

THE USE OF GRAPHING CERS (Claim, Evidence, Reasoning) TO IMPROVE SCIENTIFIC  
LITERACY

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THE USE OF GRAPHING CERS (Claim, Evidence, Reasoning) TO IMPROVE SCIENTIFIC  
LITERACY

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By

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## ABSTRACT

The purpose of this research was to determine if graphing CERs (claim, evidence, reasoning) can improve student graphing and writing skills. Research suggests that teachers are under intense amounts of pressure to improve scientific literacy in students (Allen & Rogers, 2015). “Interpreting and creating graphical representations are part of the Next Generation Science Standards (NGSS Lead States 2013), and students are assessed on these skills in the Program for International Student Assessment (PISA), the ACT [American College Testing], and state accountability exams” (Lamb, Polman, Newman, & Smith, 2014). According to Llewellyn, “...to become scientifically literate, high school students must become proficient in a) investigating phenomenon, b) collecting and analyzing data, c) making claims from the findings, and d) supporting such claims and explanations with evidence to justify and defend their assertions” (2013). The CER framework supports the development of explanations and guides students in communicating their understandings of science through writing (Zemba-Saul, McNeill, & Hershberger, 2013; as cited by Allen & Rogers, 2015). In this study, one graphing CER was given to students each unit in a General Biology high school course. The scores were recorded in an Excel spreadsheet and a paired data analysis was used to compare the first graphing CER to the second to last graphing CER for the year. The second to last graphing CER scores were significantly greater than the first.

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# CHAPTER 1

## INTRODUCTION

### Statement of the Problem

This research addresses the question: how can educators improve data analysis and writing skills to better prepare students for success on the ACT and in post-secondary education?

### Purpose of the Study

The purpose of this research is to determine if graphing CERs (claim, evidence, reasoning) can improve student graphing and writing skills. Students struggle with analyzing data and creating evidence-based arguments. These skills must be explicitly taught by teachers (Llewellyn, 2013).

...there are students entering—and leaving—undergraduate programs of study with inadequate, or absent, comprehension of science as a way of knowing—how it is conducted, the philosophical and historical frameworks of our modern understandings, and science as a self-correcting set of process skills. It is a shared responsibility of secondary and post-secondary faculties to ensure that science literacy is a priority and that approaches to teaching across levels strive to meet that goal. (Glaze, 2018, para. 1 of introduction)

Furthermore, Jonathan Osborne, from the Graduate School of Education at Stanford University, believes that there is a disconnect between how science is done and how it is taught. “There’s not enough discussion and argumentation,” (Osborne as cited by Gabrielsen, 2013). As teachers, we need to figure out how to increase opportunities for data analysis and evidenced-based argumentation in order to build these skills. The CER framework supports the development of explanations and guides young children in communicating their understandings of science through writing (Zemal-Saul, McNeill, & Hershberger, 2013; as cited by Allen & Rogers, 2015). “Many students find it easier to express their ideas about science through talking

rather than writing” (Allen & Rogers, 2015). However, writing in science has many benefits. According to Abell in 2006, “...writing in science promotes new learning, helps students consolidate and review their scientific ideas, and aids in reformulating and extending their scientific knowledge” (Abell, 2006; as cited in Allen & Rogers, 2015).

In order to construct a written evidence-based argument, students need to be able to analyze data and interpret graphs. According to Lai et al., “research identifies many weaknesses in student ability to interpret graphs” (2016). Furthermore, “Interpreting and creating graphical representations are part of the Next Generation Science Standards (NGSS Lead States 2013), and students are assessed on these skills in the Program for International Student Assessment (PISA), the ACT [American College Testing], and state accountability exams” (Lamb, Polman, Newman, & Smith, 2014).

### **Definition of Terms**

*CER (Claim, Evidence, Reasoning)*: A tool that can be used to help students learn science concepts by giving them the opportunity to justify their scientific claims (Zemba-Saul, McNeill, & Hershberger 2013; as cited in Allen & Rogers, 2015). According to Allen and Rogers, “The claim is the statement or conclusion that answers the focus question” (2015). The evidence is the data that supports the claim. The reasoning involves students connecting the evidence to the claim using scientific principles associated with the topic being discussed (Allen & Rogers, 2015).

*Scientific Literacy*: “...an ability to problem solve, make evidenced-based decisions, and evaluate information in a manner that is logical” (Glaze, 2018). Furthermore, [it is the ability to] “gather data, organize it in tables and spreadsheets, analyze it in context, and describe and

interpret it—usually as evidence to support a scientific argument (Jimenez-Aleixandre, Bugallo Rodriquez, & Duschl 2000; Kilpatrick 1985; Schoenfeld, 1992; as cited in Webber, Nelson, Weatherbee, Zoellick, & Schauffler, 2014).

*Evidence-Based Argumentation aka Scientific argumentation:* “It is a higher-level, critical-thinking skill that students use to propose, support, critique, refine, justify, and defend their positions about a specific (and sometimes controversial) scientific topic” (Llewellyn, 2013).

*Data Analysis:* “... Because raw data as such have little meaning, a major practice of scientists is to organize and interpret data through tabulating, graphing, or statistical analysis. Such analysis can bring out the meaning of data--and their relevance--so that they may be used as evidence” (NGSS Lead States 2013, Appendix F, p. 9; as cited in Webber et al., 2014).

*Graph Interpretation:* “...students need to make sense of the features of graphs--including labels, scale, shape, noise, and patterns--to describe, depict, and evaluate claims regarding scientific phenomena” (Lai et al., 2016).

### **Significance of the Study**

Schools are facing pressure to get students to score well on standardized tests, especially the ACT. According to Wilson, Taylor, Kowalski, and Carlson (2009),

The No Child Left Behind (NCLB) legislation (U.S. Department of Education, 2002) and the associated accountability movement have led to an increased emphasis on standardized testing to measure teacher and school effectiveness. In turn, some have argued (see e.g., Blanchard, Annetta, & Southerland, 2008) that standardized testing (a) has resulted in teaching practices that are at odds with those advocated in the national science education reform documents (American Association for the Advancement of Science, 1993, 2000; NRC, 1996, 2000), (b) has had negative effects on science teachers’ perceptions of the quality of their teaching (Shaver, Cuevas, Lee, & Avalos, 2007; Southerland, Abrams, & Hutner, 2007), and (c) has created pressures for teachers to prepare students for tests that cover large amounts of content and emphasize factual

knowledge (Whitford & Jones, 2000).

Since much of the science portion of the ACT involves analyzing graphs and interpreting data, teachers need assessments to help students learn these skills (Lamb et al., 2014). Graphing CERs is an example of an assessment that can be used to address this problem. By researching the effectiveness of graphing CERs in improving student graphing and writing skills, I am hoping to contribute a useful technique for teachers to use in science classrooms.

### **Assumptions**

This research project was driven by some key assumptions that are discussed below:

1. Students need to be able to create a graph before they can interpret one (Webber et al., 2014).
2. Students need to be able to interpret simple graphs before they can interpret complex graphs (Lai et al., 2016; Webber et al., 2014).
3. Students need to write in order to solidify knowledge (Abell, 2006; as cited in Allen & Rogers, 2015).
4. The more practice that students get with graphing and writing the better they will be at it.
5. Students need practice interpreting graphs in order to be successful on standardized tests that involve graphing, such as the ACT (Lamb et al., 2014).
6. Understanding how to interpret graphs and analyze data will better prepare students for post-secondary education and careers (Glaze, 2018).

7. Science literacy and data literacy can be used interchangeably.

### **Delimitation of the Study**

There are various delimitations that need to be discussed in order to accurately analyze the results of this study. The first is that I started my research in June 2018. I used Educational Resources Information Center (ERIC), an educational database to find the majority of my sources. The following words were used to find the articles: science literacy, secondary education, data analysis, graphing, CER, and Next Generation Science Standards (NGSS). Most of the sources are peer-reviewed articles that include studies and original ideas from other educators.

A second delimitation is that I teach Biology at Lancaster High School, which is a small rural school with about 270 students. According to the DPI 2016-2017 report card, Lancaster High School's student population is 96.4 % white and 31.3% economically disadvantaged. Our average class size is 20 students. I conducted this research on my General Biology students, which involved 25 students. There were 21 sophomores and 4 exceptional freshmen. At Lancaster, Biology is typically a sophomore class. Freshmen need to be approved by the guidance counselor to take both Physical Science and Biology in the same year. In order to be approved, students need to be in high academic standing. Lancaster's class periods are about 45 minutes long. Class periods change at semester, along with the combination of students. Special Education students are pulled out and put into their own section of Biology, and are not included in this study. A more diverse setting with more students might yield different results.

A third delimitation is that I had to exclude some student's scores for whom I did not receive permission. I had 51 students in General Biology for the 2017-2018 school year, but

only 25 students gave me permission to use their scores for this study.

There are various student-unique factors that could have affected the results of my study. Sometimes students have bad days and, therefore, they do not give their maximum effort. Because I gave a graphing CER each unit, and each unit is on a different topic, a student's knowledge and interest in the topic could have influenced his/her score. Although I tried to be consistent in giving the graphing CER during class, there was one (photosynthesis and cell respiration) that was given as homework. Some students put less effort into homework, as opposed to an assignment that they are given during class time. The photosynthesis and cell respiration graphing CER was also given while much of the school was on a New York trip; students were overwhelmed with the amount of homework that they had to make up. For these reasons, I decided to run my paired data analysis with the first graphing CER: Greenhouse Effect and my second to last graphing CER: Evolution.

Furthermore, if students were absent, they had to complete the graphing CER outside of class. Some students did not turn in their graphing CERs, and therefore, they didn't have as much practice with them. Lastly, even though I used a rubric to grade each graphing CER, my expectations could have changed over the course of the school year.

### **Methodology**

As stated previously, this study was done on 25 General Biology students at Lancaster High School. Most of these students were sophomores and 4 were freshmen. Students agreed to participate in this study by signing a consent form. Parents/Guardians also signed a consent form to allow their child to participate. I gave my General Biology students one graphing CER each unit over the 2017-2018 school year. This came to a total of 9 graphing CERs. I graded each

assessment using a 10 point rubric (Appendix F) and tracked each student's scores in an Excel spreadsheet. Danielle Carlson, a Biology Teacher at Fennimore High School, created the graphing CER assessments. I ran a paired data analysis to compare each student's final score to their initial score.

## **CHAPTER 2**

### **REVIEW OF LITERATURE**

#### *Science Literacy*

“Science literacy is a concept that is simple in theory yet has been a challenge to describe in terms of practice” (Glaze, 2018). As educators, we want our students to leave our science courses with the ability to problem solve and make informed decisions on scientific topics that they encounter in the news and everyday life (Glaze, 2018). This is not limited to students that are pursuing a career in science (Krajcik, 2015). “Research in science education across levels identifies gaps in foundational understandings of science among students and the public” (Glaze, 2018). These gaps and misconceptions are the driving force behind the rejection of new scientific discoveries that could otherwise be helpful. According to Glaze, in order to correct this problem, we need to reevaluate the way we teach science and what students are expected to know and understand (2018). Students need to leave our courses with not only a knowledge of content, but also with an appreciation of science and its process (Koballa, Kemp, & Evans, 1997; as cited in Glaze, 2018). Science literacy goes well beyond the classroom; it's “the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity” (National Research Council, 2013; as cited in Glaze, 2018). Furthermore, “scientific literacy involves not only the

ability to recall and apply concepts of science in the classroom, but a deeper understanding of how scientific knowledge is generated, the processes that take place, and the cultural and social context of scientific discovery and exploration” (Glaze, 2018). We owe it to the future of society to revamp our science classrooms to bridge the gap between how science is taught and how it is actually done in the real world.

“Research in science education is telling us that lecture is not as effective as other means of teaching, that active learning is the only way to engage students on a level beyond knowledge and understanding, and that, to reach higher orders of scientific literacy, we must engage students not only in explorations of the history and theory that represents science, but the processes, context, and practices as well” (Glaze, 2018). Active learning will not only be more memorable for students, but also gives teachers an opportunity to model how science is actually done. Many high school students do not get opportunities to engage in scientific practices, learn about the history that has largely influenced what we know today, or the wide range of fields that exist in science (Glaze, 2018). This especially affects universities as they are the next step that has to deal with the gaps that have been created. In addition, students who have not been exposed to various disciplines or careers in science, are less likely to pursue one.

So what needs to be done? According to Llewellyn, “... to become scientifically literate, high school students must become proficient in a) investigating phenomena, b) collecting and analyzing data, c) making claims from the findings, and d) supporting such claims and explanations with evidence to justify and defend their assertions (2013). This integrated approach to teaching science and literacy together, will not only give a better representation of how science is done in the real world, but will also promote greater scientific understanding and writing skills (Pellegrino & Hilton, 2012).

## CER

“Writing in science to enhance student understanding of scientific content and processes has been supported by many researchers” (Bass, Baxter, & Glaser, 2001; Baxter, Bass, & Glaser, 2000; Keys, Hand, Prain, & Collins, 1999; Rivard & Straw, 2000; Shepardson & Britsch, 1997; as cited in Ruiz-Primo, Li, Tsai, & Schneider, 2008). “Brown and Campione (1990) argued that asking students to write explanations push them to evaluate, integrate and elaborate knowledge in new ways that positively impacts their learning” (Ruiz-Primo et al., 2008). According to Rivard & Straw (2000), “While oral discourse is divergent, highly flexible, and requires little effort from students, written discourse is convergent, more focused, and places greater cognitive demands on the writers” (as cited in Ruiz-Primo et al., 2008). The CER format is a useful tool to help students learn how to write in science.

According to Ruiz-Primo et al. (2008), three components are being cited frequently as essential in scientific explanations (Kenyon & Reiser, 2006; Kuhn & Reiser, 2004, 2006; McNeill & Krajick, 2006; Sandoval & Reiser, 2004; Tzou, 2006):

1. *Claim*: A testable statement or conclusion that answers a scientific question. A scientific claim typically focuses on what happened, or how or why something happened.
2. *Evidence*: Investigation data that helps to construct, support, and defend a claim. Originally, Toulmin (1958) named this component *data* to refer to the statements used as evidence to support the claim.
3. *Reasoning*: Statements given to justify claims. That is, they are justifications to show why the data count as evidence to support the claim through a conceptual and theoretical link. Toulmin (1958) used the term *warrants* instead of reasons.

Writing helps students express their thinking to themselves and to their teacher (Keeley, 2015).

According to Keeley (2015), “A student’s scientific explanation can be used formatively to show evidence of meeting the learning target.”

However, students need to be taught how to write evidence-based explanations, otherwise they can struggle to fully express their thinking (Keeley, 2015). According to a study done by Ruiz-Primo et al. (2008), 18% of student explanations included all three components of the CER format, 40% of the explanations were claims without evidence or reasoning. Additionally Keeley states, “Until students have had the opportunity to learn scientific concepts through investigation, discussion, and obtaining and evaluating information, their explanations may lack the features that distinguish an “everyday explanation” from an evidence-based, scientific explanation” (2015). “Once students have had the opportunity to learn and use scientific ideas, they can construct evidence-based, scientific explanations that include a claim; data from their investigations or valid information obtained through text, discussion, or other sources; and scientific reasoning that includes scientific principles or concepts” (Keeley, 2015). Ruiz-Primo et al. believe, “...engaging students in the construction of high-quality explanations might be related to higher levels of student performance” (2008). However, Ruiz-Primo et al., also believe that students are not given enough opportunities to write in science (2008).

The CER format doesn't have to be limited to writing; it can also be used as a way to verbally communicate ideas. “Teachers and students engage in science by designing and carrying out investigations and making and debating claims supported by evidence and reasoning (Krajcik, 2015). Furthermore Krajcik (2015) states,

Seldom in science and engineering does a single individual make a major breakthrough. Diverse and collective expertise, creativity, and ideas from various individuals are needed to solve complex problems. Often collaboration engages students in arguing from evidence as students try to make sense of phenomena (NGSS Practice 7; as cited in Krajcik, 2015).

Constructing explanations, whether they're verbal or written, is part of the Next Generation Science Standards (Allen & Rogers, 2015). The CER framework “...supports students' learning

and writing through forming statements (claims) based on their observations (evidence) and then discussing these results with respect to the underlying scientific principles (reasoning) to build a deeper understanding of the content” (Allen & Rogers, 2015). Gabrielsen (2013) states “Teaching students how to argue based on available evidence engages them in the scientific process and provides a better idea of how science actually works.”

### *Graph Literacy*

Our world is full of visual data, whether it comes from the government, scientists, or another source (Lamb et al., 2014). Information about the weather, medicine, politics, finances, and nutrition are often displayed using graphs (Dash & Hug, 2014). Graphs are intended to make data easier to interpret; however, approximately 41% of adults in the United States have low graph literacy (Galesic and Garcia-Retamero 2011; as cited by Dash & Hug, 2014). “To be educated consumers and citizens, students need to understand and be critical of information presented in graphical form” (Lamb et al., 2014). Furthermore Lai et al. states, “Interpreting and creating graphs plays a critical role in scientific practice” (2016). “At a general level, graph understanding in science is the ability to recognize and communicate about features of graphs, coordinate between multiple representations conveying similar information (e.g., graph and table), and interpret graphs in a science context (Lai et al., 2016). According to Lai et al. (2016),

A graph can depict a great deal of information efficiently. To comprehend a graph, the student needs to make sense of this information. This requires understanding of the graphs’ features and context and the ability to make valid inferences with that information (Preece and Janvier 1992; Roth and Bowen 2001). The ability to make inferences from graphs represents a fundamental graphing skill (Glazer 2011; as cited in Lai et al., 2016).

According to Lai et al., students struggle with connecting graph features to science concepts (2016). Science teachers often neglect to teach graph features needed in science (Lai et al., 2016). Many students also don't know how to use data from graphs as evidence to support an argument (Lovett and Chang 2007; as cited in Lai et al., 2016). "To improve graph understanding, students need to use graphs as a communication tool, not just view graphs in a passive manner (Fry 1981; as cited in Lai et al., 2016). According to Lai et al. (2016),

Graphs take advantage of the human capacity to visualize large amounts of data in ways that reveal patterns, uncertainty, and critical events (Friel et al. 2001; Wu and Krajcik 2006). Graphs in science, specifically, require students to observe general shapes and patterns that reveal natural processes. Developing expertise with science graphs requires students to make connections between these graphical patterns and the underlying processes that support them (Shah and Hoeffner 2002). Likewise, strong science graph understanding can facilitate learning of new scientific concepts.

However, students must be able to make a graph before they can identify patterns and use data as evidence (Webber et al., 2014). Webber et al. (2014) also suggests that students use their graph to answer a question; this encourages students to think more deeply about their data as they develop their argument. Due to increased demand of graphing interpretation skills in both society and science, teachers need to provide students with opportunities to interpret information in graphical form and teach them how to transfer that knowledge into an evidence-based argument.

#### *ACT/NGSS*

Analyzing data and interpreting graphs is a major component of the science portion of the ACT. According to Aydeniz and Southerland, standardized testing largely influences instruction

and assessments in science (2012). Schools are under a lot of pressure to do well on standardized tests because the No Child Left Behind Act holds them accountable (Aydeniz & Southerland, 2012). Schools that do not meet their Adequate Yearly Progress objectives for student learning could receive fewer funds (Abrams et al. 2008; Darling-Hammond 2004; Madden 2008; as cited in Aydeniz & Southerland, 2012). Because of the high stakes testing, teachers often adjust their curriculum and teaching strategies to build skills for the test (Aydeniz 2007; Brickhouse 2006; Darling-Hammond 2004; Madden 2008; Popham 2006; as cited in Aydeniz & Southerland, 2012). These instructional strategies and assessments do not help students meet the learning outcomes of science curriculum standards, such as the National Science Education Standards (Abell and Volkmann 2006; Brickhouse 2006; DeBoer 2002; Madden 2008; Pringle and Carrier 2005; as cited in Aydeniz & Southerland, 2012). The ACT requires factual knowledge and the ability to interpret data, while the Next Generation Science Standards promote critical thinking and inquiry (Abrams et al. 2008; as cited in Aydeniz & Southerland, 2012). “Science teachers seem to be receiving two conflicting messages, one that calls on them to address the learning needs of all students by scrutinizing their instruction through testing [and] another that calls on them to teach science through methods such as problem based learning that has been proven to ensure the learning of all students” (Aydeniz 2007; Madden 2008; as cited in Aydeniz & Southerland, 2012). The good news is that both the ACT and NGSS emphasize data analysis. “The K-12 Next Generation Science Standards call for students to use graphs for scientific modeling, reasoning, and communication” (Lai et al., 2016). According to Lai et al. (2016),

One of the central goals of the NGSS is to engage students in the practices of scientists, such as making arguments from evidence. This is consistent with the role that graphs play

in conveying scientific arguments as well as their ubiquity in persuasive advertising. Thus, measuring student ability to critique scientific graphs is important for science literacy (Chang and Linn 2013).

In today's schools, teachers need to find a balance between preparing students for the high stakes ACT, a test that determines college readiness for students and the effectiveness of teachers, and teaching the skills and content required by the NGSS. Standardized tests do not accurately represent students' knowledge and skills required in the workplace and real life (Brickhouse 2006; Darling-Hammond and Adamson 2010; as cited in Aydeniz & Southerland, 2012). The NGSS are designed to give students the skills and knowledge necessary for life after high school. Instructional practices found in the NGSS have proven to be effective in helping students learn important science concepts and inquiry skills (Abrams et al. 2008; Aydeniz 2007; NRC 1996; Madden 2008; NRC 2000; as cited in Aydeniz & Southerland, 2012). My decision to incorporate graphing CERs into my science curriculum was largely driven by both the ACT and NGSS. Students need to be prepared for both.

## **CHAPTER 3**

### **METHOD**

#### *Participants*

This study was done on 25 General Biology students at Lancaster High School during the 2017-2018 school year. This is a required course typically completed during sophomore year. However, freshmen can enroll if they are approved by administration. There were 21

sophomores and 4 freshmen in General Biology. Of the 25 students, 12 were female and 13 were male. There were 3 class periods of Biology, and the students in each section were determined by the guidance counselor. As previously stated, special education students were not included in this study because they were in a separate section of Biology, taught by a different teacher. In order to participate in this study, students and parents had to sign a consent form (Appendix A and Appendix B). Consent from my principal to run this research project at school was received (Appendix C). The students who agreed to participate received a debriefing form as well (Appendix D).

### *Materials and Measurement*

The graphing CERs were created by Danielle (Balistreri) Carlson, a teacher at Fennimore High School. Each assessment included two parts. Students had to create a graph in part one and then analyze the graph by writing an explanation in CER format for part two. The assessments varied in the type of graph that had to be made and in the questions that prompted the explanation. The topics of the nine CERs used include: Greenhouse Gas Effect, Cell Respiration and Yeast Lab, Cells and Organelles, Osmosis, Cancer and Mitosis, Amino Acids, Genotypes and Expected Values/Punnett Squares, Evolution and Common Ancestry, and Photosynthesis and Cell Respiration (Appendix E). Each graphing CER was graded using a 10 point rubric (Appendix F). Typically the graph was worth 6 points, and the CER was worth 4 points. The scores were recorded in an Excel spreadsheet. A paired data analysis was run to compare each student's final score to their initial score.

### *Procedure*

Each student was given one graphing CER each unit over the course of the 2017-2018

school year. There was a total of nine CERs given. Students completed the CERs individually and during class, with the exception of the Photosynthesis and Cell Respiration CER, which was given as homework. Each graphing CER was graded by the researcher/educator. After scores were recorded, the graphing CERs were discussed as a class. Expectations were explained for the graph portion, and provided an example of a CER that would receive full credit. Students were given individual feedback on the parts of the graph or CER that were missing.

## **CHAPTER 4**

### **ANALYSIS OF DATA**

As shown in Figure 4.1 and Table 4.1, a paired data analysis was used to compare students first CER of the year (Pre Graphing CER) to the 2nd to last CER of the year (Post Graphing CER). The 2nd to last graphing CER was used instead of the last CER because there were various complications with the last CER. Many students were in New York on a school field trip. Because of this trip, students had to complete the last CER as homework instead of completing it in class. Some students do not put in as much effort into homework as they would to an assignment given in class. One student did not turn it in. Therefore, the 2nd to last graphing CER was used for comparison.

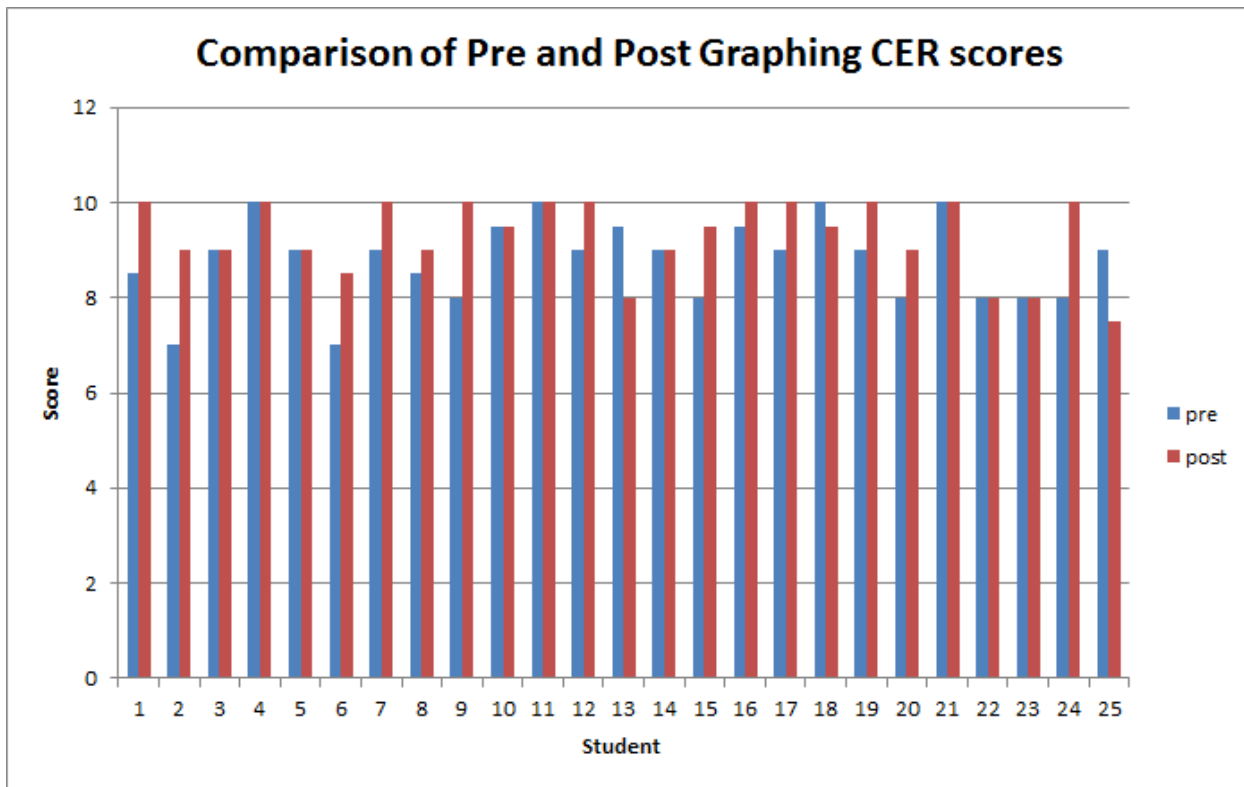


Figure 4.1. Comparison of Pre- and Post-Graphing CER Scores for 2017-2018 General Biology Students. Each Graphing CER was worth up to 10 points.

The p-value of 0.0047 for testing if the post-graphing CER was significantly greater than the pre-graphing CER, which means that the post-graphing CER was significantly higher. The p-value for testing for a difference between the pre-graphing CER mean and post-graphing CER mean was 0.0095. This indicates that the post-graphing CER mean is significantly different. As shown in Figure 4.1, 13 students improved their scores, 9 stayed the same, and 3 decreased.

Table 4.1. Statistical Calculations

| Statistic Calculation                | Data     |
|--------------------------------------|----------|
| Pre-test Mean                        | 8.78     |
| Post-test Mean                       | 9.3      |
| Mean Difference                      | -0.52    |
| P-value for post-test being greater  | 0.0062   |
| P-value for testing for a difference | 0.0125   |
| Test Statistic (t)                   | 2.700919 |
| Degrees of Freedom                   | 25       |

Table 4.2, located in Appendix E, shows student scores for each graphing CER given. The graphing CERs are arranged in the order that they were given. The paired data analysis compares the Greenhouse Effect to the Evolution graphing CER.

Table 4.3 displays student responses as to whether or not they thought that they got better at writing CERs by writing them each unit. Eighty percent of students said that they did get better and twenty percent said that they did not get better at writing CERs over the course of the 2017-2018 school year.

Table 4.3. Student Responses to: Did you get better at writing CERS by doing them each unit?

| Yes | No  |
|-----|-----|
| 20  | 5   |
| 80% | 20% |

## CHAPTER 5

### SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

#### *Summary*

The purpose of this study was to determine if graphing CERs can improve student graphing and writing skills in a high school biology classroom. Statistical analysis confirms that students had significantly higher graphing CER scores at the end of the year than at the beginning (see Figure 4.1 and Table 4.1). Therefore, the data suggests that graphing CERs can be used as a tool to improve scientific writing and graphing skills in a high school biology classroom.

#### *Conclusions*

Graphing CERs do improve student graphing and writing skills and are therefore a useful tool for teachers to use. Due to pressure to perform well on the ACT and meet the needs of the NGSS, teachers need a tool that will be both effective and time efficient. In my experience, graphing CERs are easy to make, take about 15 minutes for students to complete, and are easy to grade. The terminology breaks down a scientific argument into three simple pieces, which makes it easy for students to remember and self-check. As can be seen from the results of this study, scores did improve, and 80% of students felt that they got better at writing from doing graphing CERs regularly (see Table 4.3).

#### *Recommendations*

In order to learn more about the effectiveness of graphing CERs as a tool to improve scientific writing and graphing skills, future studies are recommended. This study was only done over the 2017-2018 school year. The data would be more reliable if this study was done over multiple years with more students. There were actually 51 students in General Biology in 2017,

but only 25 agreed to participate in this study. The results might look different if all students participated. It would also be interesting to follow those students through their high school career in a longitudinal study to see how using graphing CERs early in their high school education affects their writing and graphing skills as a junior or senior. Specifically, ACT scores could be analyzed since the science portion involves a lot of graphing and data analysis. As mentioned, the ACT is a major reason that graphing and writing skills are being emphasized in high school classrooms.

This study should also be carried out in a more diverse setting. Lancaster is a small, rural high school whose student population is about 270 and is 96.4% white. The results might be different in a large, urban district with more diversity. Furthermore, this study did not include special needs students, and it would be interesting to see if graphing CERs can improve their graphing and writing skills as well.

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## APPENDIX A

### PARENT/GUARDIAN CONSENT FORM FOR PARTICIPATION OF HUMAN PARTICIPANTS IN THE STUDY ENTITLED: THE USE OF GRAPHING CERS (Claim, Evidence, Reasoning) TO IMPROVE SCIENTIFIC LITERACY

UNIVERSITY OF WISCONSIN-PLATTEVILLE AND LANCASTER HIGH SCHOOL

1. **Purpose:** The purpose of this research is to determine if graphing CERS (claim, evidence, reasoning) can improve student graphing and writing skills. A graphing CER is an assessment in which students analyze or create a graph and then write an evidence-based explanation that answers a question.
2. **Procedure:** Your child, enrolled at Lancaster High School, was given one graphing CER each unit in General Biology. The assessments were graded using a 10 point rubric and scored as homework. The scores were tracked in an Excel spreadsheet as data for Educator Effectiveness. I am now asking permission to use your child's graphing CER assessment scores as data for my master's degree seminar project.

PARTICIPATION IS VOLUNTARY AND HE/SHE WILL BE ASKED TO GIVE HIS/HER ASSENT. YOUR CHILD'S NAME WILL NOT BE RECORDED ON THE RESEARCH MATERIALS OR IN ANY REPORTS ABOUT THE PROJECT.

3. **Time Required:** As mentioned, students already completed the assessments throughout the 2017-2018 school year in General Biology. I am now asking to use their scores as data for my master's degree seminar project. Grades were already recorded for the past school year. Participating or declining to participate in this study will not affect your child's grades at Lancaster High School.

4. **Risks:** No short-term or long-term risks are foreseen.

**Benefits:** Understanding if graphing CERs improve scientific literacy will benefit my classroom and Lancaster High School. Students tend to struggle with analyzing data and creating evidence-based arguments. These are important skills for success on the ACT, future careers, and for meeting the NGSS (Next Generation Science Standards). This research will help me determine if graphing CERs will continue to be an assessment in the science department at Lancaster High School.

5. **Your Rights as the Parent of a Student Participant:** The grades that were collected and will be used in this study are confidential. Data or summarized results will not be released in any way that could identify you or your child.

Before using the collected data, participants will be given a debriefing detailing the exact purpose of the research. If you have any questions, please feel free to contact me:

Kaitlin Landon, Researcher  
School of Education  
University of Wisconsin-Platteville  
[landonk@lancastersd.k12.wi.us](mailto:landonk@lancastersd.k12.wi.us)

Once the study is completed, you may request a summary of the results by contacting the above researcher or Dr. Jodean E. Grunow. If you have any questions about your child's treatment as a participant in this study, please call or write:

Barb Barnet  
Chair of the UW-Platteville IRB  
(608) 342-1942  
[barnetb@uwplatt.edu](mailto:barnetb@uwplatt.edu)

Dr. Jodean E. Grunow  
Department of Mathematics/Adjunct,  
School of Education  
(608) 342-1009  
[grunowj@uwplatt.edu](mailto:grunowj@uwplatt.edu)

---

I have read the above information and (check one):

DO give consent for my child to participate in the research.

DO NOT give consent for my child to participate in the research.

Please print your child's name (First, Middle, Last):

\_\_\_\_\_

Please print your full name (First, Middle, Last):

\_\_\_\_\_

Signature: \_\_\_\_\_ Date: \_\_\_\_\_

## Appendix B

### STUDENT ASSENT FORM FOR PARTICIPATION IN THE STUDY ENTITLED: THE USE OF GRAPHING CERS (Claim, Evidence, Reasoning) TO IMPROVE SCIENTIFIC LITERACY UNIVERSITY OF WISCONSIN-PLATTEVILLE & LANCASTER HIGH SCHOOL

Dear Student,

It is my job to give you the best education possible. Being a High School Biology Teacher, a major component of my job is to prepare you for the ACT, college, and future careers. Students tend to struggle with reading graphs, interpreting data, and writing explanations based on evidence. These skills can be referred to as scientific literacy, and are crucial for success on the ACT, future careers, and education. Therefore, I am conducting a research project as part of my master's degree to see if graphing CERS (claim, evidence, reasoning) improve scientific literacy.

You are being asked to participate in this study because you were enrolled in General Biology for the 2017-2018 school year. As you know, we did one graphing CER each unit. Each graphing CER was graded based on a 10 point rubric and recorded in an Excel spreadsheet. The scores that were collected were used not only for your grade in General Biology, but also for Educator Effectiveness that is required for all teachers. I am now asking for your permission to use your graphing CER scores as data for my master's seminar project. Participation will not affect your grades. The information gathered from this research is intended to improve General Biology.

Your parents have already given permission to allow me to use your grades for this research project. I am hoping that you will agree to participate, because the more data that I have the better. Your signature on this sheet shows your agreement/assent for my use of your grades. Please note that your name or information will not be tied to your data in any way.

Sincerely,

Kaitlin Landon, Researcher  
School of Education  
University of Wisconsin-Platteville  
[landonk@lancastersd.k12.wi.us](mailto:landonk@lancastersd.k12.wi.us)

Dr. Jodean E. Grunow  
Department of Mathematics/Adjunct, School  
of Education, Faculty Sponsor  
(608) 342-1009  
[grunowj@uwplatt.edu](mailto:grunowj@uwplatt.edu)

If you have any questions about your treatment as a participant in this study, please call or write either of us or contact:

Barb Barnet  
Chair of the UW-Platteville IRB  
(608) 342-1942  
[barnetb@uwplatt.edu](mailto:barnetb@uwplatt.edu)

I have read the above information and willingly consent (agree) to participate in this study.

Print \_\_\_\_\_ Sign \_\_\_\_\_ Date: \_\_\_\_\_

## APPENDIX C

### PRINCIPAL ASSENT FORM FOR PARTICIPATION OF HUMAN PARTICIPANTS IN THE STUDY ENTITLED: THE USE OF GRAPHING CERS (Claim, Evidence, Reasoning) TO IMPROVE SCIENTIFIC LITERACY

#### UNIVERSITY OF WISCONSIN-PLATTEVILLE AND LANCASTER HIGH SCHOOL

1. **Purpose:** The purpose of this research is to determine if graphing CERS (claim, evidence, reasoning) can improve student graphing and writing skills. A graphing CER is an assessment in which students analyze or create a graph and then write an evidence-based explanation that answers a question.
2. **Procedure:** The General Biology students enrolled at Lancaster High School for the 2017-2018 school year, were given one graphing CER each unit in General Biology. The assessments were graded using a 10 point rubric and scored as homework. The scores were tracked in an Excel spreadsheet as data for Educator Effectiveness. I am now asking permission to use students' graphing CER assessment scores as data for my master's degree seminar project.

PARTICIPATION IS VOLUNTARY. I WILL GET PERMISSION FROM BOTH THE PARENTS/GUARDIANS AND THE STUDENT. THE CHILD'S NAME WILL NOT BE RECORDED ON THE RESEARCH MATERIALS OR IN ANY REPORTS ABOUT THE PROJECT.

3. **Time Required:** As mentioned, students already completed the assessments throughout the 2017-2018 school year in General Biology. I am now asking to use their scores as data for my master's degree seminar project. Grades were already recorded for the past school year. Participating or declining to participate in this study will not affect students' grades at Lancaster High School.

4. **Risks:** No short-term or long-term risks are foreseen.

**Benefits:** Understanding if graphing CERs improve scientific literacy will benefit my classroom and Lancaster High School. Students tend to struggle with analyzing data and creating evidence-based arguments. These are important skills for success on the ACT, future careers, and for meeting the NGSS (Next Generation Science Standards). This research will help me determine if graphing CERs will continue to be an assessment in the science department at Lancaster High School.

5. **Your Rights as the Parent of a Student Participant:** The grades that were collected and will be used in this study are confidential. Data or summarized results will not be released in any way that could identify individual students at LHS.

Before using the collected data, participants will be given a debriefing detailing the exact purpose of the research. If you have any questions, please feel free to contact me:

Kaitlin Landon, Researcher  
School of Education, University of Wisconsin-Platteville  
[landonk@lancastersd.k12.wi.us](mailto:landonk@lancastersd.k12.wi.us)

Once the study is completed, students may request a summary of the results by contacting the above researcher or Dr. Jodean E. Grunow. If you have any questions about student treatment as a participant in this study, please call or write:

Barb Barnet  
Chair of the UW-Platteville IRB  
(608) 342-1942  
[barnetb@uwplatt.edu](mailto:barnetb@uwplatt.edu)

Dr. Jodean E. Grunow  
Department of Mathematics/Adjunct,  
School of Education  
(608) 342-1009  
[grunowj@uwplatt.edu](mailto:grunowj@uwplatt.edu)

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I have read the above information and (check one):

DO give consent for Kaitlin Landon to conduct this research at Lancaster High School.

DO NOT give consent for Kaitlin Landon to conduct this research at Lancaster High School.

Please print your full name (First, Middle, Last):

\_\_\_\_\_

Signature: \_\_\_\_\_ Date: \_\_\_\_\_

## APPENDIX D:

### DEBRIEFING FORM FOR THE STUDY ENTITLED: THE USE OF GRAPHING CERS

#### (Claim, Evidence, Reasoning) TO IMPROVE SCIENTIFIC LITERACY

Dear Student,

Thank you for agreeing to participate in this study. The general purpose of this research is to determine if graphing CERs improve scientific literacy skills. Scientific literacy includes reading graphs, interpreting data, and creating evidence-based explanations.

I have invited all students who were enrolled in General Biology during the 2017-2018 school year to participate. Student data, in the form of graphing CER scores, will be analyzed to see if there was improvement.

Based on previous studies on the effectiveness of CERs and the importance of graphing, I expect that students who get more practice with graphing and use the CER format will be better at analyzing data and creating evidence-based explanations. The results from this study will provide valuable information about the usefulness of graphing CERs to improve scientific literacy not only to teachers at Lancaster High School, but also to other educators looking to improve these skills.

If you have any questions or concerns regarding your participation in this study, please contact:

Barb Barnet  
Chair of the UW-Platteville IRB  
(608) 342-1942  
[barnetb@uwplatt.edu](mailto:barnetb@uwplatt.edu)

Once completed, the results of the study are available upon request. Please see contact information below to obtain a copy of the results.

Sincerely,

Kaitlin Landon  
School of Education, University of  
Wisconsin-Platteville  
[landonk@lancastersd.k12.wi.us](mailto:landonk@lancastersd.k12.wi.us)

Dr. Jodean E. Grunow  
Department of Mathematics/Adjunct, School  
of Education  
(608) 342-1009  
[grunowj@uwplatt.edu](mailto:grunowj@uwplatt.edu)

APPENDIX E

Table 4.2. Student Graphing CER scores over the course of the 2017-2018 school year. CER scores are shown in the order that they were given.

| CER/Student | Greenhouse Effect | Yeast | Organelle | Osmosis | Mitosis | Amino Acids | Genotypes | Evolution | Photosynthesis /Cell Respiration |
|-------------|-------------------|-------|-----------|---------|---------|-------------|-----------|-----------|----------------------------------|
| 1           | 8.5               | 6     | 7.5       | 9       | 9.5     | 9           | 10        | 10        | 8.5                              |
| 2           | 7                 | 9     | 10        | 9       | 9       | 9           | 8.5       | 9         | 8.5                              |
| 3           | 9                 | 10    | 5.5       | 9       | 8.5     | 6.5         | 10        | 9         | 8.5                              |
| 4           | 10                | 5     | 9         | 9       | 8.5     | 10          | 10        | 10        | 9.5                              |
| 5           | 9                 | 8.5   | 8.5       | 9       | 7.5     | 6           | 8         | 9         |                                  |
| 6           | 7                 | 9     | 8.5       | 7       | 7.5     | 6           | 8         | 8.5       | 6                                |
| 7           | 9                 | 9.5   | 8         | 8.5     | 9.5     | 8           | 9         | 10        | 7.5                              |
| 8           | 8.5               | 8.5   | 9         | 9.5     | 10      | 8           | 9         | 9         | 9.5                              |
| 9           | 8                 | 8     | 9         | 7.5     | 8       | 9           | 8.5       | 10        | 9.5                              |
| 10          | 9.5               | 9     | 10        | 10      | 10      | 9           | 9         | 9.5       | 10                               |
| 11          | 10                | 8     | 8.5       | 10      | 10      | 9.5         | 9         | 10        | 9.5                              |
| 12          | 9                 | 10    | 10        | 9       | 9       | 9           | 9         | 10        | 9.5                              |
| 13          | 9.5               | 8     | 9         | 8       | 8.5     | 9           | 8.5       | 8         | 9                                |
| 14          | 9                 | 8     | 7.5       | 9       | 9       | 9           | 10        | 9         | 9                                |
| 15          | 8                 | 5     | 8.5       | 9       | 9       | 9           | 8         | 9.5       | 7                                |
| 16          | 9.5               | 9     | 10        | 10      | 8       | 10          | 9         | 10        | 9                                |
| 17          | 9                 | 5     | 9         | 9       | 10      | 8           | 10        | 10        | 10                               |
| 18          | 10                | 10    | 9.5       | 10      | 10      | 9.5         | 10        | 9.5       | 9.5                              |
| 19          | 9                 | 7.5   | 9.5       | 6       | 10      | 8           | 9         | 10        | 7.5                              |
| 20          | 8                 | 7     | 7.5       | 4.5     | 8       | 6           | 8         | 9         | 5                                |
| 21          | 10                | 5.5   | 8.5       | 9       | 8.5     | 9.5         | 8.5       | 10        | 8                                |
| 22          | 8                 | 1.5   | 7         | 8.5     | 5       | 8.5         | 7         | 8         | 8                                |
| 23          | 8                 | 9.5   | 9         | 9       | 9       | 9           | 9         | 8         | 7.5                              |
| 24          | 8                 | 8.5   | 5.5       | 9       | 9       | 7           | 10        | 10        | 7.5                              |
| 25          | 9                 | 9     | 8         | 8       | 5       | 9           | 9         | 7.5       | 7                                |

APPENDIX F  
GRAPHING CER SYNOPSIS

Over the course of the 2017-2018 school year, there were 9 graphing CERs given to General Biology students at Lancaster High School. These graphing CER assessments were created by Danielle (Balistreri) Carlson, a Biology Teacher at Fennimore High School. Each assessment involves students either reading or creating a graph, and then writing an evidence-based explanation that answers a question. Below is a brief synopsis of the nine graphing CERs that were used in this study.

- Greenhouse Gas Effect- line graph
- Cell Respiration and Yeast Lab- bar graph
- Cells and Organelles- double bar graph
- Osmosis- line graph
- Cancer and Mitosis- double bar graph
- Amino Acids- double bar graph
- Genotypes and Expected Values/Punnett Squares- bar
- Evolution and Common Ancestry- bar
- Photosynthesis and Cell Respiration- line