rollercoaster design to an adjustment made to increase or decrease PE or KE. - The marble didn't go through the loop so we raised the first hill to increase the PE which gave the marble more KE to make it through the loop. - We raised the first hill to increase PE the marble started with. Marble had enough KE (speed) to make it through the loop. May also include inappropriate reasoning for other pieces of evidence.
2	Makes an accurate and complete claim. Claims can vary but must make an accurate statement about how kinetic energy affected their coaster design. <u>AND</u> Claims can vary but must make an accurate statement about how potential energy affected their coaster design.	Provides at least 2 pieces of evidence from their roller coaster data that supports their claim of how kinetic <u>AND/OR</u> potential energy affected their coaster design. May also include inappropriate evidence from their data.	Provides appropriate reasoning linking marble behavior or coaster design success/failure to kinetic <u>AND/OR</u> potential energy for at least 2 pieces of evidence. May also include inappropriate reasoning for 1 piece of evidence.
3	N/A	Provides at least 3 pieces of evidence from their roller coaster data that supports their claim of how kinetic <u>AND</u> potential energy affected their coaster design. Does not include any inappropriate evidence.	Provides appropriate reasoning linking marble behavior or coaster design success/failure to kinetic <u>AND/OR</u> potential energy for at least 3 pieces of evidence. Within the 3 pieces of evidence, appropriate reasoning must be provided for both kinetic and potential energy.

Wrote WIS statements: All / Some / None

Wrote WIM statements: All / Some / None

Used WIS format correctly: All / Some / None

Used WIM format correctly: All / Some / None

Used WIS statements in CER: Yes / No

Used WIM statements in CER: Yes / No

Other Notes:

Other Notes:

APPENDIX F

CER POST-ASSESSMENT: ROLLERCOASTER LAB CER

Observational CER

How did Kinetic and Potential Energy affect the design and success of your roller coaster?

(For example: What were some problems you encountered while testing and how did you solve them using what you know about kinetic and potential energy? How does the first drop affect the success of your design?)

This image shows a single sheet of white paper with horizontal blue ruling lines. The lines are evenly spaced and run across the width of the page. There are no margins, text, or other markings on the paper.

APPENDIX G

STUDENT POST-INSTRUCTION SURVEY

Student Post-Instruction Survey

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way.

The purpose of this questionnaire is for your teachers to understand any changes to your confidence or level of understanding in some of the skills and strategies we have worked on during summer school. This will not be graded and will not affect your standing in this class.

* 1. What is your first name?

* 2. What is your last name?

* 3. During the 2020-21 school year, I was in

☐ 7th Grade

☐ 8th Grade

Student Post-Instruction Survey

Analyzing Data

* 4. When asked to "analyze data" from a data table or graph, I understand what that means.

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

* 5. I feel confident in my ability to analyze and interpret data from various sources (data tables, graphs, diagrams, written observations, etc.).

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

Explain why you selected your response:

* 6. In 7th or 8th grade, I was shown how to use the Identify and Interpret (I2) strategy to analyze and interpret data. (Does not include summer school 2021)

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

* 7. I know how to use the Identify and Interpret (I2) strategy to analyze and interpret data.

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

* 8. Using the Identify and Interpret (I2) strategy has increased my confidence in my ability to analyze and interpret data.

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

Explain why you selected your response:

Student Post-Instruction Survey

Constructing Explanations (C-E-R: Claim, Evidence, Reasoning)

* 9. When asked to write a scientific explanation, or C-E-R, I understand what that means.

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

* 10. I feel confident in my ability to write a claim in a scientific explanation, or C-E-R.

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

Explain why you selected your response:

* 11. I feel confident in my ability to select and use appropriate (correct/accurate) and sufficient (enough) evidence when writing a scientific explanation, or C-E-R.

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

Explain why you selected your response:

* 12. I feel confident in my ability to provide reasoning when writing a scientific explanation, or C-E-R. Reasoning is using a science concept or principle to justify why the evidence connects to the claim.

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

Explain why you selected your response:

Student Post-Instruction Survey

Using the Identify & Interpret Strategy with Constructing Scientific Explanations (C-E-R)

* 13. Using the Identify and Interpret (I2) strategy has increased my confidence in my ability to write a C-E-R explanation.

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

Explain why you selected your response:

* 14. Using the Identify and Interpret (I2) strategy has increased my confidence in my ability to select evidence to support my claim in my C-E-R explanations.

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

Explain why you selected your response:

* 15. Using the Identify and Interpret (I2) strategy has improved my use of appropriate (correct/accurate) and sufficient (enough) evidence in my C-E-R explanations.

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

Explain why you selected your response:

* 16. Writing the "What I See" (WIS) part of the Identify and Interpret (I2) strategy has improved my use of evidence in my C-E-R explanations.

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

Explain why you selected your response:

* 17. Writing the “What it Means” (WIM) part of the Identify and Interpret (I2) strategy has improved my reasoning in my C-E-R explanations.

☐ Strongly agree ☐ Agree ☐ Neither agree nor disagree ☐ Disagree ☐ Strongly disagree

Explain why you selected your response:

* 18. How did the Identify and Interpret (I2) strategy help you in writing your C-E-R explanations? If it did not help you at all, please explain why.

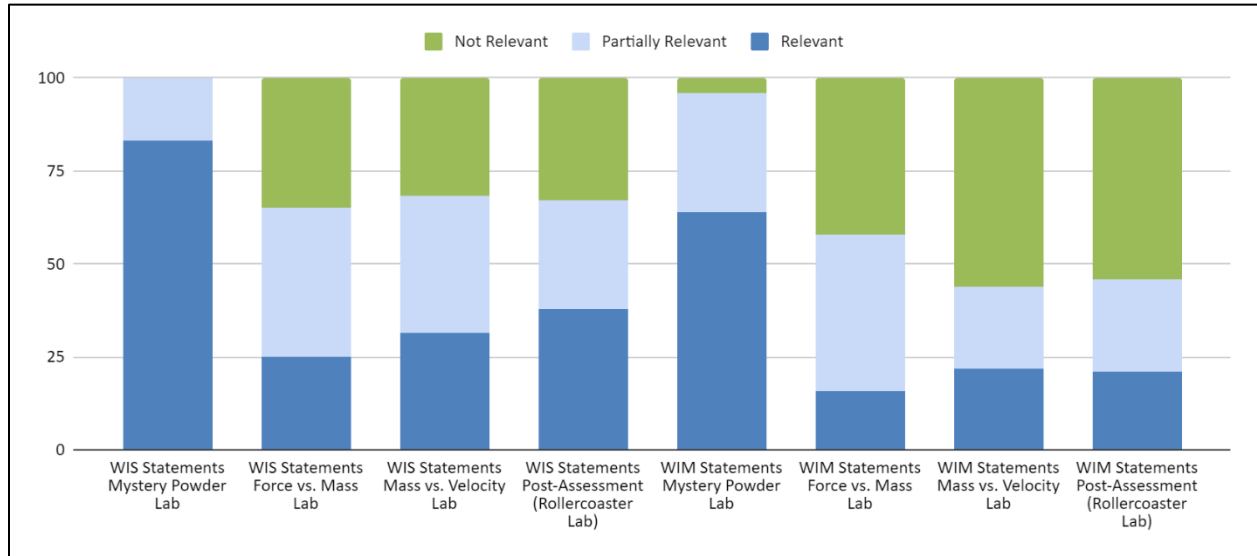
* 19. Was there anything else you did during summer school that you felt helped you improve your use of evidence in your C-E-R explanations?

* 20. Was there anything else you did during summer school that you felt helped you improve your use of reasoning in your C-E-R explanations?

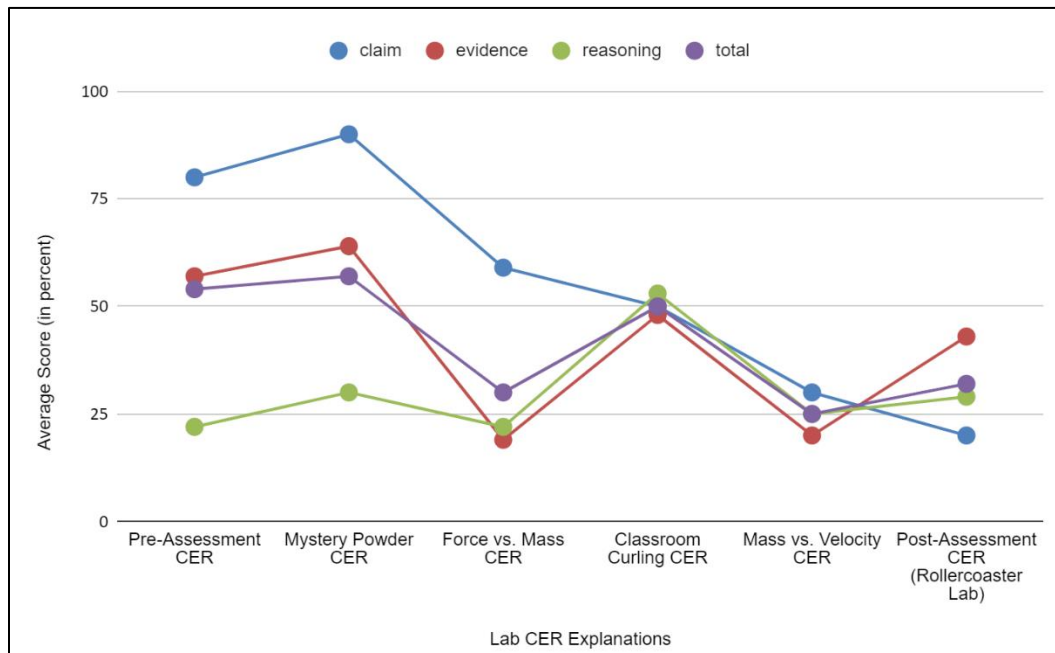
APPENDIX H

STUDENT DATA: RELEVANCE OF WIS AND WIM STATEMENTS

The graph below shows the relevance of WIS and WIM statements students wrote across the four labs students engaged in the Identify and Interpret strategy.



The graph below shows the CER component scores across the study for comparison.

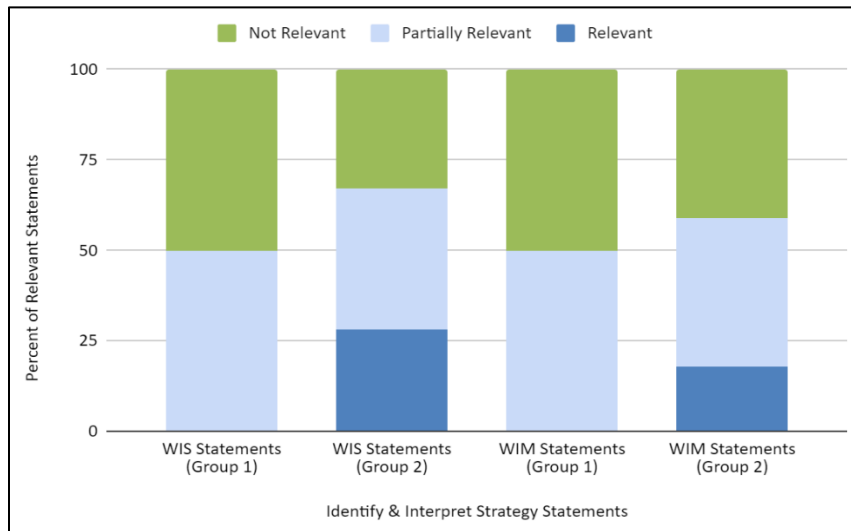


APPENDIX I

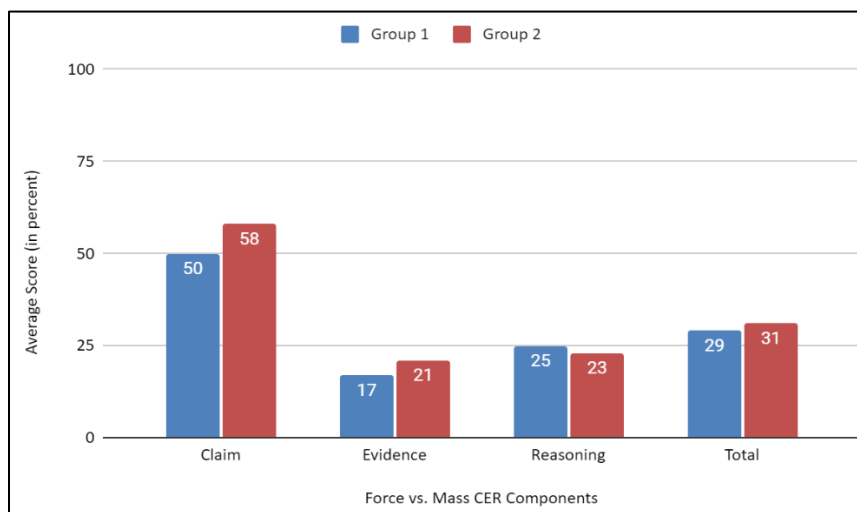
GRAPHS OF GROUP 1 AND GROUP 2 DATA

Force vs. Mass Lab

The graph below shows the relevance of the WIS and WIM statements group 1 ($n=2$) and group 2 ($n=18$) wrote on the graphs. Group 1 used their WIS and WIM statements in their CER, and group 2 did not.

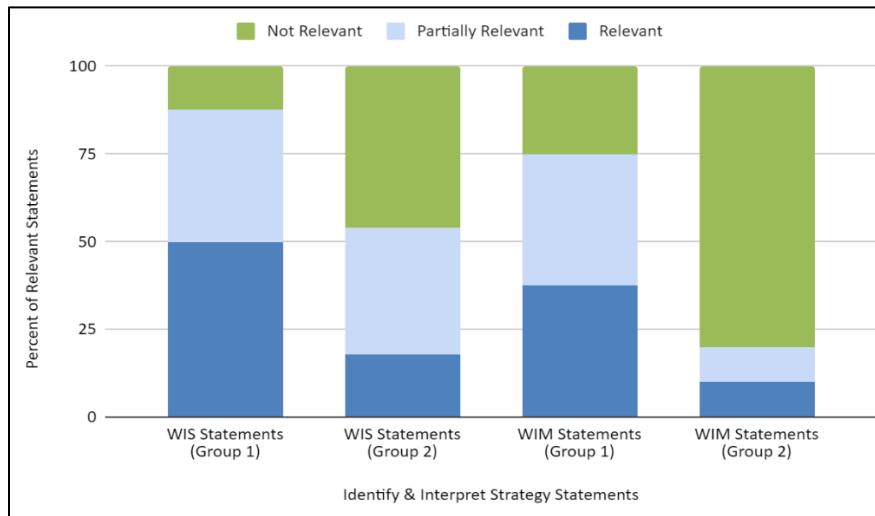


The graph below shows the CER component and total scores for group 1 ($n=2$) and group 2 ($n=18$).



Mass vs. Velocity Lab

The graph below shows the relevance of the WIS and WIM statements group 1 ($n=8$) and group 2 ($n=11$) wrote on the graphs. Group 1 used their WIS and WIM statements in their CER, and group 2 did not.



The graph below shows the CER component and total scores for group 1 ($n=8$) and group 2 ($n=11$).

