CORRELATION OF CLAIM, EVIDENCE, AND REASONING AS A WRITING FRAMEWORK AND STUDENTS' SUCCESS RATES IN HIGH SCHOOL SCIENCE DISTRICT STANDARDIZED TESTS

by

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DISSERTATION

Presented to the Faculty of

The University of Houston-Clear Lake

In Partial Fulfillment

Of the Requirements

For the Degree

DOCTOR OF EDUCATION

in Curriculum and Instruction

THE UNIVERSITY OF HOUSTON-CLEAR LAKE

MAY, 2020

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Acknowledgements

This journey commenced as a joint venture with my remarkable children, who drives me to be the best father and person I can be. My oldest daughter started her four years of pharmacy school a year before I launched to my doctoral, program, and we quickly made a pact to graduate at the same time. I am also grateful to my son, who forced me to get my doctorate and my middle daughter, who is in second-year pre-med school now, helped develop my writing skills as an English Language Learner(ELL). My son graduated last year with Master of Accountancy degree. My youngest daughter is also a motivational and encouraging factor for me and kept periodically asking me, "Hey, Baba, how's your doctorate going?"

Also, I would like to thank my professors, who helped me believe that I have what it takes to complete this journey. As an ELL, my professors have helped, guided, coached, and encouraged me in writing this dissertation. Thank you to Dr. Brenda Weiser, my dissertation chair, for her unwavering support through this process. I also want to thank Dr. Michelle Peters for her endless time assisting me no matter the day or time. I am also thankful to Dr. Amy Orange for her continuous assistance in writing. Finally, thank you to Dr. Roberta D. Raymond for also serving on my committee. Her dedication to my success is greatly appreciated.

Lastly, I would be remiss if I did not thank my wife, Salma Abid. For three years, she provided me the love, support, and space needed to take on such a huge endeavor. She is my purpose in living.

ABSTRACT

CORRELATION OF CLAIM, EVIDENCE, AND REASONING AS A WRITING FRAMEWORK AND STUDENTS' SUCCESS RATES IN HIGH SCHOOL SCIENCE DISTRICT STANDARDIZED TESTS

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The purpose of this mixed-methods study was to examine the relationship between science writing and student science achievement and how teachers implement the writing strategy claim, evidence, and reasoning (CER) in their science classrooms. Writing is a critical tool for scientific literacy and student achievement. We must teach our students to write well. To accomplish the study, twenty-five science teachers from five high schools of a large urban school district located in southeast Texas participated in the study. The study provided significant results of students' achievement in science by the implantation of writing CER in science classrooms. Nine teachers from two schools where the researcher served, participated in the semi-structured interviews regarding the implementation of the CER writing framework in their science classrooms. Interviewees' responses revealed that teachers showed positive perceptions regarding CER, CER training, and its implementation in science classrooms.

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CHAPTER I:

INTRODUCTON

In the past few decades, developing literacy skills in students has become an international goal of schools' science education programs (Bybee, McCrae, & Laurie, 2009). Helping students become more skilled and confident writers has social implications beyond the classroom. Helping these young people learn to write clearly, coherently, and logically expands their access to higher education, gives them the skills needed to be successful at work, and increases the likelihood that they will actively participate as citizens of a literate society (Graham, Harris, & Hebert, 2011)

According to Yore (2006), writing is a critical tool for scientific literacy and inquiry. Many students struggle to communicate their ideas, support a claim with evidence, coordinate evidence and theory, or provide an adequate challenge to an alternative claim when they are asked to craft an argumentative writing in the context of science (Kelly, Regev, & Prothero, 2008; Kelly & Bazerman, 2003; Kelly & Takao, 2002). One of the instructional writing frameworks, which may address this problem is known as Claim, Evidence, and Reasoning (CER), which helps students write to support scientific explanations (Zembal-Saul, McNeill, & Hershberger, 2013).

Research Problem

Writing is the seed, the fruit, and pickles of our understanding (Tyler, 2009). In other words, writing is one of the life skills that students have to develop consistently. It is not just an option for our students to write well. It is a necessity because possessing excellent writing skills is an indicator of educational achievement and an essential requirement of the life-skills needed for participation in civic life and the global economy (Graham & Perin, 2007). According to Wise (2005), writing is one of the foundations of a successful public relations practitioner, and the ability to communicate messages clearly, and concisely is one of their differential skills. Bangert-Drowns, Hurley, and Wilkinson (2004) stated that many educators have touted writing as a means of enhancing learning. Writing serves multiple purposes in schools. One purpose is to teach students to communicate well through writing. A second purpose is to assess students' understanding of subject matter in both formative and summative form. A third purpose is to think and learn about the subject matter in disciplines such as science, history, mathematics, and English studies (Bangert-Drowns, Hurley, & Wilkinson, 2004; Klein & Boscolo, 2016).

Therefore, we must teach our students to write well. Teaching students to write well gives them powerful thinking, understanding, and learning tool (Moore, 1993). An argument writing can play a great role in teaching students to communicate well, understand, and think critically, helping them to learn the subject matter in a discipline such as science, (Klein, Haug, & Bildfell, 2018). A writing-to-learn (WTL) process-based study concluded that argument writing is one of the genres of writing that can help students think critically to understand social or scientific controversies and to address students' scientific misconceptions (Klein et al., 2018). Additionally, the new Common Core Standards (CCS) requires students to write arguments to support claims with clear reasons and relevant evidence (Kuhn, Hemberger, & Khait, 2017). Also, argument writing is a communication skill that is required by many state or national curricula (Klein et al., 2018).

The National Assessment of Educational Progress (NAEP) writing assessment found that only 24% of students in 8^{th} and 12^{th} grades nationwide were proficient in writing. Fifty-four percent of eighth-graders and 52% of 12^{th} graders performed at the basic level. Only 3% of 8^{th} and 12^{th} graders performed at the advanced level in writing (NRC, 2011). Furthermore, NAEP science assessment requires students to use writing to predict, describe, explain, and draw conclusions about various science topics (National Center of Education Statistics [NCES], 2012). Additionally, middle and high school students are not only required to meet general reading and writing competencies but also to master literacy skills and strategies to unlock and convey content knowledge within a given discipline, such as science (National Research Council, 2012). For example, at the secondary school level, a sample item in a NAEP test asked students to draw a conclusion from a given data table and construct a written response explaining their answer; only 15% of respondents provided a complete solution (NCES, 2012). Additionally, Gopee and Deane (2013) stated that students struggle as academic writers if they do not receive education on appropriate and effective academic writing through institutional provisions.

One way to help address the issues mentioned above, like the low performance of secondary science students on the nationwide writing test, struggling in drawing conclusion-based writing, and academic writing is to develop instructional models or a framework that teachers can use to help students develop science-specific argumentative writing skills and learn about the core ideas of science at the same time (Sampson, Enderle, Grooms, & Witte, 2013). One instructional writing framework which may address this problem is known as Claim, Evidence, and Reasoning (CER). It is argumentative writing, which helps students write to support scientific explanations (Zembal-Saul et al., 2013). According to McNeil and Krajcik (2008) a *claim* is a statement or answer to a question or problem about a concept. The *evidence* statements support the student's claim using scientific data. The *reasoning* statements *create* links between claim and evidence and show why the data quantify as evidences to support a conclusion. Incorporating this CER writing framework for a scientific explanation into curriculum materials, teacher instructional strategies, and assessments enhance students' conceptual understanding and improves their thinking and communicating skills in science by carefully analyzing evidence and backing up their claims (McNeill & Krajcik, 2011).

Krajcik and McNeil (2008) state that teachers should discuss with students that only providing a claim is not as persuasive by itself, but by providing evidence and reasoning, a claim generates a more compelling argument for why it is correct. Additionally, students gain an understanding of constructing scientific explanations when they see examples of well-written explanations. Students must not only learn the rules of writing a scientific reason but also see what appropriate writing looks like when it is done effectively (Krajcik & McNeil, 2007). Giving students opportunities to write reports encourages learning and leads to informative response discussions (Krajcik & McNeil, 2007). Therefore, teachers need to help students during class by promoting discussions, prompting students to make a claim, and providing an explanation of that claim by offering evidence and reasoning to support it (Krajcik & McNeil 2005).

According to Kelly and Bazerman (2003), studies in science education have provided evidence that supports the importance of student writing in order to understand and use scientific concepts, as well as learning to participate in science. Another study conducted by Zohar and Nemet (2002), reported that writing helps students learn science concepts in a constructivist approach. According to Xu and Shi (2018), a constructivist approach advocates student-centered learning under the guidance of teachers where students build their conceptual understanding through investigation, experience, and inquiry, especially in science. The results of the study found that student content knowledge increased when they created, supported, and evaluated claim statements (Zohar & Nemet, 2002).

Significance of the Study

One of the most important reasons students should write in science is to cultivate conceptual understanding. Writing in science can be used to evaluate knowledge and skills, draw on prior knowledge for new investigations, facilitate new learning, strengthen and evaluate ideas, and articulate and broaden comprehension (Abell, 2006). When educational researchers, administrators, and teachers view writing in science as a method to engage students in serious writing practices, they move beyond a simple approach to science to active work with scientific evidence, knowledge and concepts, and thereby learn social disciplinary standards and practices (Kelly & Bazerman, 2003). This study examines the correlation between writing in science and student achievement in their corresponding subject (biology, chemistry, or physics). Therefore, CER may be a writing framework that can be used in science to improve students' conceptual understanding and critical thinking.

Research Purpose and Questions

The purpose of this study was to examine the relationship between science writing and student science achievement and how science teachers implement the CER literacy writing framework in their science classrooms. The study addressed the following research questions:

R1. Is there a relationship between students' Biology writing CER scores and their achievement on the Biology district CBA?

R2. Is there a relationship between students' Physics writing CER scores and their achievement on the Physics district CBA?

R3. Is there a relationship between students' Chemistry writing CER scores and their achievement on the Chemistry district CBA?

R4. How do science teachers implement the literacy CER writing framework in their science classrooms?

R5. What are teacher's perceptions of the obstacles to the implementation of CER in their classrooms?

Definitions of Key Terms

Important terms for this research are listed below:

Claim: An "assertion or conclusion that addresses the original question or problem about a phenomenon." (Krajcik & McNeil, 2008, p. 123).

Evidence: " The evidence supports the student's claim using scientific data." (Krajcik & McNeil, 2008, p. 123).

No Child Left Behind – Federal legislation aimed at closing the achievement gap in achievement scores on academic assessments for minority students and students of poverty (USDE, 2002). The revised Act (Capps, Fix, Murray, Ost, Passel, & Herwantoro, 2005) stated that federal law holds schools accountable for the academic performance of limited English-speaking children and other groups that include many children of immigrants.

Reasoning: The ability to build a logical argument about the relationship between the claim and evidence, by showing how the connections follow logically from scientific principles (Krajcik & McNeil, 2007)

Student achievement: A measure of growth of knowledge in a specific content area. This growth can be measured through either standardized or non-standardized measures (Johnson & Hull, 2014).

Writing: The conceptualization of "literacy events" or "occasions in which written language is integral to the nature of participants' interactions and their interpretive processes and strategies" (Heath, 1982, p. 50).

Conclusion

The purpose of this study was to examine the relationship between science writing and student science achievement and how science teachers implement the CER literacy writing framework in their science classrooms. This chapter provides an overview of the research problem, significance of study, research purpose and questions, and the definitions of key terms. Next, chapter two, provides a literature review of this study.

CHAPTER II:

REVIEW OF LITERATURE

Schools and districts across the nation continuously implement instructional strategies aimed to improve student achievement. No Child Left Behind (NCLB) (2002) developed legislation aimed at closing the achievement gap in academic assessments for minority students and students of poverty (U.S. Department of Education [USDE], 2002). This legislation holds schools and districts in the U.S. responsible for federal guidelines in student performance (USDE, 2003). This legislation has increased accountability, which, when coupled with changing demographics, has pushed teachers to modify their practices in search of high-yield, research-based instructional strategies, especially literacy strategies in science that meet the needs of all learners. This study will contribute to previous studies related to literacy strategies in science such as writing implementation in science and student achievement.

The purpose of this study was to examine the relationship between science writing and student science achievement and how the teachers implement the CER writing framework CER in their biology, chemistry, and physics classrooms. The areas of literature relevant to this study include: (a) science writing, (b) science literacy and student achievement, (c) writing to learn and student achievement, (d) science-specific argumentative writing and student achievement, (e) the CER writing framework and students using Evidence and Reasoning, (f) the CER writing framework and student achievement, and (g) teacher training and student achievement.

Science Writing

Turner and Broemmel (2006) found that science writing serves two purposes. First, it increases scientific understanding and engages students in activities that are useful in the science assessment process. Second, it provides opportunities that connect students and their personal experiences with the content writing assignments and requires students to analyze the subject material intensely.

In well-planned science writing assignments, three critical attributes help make the writing assignment intelligible, valuable, and practical. These vital attributes are: (a) to provide authentic purposes for writing; (b) to motivate students to want to write and participate in science, and (c) to plan and structure both their writing and science activities (Turner & Broemmel, 2006).

Writing in science can be used to evaluate knowledge and skills, draw on prior knowledge or experience for new investigations, facilitate new learning, strengthen and assess ideas, and articulate and broaden comprehension (Abell, 2006). Therefore, when using writing in science, teachers can assess the students' levels of understanding of the specific concept via the students' demonstration of content knowledge through their writing, which benefits students developing conceptual understanding of science (Choi, 2010; Prain & Hand, 1996; Kelly & Bazerman, 2003; Keys, 2000). In other words, according to Miller and Calfee (2004), the use of science in writing makes thinking visible. Many studies have analyzed the role of writing in the learning process, demonstrating that writing, in conjunction with other activities such as reading and hands-on experiences, contributes to greater critical thinking, thoughtful consideration of ideas, and better concept learning (Miller & Calfee, 2004). For science writing and student achievement, students need opportunities to make claims based on available evidence and then use science concepts to justify why the evidence supports the claim (Novak & Treagust, 2018). After viewing the purpose of science writing, it is crucial to determine the relationship between science literacy and student achievement.

Science Literacy and Student Achievement

Yore and Treagust (2006) reported that science literacy is associated with the learning models, discourse, reading, and writing and their underlying pedagogical assumptions. Shaw, Lyon, Stoddart, Mosqueda and Menon (2014) conducted a study to determine the relationship between science literacy (focusing on science concepts, writing, and vocabulary) and student achievement. The study examined whether there was a relationship between the integration of science language and literacy practices and the improvement of English Language Learners' (ELLs) achievement in science concepts, writing, and vocabulary. Students from grades 3 to 6 (N = 191) were required to take a pre- and post-assessment designed by the Effective Science Teaching for English Language Learners (ESTELL) project. The assessment was composed of items from the Soil Habitats summative assessment packet (Lawrence Hall of Science, Dorph, Goldstein, Lee, Lepori, Schneider, & Venkatesan, 2007), administered by nine first-year teachers (FYTs) who taught a standard science unit under the ESTELL project.

This project focused on preparing pre-service teachers to integrate teaching science with English language and literacy, especially for ELLs. The framework of the ESTELL project was based on research exploring teaching practices that promote science, writing, and literacy learning and it include: (a) the USDE funded Center for Research on Education Diversity and Excellence (CREDE) project (Doherty & Penal, 2004) and (b) a set of NSF funded science-language-literacy integration project (Cervetti, 2007).

Findings showed that students demonstrated achievement gains from pre to post-test. The average composite score was 35.07 out of a possible 62.00 (SD = 11.82), while the post-test score was 41.26 (SD = 9.49), yielding an average gain of 6.18 (SD = 7.55). The findings showed a statistically significant relationship between the integration of science language and literacy practices and the improvement of ELLs' achievement scores in science. Since writing is one of the essential components of literacy practices, the literature of writing-to-learn and student achievement is discussed next.

Writing to Learn and Student Achievement

Nelson (2001) reported that the writing-to-learn (WTL) theory is supported by the constructivist approach (Vygotsky, 1978), related to humans developing knowledge and communication through writing. Writers' knowledge of the subject matter of an academic discipline improves, and they benefit from learning the ways of writing associated with the discipline. Newell (2006) described that writing in schools, plays a role in the intellectual development and academic life of all students, and in the practices of all teachers, how writing functions within curricular conversations, as well as the social life of classrooms, seems particularly important. Additionally, writing in the curriculum should have assessments based on what is valued in the disciplines. Therefore, writing could be a means for both learning and assessment.

Bangert-Drowns, et al. (2004) found that writing serves multiple purposes in our classrooms. One purpose is to teach students to communicate well through writing. A second purpose is to assess students' understanding of subject matter, both formative and summative. A third purpose is for students to think and learn about the subject matter in disciplines such as science, history, mathematics, and English studies. The study also concluded that there are two kinds of evidence that support the WTL theory. The first correlational research showed that students who apply cognitive and metacognitive strategies during writing learn more than students who do not. Second, the experimental study found that prompting students to use cognitive and metacognitive strategies in their writing significantly increases their learning (Glogger, Schownke, Holzapfel, Nuckles, & Renkle, 2012).

Another scientific experimental study regarding writing concluded that equipping students with clear, specific, and reasonably challenging goals for their writing tasks, improves the quality of what they write (Graham & Harris, 2013). For example, when students are provided an environment where they work collaboratively to plan, draft, revise, or edit a composition, the quality of their writing improves (Graham, MacArthur, & Fitzgerald, 2013). This practice encourages students to apply discussion or deliberation in a collaborative environment that leads to argument writing, which has been proven to be a useful tool for learning across a variety of subjects (Felton, Garcia-Mila, & Gilabert 2009; Lewis & Ferretti, 2011; Zohra and Nemet, 2002). According to Felton et al. (2009), based on the social constructivist perspective (Vygotsky, 1978), argumentative dialogue, before allowing students to write, provides an ideal context for knowledge building. When students explore their diverging views on a topic, they engage in a host of activities that socially scaffold knowledge construction by producing questions, statements, and objections that prompt each other to clarify claims, provide evidence, reasoning, and rebut counterclaims (Felton & Kuhn, 2001).

Graham, MacArthur, and Fitzgerald (2013) discussed the writing activities, which contributed to learning at the elementary and secondary school levels. The five writing activities were: (a) journal writing, (b) summary and discourse synthesis, (c) argumentation, (d) the science-writing heuristic (SWH), and (e) multimodal composing. Teachers can incorporate these writing activities into content-area subjects and optimize its effects on learning. By comparing these writing activities, the study found that the most effective method of supporting students was to provide them with a series of rhetorical sub-goal prompts. The prompts guided them through the different elements of argumentative writing, such as claim, evidence, reasoning, and rebuttal (Klein et al., 2016). Therefore, the next section will explore the relationship between science-specific argumentative writing and student achievement.

Science-Specific Argumentative Writing and Student Achievement

Sampson, Enderle, Grooms, and Witte (2013) conducted a quantitative study to examine the relationship between students' understanding of core ideas and their science-specific argumentative writing skills. For this study, they used the Argument-Driven Inquiry (ADI) instructional model for their design. The ADI model is student-centered and involves argumentative writing based on laboratory instruction. During this study of one school year, students participated in a series of science experiments or labs based on the ADI instructional model. The study collected and analyzed data using a set of paired-samples t-tests to determine whether the students' scores on the content assessments changed in each course (life science, physical science, biology or chemistry) at the end of the first and second semesters of instruction. The study concluded that the students' science-specific argumentative writing skills and their understanding of core scientific ideas improved throughout the intervention using ADI instructional model.

Another study conducted by Huerta, and Spies (2016) suggested that one practical way for educators to simultaneously build students' conceptual understanding and academic language in science is to integrate science inquiry with writing. As one of their teaching methods, teachers used the 5E Model (Engage, Explore, Explain, Elaborate and Evaluate) (Bybee et al., 2006) as an inquiry model, which has been used successfully in general and in intervention studies with English Language Learners (ELLs) in the science classroom (Tong et al., 2014). In this elementary-level study, they used notebooks as a writing tool. They concluded that by integrating literacy activities such as writing in science using journals and inquiry, the lesson model improved students' conceptual understanding and academic language.

In summary, both the studies: (a) the ADI instruction model and (b) the 5E Inquiry lesson Model interventions concluded that by integrating literacy activities such as argumentative writing based on laboratory investigation, the science inquiry model using journals improved students' achievement in science. The next section will discuss the use of CER writing framework and to help students improve the frequency of using evidence and reasoning in justifying their claims.

CER Writing Framework and Students Using Evidence and Reasoning

Loch (2017) conducted a study that used the CER writing framework as argumentative writing in science. The importance of argumentative writing in science is reflected in the recommendations of professional organizations such as the National Science Teachers Association (NSTA) and widely adopted by the next generation science standards (NGSS) (Bybee, 2014). The problem of the study was that students struggled with using evidence and reasoning when making claims while using argumentative writing during lab investigation. The study was performed with ninth-grade biology students over the course of six weeks. The researcher introduced the claim, evidence, reasoning (CER) framework to their students, helping organize and develop scientific arguments in science lab conclusions. The purpose of the study was to use the CER framework to develop explanatory and argumentative writing skills among students during scientific investigations.

Loch (2017) included both pre- and post-survey and writing assessments in their study before and after the introduction to the CER framework in this research. The purpose of the study was to find out whether the CER writing framework would increase the number of times students used evidence and reasoning when making their claims. The findings of the study indicated that the use of the CER writing framework increased student's number of times using evidence and reasoning in their claims. However, still, students struggled in making connections to the science concept with evidence and reasoning to justify their claim. The next section will examine the relationship between a literacy CER framework for writing explanations and student achievement.

CER Writing Framework and Student Achievement

It is critical to analyze whether the same pattern is repeated when examining the relationship between using the CER writing framework and student achievement at the high school level. For science writing and student achievement, students need opportunities to make claims based on available evidence and then use science concepts to justify why the evidence supports the claim (Novak & Treagust, 2018). The literacy integration method that can improve students' conceptual understanding is a CER writing framework. CER is a process of teaching students to use claim, evidence, and reasoning to support scientific explanations (Zembal-Saul, et al., 2013). McNeill and Krajcik (2008) conducted a study in which they developed a writing instructional framework and broke down scientific explanation into three components: claim, evidence, and reasoning (CER). The claim is a statement that answers the question that the students are asked. It is a comparatively comfortable part for students to respond to a question or a problem. According to McNeil and Krajcik (2008), the evidence is defined as the scientific data that supports the claim. It can either come from the investigations that the students complete or second-hand sources such as articles, content readings, newspapers, or digital resources. The evidence that students collected should be both appropriate and sufficient. The reasoning is defined as the validation or justification based on the scientific principles that students use to verify whether their evidence supports their claim. A recent study concluded that the use of the CER writing framework improves students' ability to make a claim and use evidence within conclusion writing. However, students still struggled with the reasoning section (Traut, 2017).

In an attempt to analyze students' CER framework for writing explanations in science, McNeill and Krajcik's (2006) team developed a general or base explanation rubric for scoring their scientific explanation of the written assignment (see Appendix A). The rubric is designed to align with the three components of the CER framework of a scientific explanation. The rubric also offered guidance to think about different levels of student achievement for each component. For example, the base rubric could be adapted to create a specific rubric for a particular task, or the base rubric could be used across content areas and time to develop an understanding of how students' abilities to engage in scientific explanations develop (McNeil & Krajcik, 2008). The study concluded that engaging students in writing a scientific explanation, using a content-specific rubric benefits in terms of both learning and assessment because it touches on the science, on writing skills, and on critical thinking (McNeil & Krajcik, 2008).

Generally, a scientist poses a question about the natural world and provides evidence-based explanations. These scientific explanations include making a claim and then using evidence and scientific reasoning to support the stated claim. Another study at the elementary level conducted by Jackson, Durham, Dowell, Sockel, and Boynton (2016) used the same concept to consider the connection between scientific claims and evidence, describe what counts as evidence, and explore the role of scientific explanation. The researchers shared the example of the 1st -grade teacher who used the CER writing framework with sentence stems. Examples of sentence stems were: "I claim ____________________ (what the student knows/answer to a question or solution to a problem), because ________ (evidence/ data) _________________, and I know I am right because ___________________ (scientific concept, rule, or principle) __________________". The use of sentence stems can add a scientific rationale that links scientific evidence to a claim statement. Some teachers created CER sentence stem anchor charts to scaffold student writing. The researchers concluded that CER sentence stems help students become familiar with and comfortable using the scientific discourse they will encounter when speaking, reading, or writing about science. They also concluded that the CER writing framework supports creating and using scientific explanations in elementary school classrooms. It provides a template that teachers and students may use to structure science talk and science writing.

As portrayed by the above studies, the CER writing framework helps students understand the science concepts deeply, and ultimately it improves student achievement. The next session will examine one of the factors that influence writing in science and student achievement.

Teacher Training and Student Achievement

When examining the factors that are influencing writing in science and student achievement, teacher training is considered essential. Many studies have demonstrated that effective teachers have a high correlation with student success (Brown, Jones, LaRusso, & Aber, 2010; Hamel & Merz, 2005; Marchant, 2004). Ball and Forzani, Darling-Hammond, and Hinchey (2010) reported that high-quality instruction is not possible without high-quality teachers. To improve students' achievement at levels demanded by the high standards expected by states and districts, teachers will have to help them reach these levels. Therefore, students' performance depends on the qualifications and effectiveness of teachers. As a result, professional teacher training is a significant focus of districts' systemic initiatives (Vangrieken, Meredith, Packer, & Kyndt, 2017). Ball and Forzani (2010) suggested the criteria necessary to develop an effective teacher and cite the importance of content knowledge and opportunities for practice as critical elements. Also, Ball and Forzani (2010) include the ability to assess student learning and the ability to interpret data to inform classroom instruction as characteristics of effective teachers. Teaching is a continuous professional activity rather than something that can be mastered once through achievement of a controlled set of competencies (Asghar, 2014).

This study finds a link between professional development and improved teaching contingent on structural features such as form, duration, and participation (Birman, Desimone, & Porter, 2000; Desimone, Garet, Birman, Porter, & Yoon, 2003).

Effectiveness also hinges on process features such as content focus, active learning, and coherence. These three process features emerged from survey responses of teachers (N = 1,027) participating in the Eisenhower Professional Development Program (EPDP) (Garet, Porter, Desimone, Birman, & Yoon, 2001). The federal government funded the program to improve teachers' knowledge and skills, primarily in mathematics and science classrooms. The study included 16 case studies and an extensive survey of the participants. The survey results showed that qualities of professional development activities impact classroom practice and student achievement. The study does not include objective measures of actual impact. However, the study provides insights into the characteristics of training most likely to engage adult learners.

Summary of Findings

According to NRC (1996), the U.S. National Science Education Standards stated that science literacy is a necessity for everyone. Science writing is a critical tool for science literacy. Research on science writing conducted by Turner and Broemmel (2006) research indicated that science writing serves two purposes. First, it increases scientific understanding and engages students in activities that are useful in the science assessment process. Second, it provides opportunities that connect students and their personal experiences with the content writing assignments and requires students to analyze the subject material intensely.

Research related to science literacy and student achievement, conducted by Shaw, Lyon, Stoddart, Mosqueda, and Menon (2014), found a statistically significant relationship between the integration of science language and literacy practices and the improvement of students' achievement scores in science especially ELLs'. Huerta and Spies (2016) conducted a similar study, concluding that integrating literacy activities such as writing in science using journals and inquiry-lesson model improved students' conceptual understanding and academic language.

A WTL process-based study showed that writing in schools plays a role in the intellectual development and academic life of all learners (Newell, 2006). The study also showed that writing serves multiple purposes in our classrooms. Writing helps students to communicate well, understand the subject matter, and helps them think cognitively and metacognitively to understand and learn about the concepts in a discipline such as science, mathematics, history, and English (Bangert-Drowns, et al., 2004). In a similar study looking for the best practices in writing Klein, Haug, and Arcon (2016) found that argumentative writing activity is the most effective activity among other writing activities such as journal writing, summary writing, or synthesis-discourse writing.

Sampson, et al. (2013) researched science-specific argumentative writing and student achievement. Their study concluded that the students' science-specific argumentative writing skills and their understanding of core scientific ideas improved throughout the implementation of the Argument-Driven Inquiry (ADI) instructional model, implemented at a high school level.

Loch (2017) conducted a study that used the CER writing framework as argumentative writing in science. The purpose of the study was to find out whether the CER writing framework would increase the number of times students used evidence and reasoning when making their claims. The study concluded that the use of the CER writing framework increased student's number of times using evidence and reasoning in their claims.

McNeill and Krajcik (2008) conducted a research related to the CER writing framework and student achievement. In this study, they developed a writing instructional framework and broke down the scientific explanation into three components: claim, evidence, and reasoning (CER). In an attempt to analyze students' writing assignment in science, McNeill and Krajcik's team developed a base explanation rubric for scoring their scientific explanation of the written assignments. The study concluded that using rubrics allows teachers to determine students' strengths and weaknesses, which can inform teachers whether to modify or re-design their future instruction.

Another study related to teacher training and student achievement was conducted by Garet, Porter, Desimone, Birman, and Yoon (2001). In this study, teachers (N = 1,027) participated in a survey designed by the Eisenhower Professional Development Program (EPDP). The survey results showed that qualities of professional development activities impact classroom practice and student achievement.

Theoretical Framework

This study used the constructivist theory of learning, tied to science writing, as a theoretical framework. Piaget and Vygotsky are the pioneer theorists of constructivism. According to Kalina & Powell (2009), there are two significant types of constructivism in the classroom: (1) Cognitive or individual constructivism depending on Piaget's theory, where ideas are constructed in individuals through a personal process, and (2) Social constructivism depending on Vygotsky's theory (1978), where ideas are constructed through interaction with the teacher and other students. Both cognitive and social constructivist teaching strategies are useful in the classroom. Teachers need to understand these theories, as well as, know how to incorporate constructivist teaching methods, strategies tools and practices to develop an effective learning environment (Kalina, & Powell, 2009). To use constructivism effectively, teachers have to know where the student is at a given learning point of a subject and help the student to create personal meaning when new information is exposed to them. In other words, the constructivist learning theory advocates the student-centered learning under the guidance of teachers (Xu & Shi, 2018).

The constructivism theory was developed by Jean Piaget (1896-1980). The theory provides a framework for understanding children's ways of doing and thinking at different developmental levels. According to Ackermann (2001), Piaget's constructivism offers a window into what children are interested in and can achieve at various stages of their development. The social constructivist theory was developed by Vygotsky (1978). This theory states that a child's development is a complex dialectical process. It is a process between the child and the social environment. The social environment supports the child's development so that what a child can do in collaboration now, they can do independently later (Vygotsky, 1978). The Constructivist view of learning says that learners are actively involved in building their own knowledge. This process is a way of scaffolding new information on what is already known (Reisetter & Fager, 1995). The constructivism involves both the assimilation of new knowledge and the accommodation of that knowledge with existing knowledge structures. The goal for teaching and learning in a constructivist framework is for the learner to play an active role in assimilating new knowledge onto and into his or their existing mental framework (Barrett & Long, 2012). Students are well engaged in their learning process when the constructivist theory of learning is implemented in the classroom. Constructivism implies the view that science is not independent of its object but construct it (Delantly, 1997). Therefore, this theoretical framework supports science writing by constructing a scientific explanation. Using the constructivist approach (Vygotsky,1978), when students write in science, they construct, organize their thoughts and think about the laboratory process experienced, then produce written text to explain the laboratory process and how the laboratory experiment connects to science concepts and process skills under the guidance of a teacher.

Writing allows students to express their full understanding of the objectives presented in the laboratory experiment. For example, when students construct explanations based on laboratory investigation, they actively use the scientific principles to explain the phenomena that develops a deeper understanding of the content (Zohar & Nemet, 2002). Constructing explanations may also help change students' views of science. Often, students see science as a static set of facts that they have to memorize. They do not understand that scientists socially construct scientific ideas and that this science knowledge can change over time (Bell & Linn 2000). For example, when a scientist constructs their theory or concept, they communicate and verify their findings with other scientists regarding their research that may change over time.

As reported by Krajcik and McNeil (2005), secondary school students find constructing their scientific explanations particularly challenging. Therefore, it is essential for teachers to reinforce the CER framework, especially regarding when, how, and why it can be used. To do so, teachers can explicitly explain each part of CER to help students understand the importance of each component. Not only must students understand what a CER framework explanation is, they must also understand how the CER framework can construct a scientific explanation. Additionally, students need to witness examples of a well-written explanation in science. For example, in one study, Krajcik and McNeil (2008) worked with 7^{th} grade teachers and asked students to write a scientific explanation that states whether any of the given liquids were the same substance. Students had to construct their scientific explanation based on the data such as mass, density, color and boiling points of each liquid given in a data table. Students examined the data table and claimed that liquid 1 and liquid 4 were the same because, their density, color, and melting points(useful data) were the same whereas the masses of the liquids (not useful data) were not the property to consider in this explanation. In this example, students constructed their claim based on the data (evidence) and then they used the scientific principle that if two liquids have identical color, density, and melting points, regardless of their masses then the substances are the same (reasoning). This was an explicit example of how the use of CER writing framework leads a well-written scientific explanation.

Many times, students wonder why they must learn a scientific concept and how it will be beneficial to later success in life, this emphasize why it is so important to discuss the logic of scientific explanations. Krajcik and McNeil (2005) state that teachers should confer with students that providing a claim is not sufficient to persuade on its own. However, if evidence and reasoning are well presented (as described in the above example), then a claim can form a more persuasive argument for why that stated claim is correct. It is necessary for teachers to model how to construct scientific explanations using the CER framework by discussing and writing with the students (Krajcik & McNeil 2005). Additionally, the students need to witness examples of what a well-written explanation is and be able to analyze what writing is appropriate and effective. Moreover, giving students the chance to write in science encourages learning and leads to informative response discussions (Krajcik, & McNeil, 2007). Also, teachers should encourage students to participate in class by promoting such discussions, should prompt students to establish claims, and then support their stated claim by offering evidence and reasoning(Krajcik and McNeil, 2008).

Conclusion

This chapter presented a review of relevant literature relating to the purpose of this study and examine the relationship between science writing and student science achievement, and how science teachers implement the CER literacy writing framework in their biology, chemistry, and physics classrooms. Critical details discussed include scientific literacy, writing in science, science literacy and student achievement, writing -to-learn and student achievement, science-specific argumentative writing and student achievement, CER writing framework and students using evidence and reasoning, CER writing framework and student achievement, teacher training and student achievement, and the theoretical framework.

In the next chapter, an overview of the research problem, the operationalization of theoretical constructs, research purpose, question, research design, population, sampling selection, instrumentation to be used, data collection procedure, data analysis, privacy and ethical considerations, and the limitations of research design will be introduced. The methodology of this study is discussed in chapter three.

CHAPTER III:

METHODOLOGY

The purpose of this study was to examine the relationship between science writing and student science achievement and how teachers implement the writing strategy claim, evidence, and reasoning (CER) in their science classrooms. This mixed methods study collected data from a purposeful sample of high school students and their respective teachers within a large urban school district located in southeast Texas. Quantitative data, collected from the claim, evidence, and reasoning (CERs) writing framework and the Curriculum-Based Assessments (CBAs), were analyzed using Pearson's product moment correlations (r). Data from the teacher interview responses were analyzed by an inductive coding process using NVivo to look for themes that may emerge. This chapter presents an overview of the research problem, operationalization of theoretical constructs, research purpose and questions, research design, population and sampling selection, instrumentation to be used, data collection procedures, data analysis, privacy and ethical considerations, and the research design limitations of the study.

Overview of Research Problem

Writing is a critical tool for scientific literacy and inquiry (Yore & Treagust, 2006). The Science National Assessment of Education Progress (NAEP) requires students to use writing to predict, describe, explain, and draw conclusions about various science topics (NCES, 2012). Many students struggle to communicate their ideas, support a claim with evidence, coordinate evidence and theory, or provide an adequate challenge to an alternative claim when they are asked to craft an argumentative text in the context of science (Kelly et al., 2008; Kelly & Bazerman, 2003; Kelly & Takao, 2002). One instructional writing framework which may address this problem is known as writing CER framework, a process of teaching students writing to support scientific explanations

(Zembal-Saul, et al. , 2013). The CER writing framework is designed to serve as a template or a guide that teachers can use to create science laboratory experiences, promote the reading of scientific articles, scientific clips or videos, and science concept-based scenarios, etc. Providing students with opportunities to write scientific explanations as an implementation of scientific literacy by conducting investigations and using the CER writing framework allows them to become proficient science writers which promotes student science achievement.

Operationalization of Theoretical Constructs

This study consisted of two constructs: (a) scientific literacy and (b) student achievement. According to National Research Council (1996), "scientific literacy" can be described as the knowledge and understanding of scientific concepts and processes required for personal decision making, participation in civic and cultural affairs, and economic productivity. This construct will be measured by the CER writing scores. Student achievement is defined by how well students perform on the standardized test (Texas Education Agency, 2012). Student achievement will be measured using each participating teacher's biology, physics, or chemistry students' district CBA scores.

Research Purpose and Questions

The purpose of this study was to examine the relationship between science writing and student science achievement and how teachers implement the writing strategy claim, evidence, and reasoning (CER) in their science classrooms. The study addressed the following research questions:

R1. Is there a relationship between students' Biology writing CER scores and their achievement on the Biology district CBA?

Ha: There is a relationship between students' Biology writing CER scores and their achievement on the Biology CBA

R2. Is there a relationship between students' Physics writing CER scores and their achievement on the Physics district CBA?

Ha: There is a relationship between students' Physics writing CER scores and their achievement on the Physics CBA

R3. Is there a relationship between students' Chemistry writing CER scores and their achievement on the Chemistry district CBA?

Ha: There is a relationship between students' Chemistry writing CER scores and their achievement on the Chemistry CBA

R4. How do science teachers implement the CER literacy writing framework in their science classrooms?

R5. What are teacher's perceptions of the obstacles to the implementation of CER in their classrooms?

Research Design

For this study, the researcher used a sequential mixed methods design (QUAN → qual). This design consisted of two phases: first, a quantitative phase and second, a qualitative phase. The advantage of implementing this design is it allows for a more thorough and in-depth exploration of quantitative result by following up with a qualitative phase. The researcher collected data from a purposeful sample of high school 9-12 grade science students and their respective teachers within a large urban school district located in southeast Texas. Quantitative data, collected from the CER writing framework and the CBA were analyzed using Pearson's product moment correlations (r), The researcher also collected data from a purposeful sample of high school science teachers participating in a semi-structured interviews. Qualitative data collected from the selected teacher interviews were analyzed using an inductive coding process using NVivo. The qualitative data analysis examined science teachers' understanding of how they implement the CER literacy writing framework and what were the teachers' perceptions of the obstacles in the implementation of CER in their science classrooms.

Population and Sample

The population of this study consisted of two high schools of a large urban school district in the southeast portion of US. The school district consisted of eight early childhood centers, 160 elementary schools, 38 middle schools, 37 high schools, and 37 combined schools. The district employed over 11,500 teachers and has a student population over 209,000 students (49% female and 51% male). Of these students, 62% were Hispanic, 23% African American, 9% White, 4% Asian. The district has 80% Economically Disadvantaged, 65% At-risk, 14% ELL, and 8% Special Education students (TEA, 2018). Table 3.1 provided the student district data obtained from the 2018-2019 Texas Academic Performance Report.

Table 3.1

District Student Demographic Data

	Frequency (n)	Percentage (%)
Female	102,788	49.0
Male	106,983	51.0
African American	49,046	23.4
Hispanic	130,284	62.1
White	18,591	8.9
American Indian	352	0.2
Asian	8,783	4.2
Pacific Islander	124	0.1
Two or More Races	2,592	1.2
Economically Disadvantage	167,456	79.8
English Language Learners	28,642	13.7
At- Risk	136,849	65.2
Special Education	15,831	7.5

A purposeful sample of 25 high school biology, physics, or chemistry teachers and their respective students in the participating district were solicited to participate in this study. The two high schools within this study are comprehensive grade 9-12 campuses with student populations of 1,150 and 1,850, respectively. Each campus has only one principal, and most have four or five assistant principals, one dean of instruction, and three to five content specialists. Table 3.2 presents the district and the two high schools student enrollment data.

Table 3.2

Student Enrollment for High Schools

	District	School A	School B
Biology	6,102	301	238
Physics	3,577	323	161
Chemistry	4,519	279	268
Student Total (n)	14,198	903	667

The district selected is a large district located in the SE portion of the United States. The average enrollment of a typical high school of the district similar to School A and School B, students in Biology ranges from approximately 250 to 450; Physics ranges 150 to 425, and Chemistry ranges from 250 to 400. In the high schools across the district the average percentage of students per teacher is 27.3 % and the percentage of students per teacher ranges from 23.4% to 31.2%. School A has 48% female, 52% male, 38% African American, 60% Hispanic, 2% others, 76% Economically Disadvantage, 19% ELL, 66% At-Risk and, 12% Special Education (SPED). School B has 52% female, 48% male, 51% African American, 46% Hispanic, 2% others, 80% Economically Disadvantage, 13% ELL, 65% At-Risk, and 15% SPED. Table 3.3 presents the student demographics for the district broken down by the two participating campuses.

Table 3.3

Student Demographics of District and High Schools

	District (%)	A (%)	B (%)
Female	49.0	48.0	52.0
Male	51.0	52.0	48.0
African American	23.3	38.0	51.5
Hispanic	62.1	60.0	45.7
White	8.9	0.5	1.9
American Indian	0.2	0.3	0.1
Asian	4.2	0.6	0.4
Pacific Islander	0.1	0.5	0.4
Two or More Races	1.2	0.4	0.4
Economically Disadvantage	79.8	76.0	80.0
English Language Learners	13.7	18.7	13.1
At-Risk	65.2	66.3	64.5
Special Education	7.6	12.1	15.2

Participant Selection

Teachers who have attended a structured professional development training on writing CERs offered by the district Secondary Science Curriculum Department and whose students have taken CERs were invited to participate in the semi-structured interviews. Nine teachers participated in the interviews. The interviews were conducted on site face to face, or through telephone or via email, with the high school science content (biology, chemistry or physics) teachers from the two participating schools.

Instrumentation

Curriculum Based Assessment (CBA)

Student achievement were measured and analyzed by the district CBA data from the participating schools during one academic school year. The CBAs are developed by the district secondary science curriculum department using the district test bank questions following the district assessment protocol. Each CBA has two distinct purposes: (a) to measure individual student achievement by science conceptual understanding based on 10-12 multiple choice questions and (b) to assess individual student's understanding of science concepts by the integration of the CER writing framework based on one open-ended question response. More specifically, the CBAs assess students' knowledge and retention of science concepts learned in their corresponding biology, physics, and chemistry courses.

Each content (Biology, Chemistry, or Physics) CBA has two parts: (a) Part 1 contains 10-12 multiple-choice questions based on the content of Texas Education Knowledge and Skills (TEKS) and the district scope and sequence and (b) Part 2 contains one open-ended question based on science content specific laboratory experiences, scientific articles, scientific clips, videos, scenarios, etc. The CBA 1 is given in the middle of semester one, and CBA 2 is given in the middle of semester two of the school year. The results of the CBAs provide the instructor with insight into which science concepts students have a clear understanding and science concepts in which students do not have a clear understanding by analyzing students' CER and CBA scores.

Claim Evidence and Reasoning (CER) Rubric

In an attempt to analyze students' writing CERs in science, McNeill and Krajcik's (2006) team developed a general or base explanation rubric for scoring their scientific explanation of the written assignment (see Appendix D). This rubric can be used for different content and learning tasks (Harris, McNeill, Lizotte, Marx, & Krajcik, 2006; McNeill et al., 2006). The rubric is designed to align with the three components (CER) of a scientific explanation. The rubric also offered guidance to think about different levels of student achievement for each component. The base rubric could be adapted to create a specific rubric for a particular task. The study suggests using the base rubric across content areas and time to develop an understanding of how students' ability to engage in scientific explanations is developing (McNeil & Krajcik, 2008). The study concluded that engaging students in writing scientific explanation using content specific rubric benefits in terms of both learning and assessment because it touches on the science, on writing skills, and on critical thinking (McNeil & Krajcik, 2008).

The base rubric for scoring CER was developed by McNeill et al. (2006) and was used during the study of "Supporting Students' Construction of Scientific Explanation through Generic versus Context- Specific Written Scaffolds" (McNeill, & Krajcik, 2006). The purpose of the rubric was to score scientific explanations across different content and learning tasks. It included the three components of a scientific explanation (claim, evidence, and reasoning). It was standardized to decrease teacher bias by providing clear descriptions of each component and is based on a 3-point scale; three points for each section in the rubric: claim, evidence, and reasoning. Students scoring 2-points showed a clear understanding of the science content. Those scoring 1-point confirmed that they are still developing their understanding of the science content. And finally, students scoring 0-points showed that they do not understand the science concept (see Appendix D). It was recommended that the base rubric could be adapted or modified to create a specific rubric for a particular task. The specific rubric combines both the general structure of a scientific explanation with the appropriate science content for the particular task.

In this study, for scoring students' scientific literacy, the teachers will use the district modified CER rubric similar to McNeil and Krajcik (2006). The participating schools are using the modified CER rubric adapted from McNeill, and Krajcik (2008), NSTA, and SBAC Argumentative Writing Rubric for grades 6-11 (see Appendix E). The modified rubric is standardized to decrease teacher bias by providing clear descriptions of each component and is based on a 5-point scale. Students scoring 4-points will show a clear understanding of the science content; 3-points will show high-medium understanding of the science content. Those scoring 2-points will show a medium understanding of the science content. Those scoring 1-point will show low-medium understanding of science content, and those scoring 0-point will show no understanding of the science content.

Data Collection Procedures

Quantitative

Before data collection, the researcher obtained permission to conduct the study from the University of Houston-Clear Lake (UHCL) Committee for the Protection of Human Subjects (CPHS) and the participating school district's Institutional Review Board (IRB). Next, the researcher contacted the participating high schools' principals personally and provided information regarding the purpose of the study and the process of teachers' interview participation. The researcher solicited the names and e-mail addresses of all the participating teachers from the research and accountability department within the participating school district. The researcher personally contacted the participating teachers and obtained the Informed Consent form signed by the site teachers prior to their participation in the interview questionnaire of the study (see Appendix C).

The length of data collection time was one academic school year. For quantitative data collection, students of the participating teachers took the content specific CBA during one academic school year. Each district CBA included 10-12 multiple-choice questions and one open-ended question to answer using the CER writing framework. The teachers graded the CER utilizing the district modified CER rubric similar to the base explanation rubric used in the McNeil and Krajcik (2005) study (see Appendix A). Two weeks prior to each district CBA window, a blueprint of each CBA, based on Texas Essential Knowledge and Skills – TEKS (2015) by content were shared with the participating high school science teachers. Therefore, teachers were able to plan, teach and provide an opportunity to their students to write some practice sample CERs based on the TEKS listed in the blueprint. For advanced planning of CER samples, the district scope and sequence was released to teachers at the beginning of the school year.

Upon completion of the CBAs, quantitative data were generated from the district assessment data collection system "OnTrack." The researcher used the district CBA data to measures the students' ability to construct scientific explanations and see the correlation of students' CBA scores and the CER scores. All data will be secured in a password-protected folder on the researcher's computer and in the researcher's office within a locked file cabinet at all times. At the culmination of the study, the data will be maintained by the researcher for five years, which is the time required by CPHS and district guidelines. The researcher will destroy the contents of the file once the deadline expires.

Qualitative

Teacher perceptions of using CER as a writing framework for the literacy integration in science were examined by information gathered from the teacher interviews. The interview protocol was designed with overarching open-ended questions that focused on the major themes; teacher perceptions of using CER, training regarding implementing CER, using the CER rubric for grading, and, hindrances or obstacles in using CER writing framework in their classrooms. For qualitative data collection, the researcher e-mailed or personally shared with the site teachers the Interview Questionnaire on the prescribed form (see Appendix C). Teachers were given three options (a face to face interview, a phone interview or interview responses via e-mail) using the interview questionnaire. The duration of the oral interviews lasted from 20-25 minutes. Prior to conducting the interviews, a panel of experts in the field of qualitative research examined the interview protocol for alignment goals to support the validity of the study better. The researcher assigned code names to the participants' responses. The interview responses were analyzed using an inductive coding process in NVivo.

Data Analysis

Quantitative

The researcher used IBM SPSS statistics software to analyze the data. To address the research questions 1-3, a Pearson's product-moment correlation (r) was conducted to determine if there is a relationship between students' biology, physics, or chemistry writing CER scores and their achievement in the district content CBA scores and Biology EOC scores. All variables were continuous in measurement. The writing CERs and CBAs student achievement data were collected as a percent correct score for each student of the participating teachers in the study. The effect size was measured using the coefficient of determination (r^2) and a significance value of .05 was used for this study.

Qualitative

The data gathered from the teacher interviews were examined, analyzed, and coded for themes using NVivo, a qualitative software analysis program. The coding process began by recognizing in NVivo codes. After identifying the appreciate codes, emphasis was placed on the search for themes and patterns from the data (Coffee & Atkinson, 1996). The researcher used mixed emergent and prior codes to identify relevant information in the data. Once the themes were established, codes were again organized into subthemes and findings were recorded such as teacher's educational background and experiences, teachers' prior writing experiences during their collegiate level, teachers' perceptions regarding CER and CER training, etc.

Validity

The qualitative analysis process used triangulation of individual teacher response by campus to enhance the validity of the results. The data collected during the interviews were subject to member checking by having teacher participants review the transcripts to enhance the accuracy of the responses provided. The interview questions and results were peer-reviewed by experienced educators including district-level administrators and professors to ensure the questions solicited the information needed to answer the research questions. The peer review served the purpose of obtaining feedback related questions posed to teachers related to their perceptions regarding the use of the CER writing framework in their classrooms. During the interview process, every attempt was made to put participants at ease so the responses would be as objective and honest as possible. Questions reviews, transcripts reviews and the triangulation of responses took place. Hence, it provided a check to confirm emerging themes.

Privacy and Ethical Considerations

Before collecting data, the researcher obtained permission to conduct the study from UHCL's CPHS and the participating school district's IRB. To maintain confidentiality, the name of the school district in which the study was conducted, was not mentioned in the study, and specific codes were given to the names of the participating teachers in the semi-structured interview. The participating teachers' informed consent forms were collected prior to the data collection for the study. All data collected were kept secured in a password-protected folder on the researcher's computer and in the researcher's office within a locked file cabinet at all times. The researcher will maintain the data for five years as required by the CPHS and school district guidelines. After the deadline has passed the researcher will destroy all data files associated with the study.

Research Design Limitations

Limitations are potential weaknesses or problems with the research that are identified by the researcher (Creswell, Shope, Plano Clark, & Green, 2006; Creswell, 2002). There are a few limitations to this research. First, scheduling the interviews with the participating teachers, presented a barrier in coordinating with their instructional and planning time to avoid any conflicts in their duty time. This potentially could impact the validity of the study by a limited number of participants in the interview questionnaire. Second, all training settings might not equivalent; the Writing CER trainings were conducted by different presenters of the district curriculum trainers and at various locations with different settings, though the training materials and activities were the same. This potentially could impact the teacher's understanding of the training materials and the process of implementation of CER in their classrooms.

Third, the researcher had access to only two schools in the participating district, so, the data was limited, it may be difficult to generalize. Fourth, not every participating teacher consistently implements the CERs in their classroom because of having limited time, and teachers need to accomplish the full curriculum in a required time following the district pacing scope. One must assume participants are candid when responding to the interview questionnaire. The validity of the finding will be jeopardized if the participants were dishonest. Lastly, the implementation of CER in secondary science classrooms is not mandatory; the district highly recommends it. This could allow teachers a gray area for implementing of CERs; even if students attempted the CER open-ended question, teachers might not have graded it. This could have limited the CER data collection.

Conclusion

The purpose of this study was to examine the relationship between science literacy and student achievement on standardized tests such as district CBAs in Biology, Physics or Chemistry. This chapter provided an overview of the research problem, the operationalization of theoretical constructs, research purpose and questions, research design, population, and sampling selection, instrumentation to be used, data collection procedures, data analysis quantitatively and qualitatively, privacy and ethical considerations, and research design and limitations. In Chapter IV, teacher interviews and achievement data were analyzed and discussed.

CHAPTER IV:

RESULTS

The purpose of this study was to examine the relationship between science writing and student achievement. This chapter presents the findings of quantitative and qualitative data analysis of the study. The research questions are presented and addressed in a chronological order starting with the analysis of the quantitative data using a Pearson Product-Moment Correlation (r) to address Research Questions one, two, and three. An analysis of the qualitative data collected from teacher interviews addressed Research Questions four and five. This chapter concluded with a summary of the findings.

Participant Demographics

Teacher Data

The district CER and CBA data for 25 teachers from the five participating High schools 9-12 was generated from the district data system "OnTrack." Out of 25 participant teachers, male participants comprised (12.0%, n = 3) of the sample, female participants were in majority with 88.0% (n = 22). The highest population of the participants were African American (56.0%, n = 14), while the second highest population of the participants were Asian Indian American (20.0%, n = 5), whereas the lowest population of the participants were Japanese/Filipino (4.0%, n = 1). Out of 25 participants, Biology teachers comprised (44.0%, n = 11), Chemistry (28.0%, n = 7), and Physics (28.0%, n = 7). Table 4.1 provides participating teacher demographics.

Table 4.1

Teacher Participant Demographics

	Frequency (*n*)	Percentage (%)
1. Gender		
Male	3	12.0
Female	22	88.0
2. Racial/Ethnicity		
African American	14	56.0
Hispanic/Latino	2	8.0
Asian/Indian/Pakistani	5	20.0
Caucasian/White	3	12.0
Japanese/Filipino	1	4.0
3. Subject Taught		
Biology	11	44.0
Chemistry	7	28.0
Physics	7	28.0
Total Participants	25	100.0

Student Data

The district CER and CBA data for the 11 Biology teachers was comprised of 638 students. Out of those, male participants were 51.0% (n = 325) and female participants were 49.0% (n = 313). The highest population of the participants were Hispanic/Latino (48.5%, n = 309), while the second highest population of the participants were African

American (37.5%, n = 240), whereas the lowest population of the participants were Two or More races (1.2%, n = 8). Table 4.2 provides participating Biology student demographics.

Table 4.2

Biology Student Participant Demographics

	Frequency (*n*)	Percentage (%)
1.Gender		
Male	325	51.0
Female	313	49.0
2. Racial/Ethnicity		
African American	240	37.5
Hispanic/Latino	309	48.5
Asian/Indian/Pakistani	28	4.3
Caucasian/White	53	8.3
Two or More	8	1.2
Total Participants	638	100.0

The district CER and CBA data for the seven Chemistry teachers was comprised of 657 students. Out of those, male participants were 52.0% (n = 342), and female participants were 48.0% (n = 315). The highest population of the participants were Hispanic/Latino (48.3%, n = 317), while the second highest population of the participants were African American (37.4%, n = 246), whereas the lowest population of the participants were Two or More (1.2%, n = 8). Table 4.3 provides participating Chemistry student demographics.

Table 4.3

Chemistry Student Participant Demographics

	Frequency (*n*)	Percentage (%)
1. Gender		
Male	342	52.0
Female	315	48.0
2. Racial/Ethnicity		
African American	246	37.4
Hispanic/Latino	318	48.3
Asian/Indian/Pakistani	56	4.5
Caucasian/White	29	8.3
Two or More	8	1.2
Total Participants	657	100.0

The district CER and CBA data for the seven Physics teachers was comprised of 481students. Out of those, male participants were 53.0% (n = 243), and female participants were 47.0% (n = 216). The highest population of the participants were Hispanic/Latino (49.5%, n = 227), while the second highest population of the participants were African American (36.6%, n = 169), whereas the lowest population of the participants were Two or More (1.1%, n = 5). Table 4.4 provides participating Physics student demographics.

Table 4.4

Physics Student Participant Demographics

	Frequency (*n*)	Percentage (%)
1. Gender		
Male	243	53.0
Female	216	47.0
2. Racial/Ethnicity		
African American	169	36.6
Hispanic/Latino	227	49.5
Asian/Indian/Pakistani	21	4.5
Caucasian/White	37	8.3
Two or More	5	1.1
Total Participants	459	100.0

Interviewees

Teachers who had attended a structured professional development training on CER writing framework offered by the district Secondary Science Curriculum Department at the beginning of the school year or during professional learning community (PLC) meetings throughout the school year, were invited to participate in the semi-structured interviews. Another requirement for interviewees was that their students must have taken the district CER during the district assessment CBA. The interviews were conducted on the site with the high school science teachers from the two low socio-economic schools of the district. Out of the nine interviewees, 77.8% were female (n = 7)

22.2% male (n = 2), 66.7% African American (n = 6), 22.2% Indian (n = 2), and 11.1% White/Caucasian (n = 1)

Total Content Group Comparison

Overall students in each content group – Biology, Chemistry, and Physics showed their average CER score (47.5%) and their average CBA score (46.3%). Findings indicated that as students' CER scores increase so does their CBA score. In other words, there is a statistically significant relationship between students writing CER scores and their CBA score. Each content group teachers' number of students' attempted CER and CBA, and correspondingly their average CER and CBA scores in percentages in collapsed form is provided in Table 4.5; and Table 4.6 shows the Pearson's Product Moment Correlations of students' CER and CBA scores by content.

Table 4.5

Average District CER and CBA Scores by Content

# Teachers	Groups	# St. took CBA	Av. CER Scores (%)	Av. CBA Score (%)
11	Biology	638	33.9	38.1
7	Chemistry	657	61.7	55.7
7	Physics	459	46.8	45.1
25	All	1,754	47.5	46.3

Table 4.6

Pearson's Product Moment Correlation of Students' CER and CBA Scores by Content

Content	N	r -value	p-value
Biology	638	.189	< .001
Chemistry	657	.178	< .001
Physics	459	.393	< .001

*Statistically significant (p < .05)

Research Question One

Research question one, *Is there a relationship between Biology writing CER scores and their achievement on the Biology district CBA scores?,* was measured using a Pearson Product-Moment Correlation (r). From the three high schools, in 11 Biology teachers' classrooms, 638 students completed both the Biology CER and CBA. The average CER scores was 33.9% and average CBA score was 41.3%. Findings of the Pearson's r suggested that a statistically significant positive relationship existed between students' Biology CER writing scores and their Biology CBA scores, $r(638) = .189$, $p < .001$, $r^2 = .036$. As the student's writing CER score increased, so did the CBA score. The proportion of variation in CBA score attributed to the student writing CER was 3.6%. The CER and CBA data of the participating Biology students in percentage by each Biology teacher is provided in the Table 4.7

Table 4.7

Participant Biology Teachers' District CER Scores (%) and CBA Scores (%)

	Teachers	# St. took CBA	CER Scores	CBA Scores
1.	Biology M BS	151	43.8	49.1
2.	Biology M BA	124	33.71	40.09
3.	Biology M DM	50	34.67	33.57
4.	Biology F DJ	74	43.29	49.93
5	Biology F JA	14	41.56	60.69
6.	Biology W BS	8	44.38	46.61
7.	Biology W GC	48	34.92	38.35
8.	Biology W LG	36	28.93	35.08
9.	Biology W LM	84	18.37	42.37
10.	Biology W PL	36	32.74	26.1
11.	Biology W BR	7	16.67	32.61

Research Question Two

Research question two, *Is there a relationship between students' Chemistry writing CER scores and their achievement on the Chemistry district CBA?* was measured using a Pearson Product-Moment Correlation (r). From the four high schools, in seven Chemistry teachers' classrooms, 657students completed both the Chemistry CER and CBA. The average CER score was 61.7% and average CBA score was 55.7%. Findings of the Pearson's r suggested that a statistically significant positive relationship existed between students' Chemistry writing CER score and their Chemistry CBA scores, $r(657) = .178$, $p < .001$, $r^2 = .032$. As the student's writing CER score increased, so did the CBA score. The proportion of variation in CBA score attributed to the student writing CER was 3.2%. The CER and CBA data of the participating Chemistry students in percentage by each Chemistry teacher is provided in the Table 4.6.

Table 4.8

Participant Chemistry Teachers' District CER Scores (%) and CBA Scores (%)

	Teachers	# St. took CBA	CER Scores	CBA Scores
1.	Chemistry M DR	110	79.4	59.8
2.	Chemistry M DJ	92	53.57	38.64
3.	Chemistry M EG	73	74.36	42.79
4.	Chemistry F GS	107	35.94	65.97
5	Chemistry F MZ	82	58.47	71.63
6	Chemistry K BS	78	44.62	42.69
7.	Chemistry C TM	115	85.38	68.51

Research Question Three

Research question three, *Is there a relationship between students' Physics writing CER scores and their achievement on the Physics district CBA?*, was measured using a Pearson Product-Moment Correlation *(r).* From the three high schools, in seven Physics teachers' classrooms, 459 students completed both the writing CER and CBA. The average CER score was 46.8% and the average CBA score was 45.1%. Findings of the Pearson's *r* suggested that a statistically significant positive relationship existed between students' Physics CER writing score and their Physics CBA scores, $r(459) = .393$,

$p < .001$, $r^2 = .154$. As the student's writing CER score increased, so did the CBA score. The proportion of variation in CBA score attributed to the student writing CER was 15.4%.

The CER and CBA data of the participating Physics students in percentage by each Physics teacher is provided in the Table 4.7.

Table 4.9

Participant Physics Teachers' District CER Scores (%) and CBA Scores (%)

	Teachers	# St. took CBA	CER Scores	CBA Scores
1.	Physics M EI	93	50.99	45.66
2.	Physics M GV	149	45.67	44.91
3.	Physics M CL	57	53.41	34.23
4.	Physics M EG	30	55.38	41.16
5	Physics L CO	101	80.05	57.79
6	Physics F CR	16	13.68	44.38
7.	Physics F VG	9	28.08	47.34

Research Question Four

Research question four, *How do science teachers implement the literacy writing framework CER in their science classrooms?,* was answered based on the data collected from participating teachers' interview responses from the two schools. The teachers who participated in the district CER training were invited to participate in the interviews.

During the training, the district coaches trained teachers about CER writing framework and how teachers can implement it in their science classrooms with guided and independent practices. Teachers learned during the training how to grade a writing

CER using sample CERs and the district modified CER rubric. For norming the CER grading process, the district coaches provided opportunities to the teachers to grade CER samples based on the district modified CER rubric (as shown in Appendix E). Also, once the teachers completed their content specific CER practices, they practiced by grading each other's CER practices using the district modified rubric. This way, teachers were trained and normed with grading a CER.

In an attempt to capture a more in-depth relationship between students' CER writing scores and the students' achievement, nine teachers (3 chemistry, 3 biology, and 3 physics) were interviewed. The collected data were analyzed using the NVivo, inductive thematic coding process. Participants included two chemistry teachers from school A, One from school B; Two biology teachers from school A, One from school B; Two physics teachers from school A, and one from school B. From the interviews, responses regarding the implementation of CER were categorized into two major themes. The first theme was *how teachers implement CER in their classrooms.* The second theme was *how teachers grade student's CER responses*. During the interviews, the teachers responded that they loved the training and they implemented CER writing in their classrooms as a lab write up, open-ended response form, question annotation, mini CER Gallery walks, and prompt-based writing but their opinion regarding grading CER differed. To understand how science teachers implemented writing CER in their classrooms, the above-mentioned themes were additionally evaluated. The major themes and subthemes obtained from teacher's interview responses are provided below.

CER Implementation

The term *CER implementation* was chosen because the term incorporates the prevailing views of the secondary science teachers regarding the implementation of a literacy instructional strategy CER at a campus level. An inductive thematic coding process using NVivo derived this theme into additional themes based on the teachers' responses concerning the implementation of CER in their classrooms: (a) Teachers' education and experience, (b) Teachers' perceptions regarding CER training, (c) Teachers' perceptions about CER, (d) Teachers' comfort level of implementing CER, and (e) Teachers' providing practicing CERs to their students. It is noted that the district highly recommends the implementation of CER, but it is not required. If the teachers are implementing this strategy in their classrooms, it means they have some comfort level regarding its implementation. Their educational backgrounds, teaching experiences, and writing experiences during their academic years, are benefiting them in implementing CER in their classrooms. They might have positive perceptions regarding CER and CER training. They are also providing some practicing CER opportunities to their students. The students' CER samples shared in this research are the reflection of how teachers are implementing this strategy in their classrooms. For standardization, students' samples of the District CER in each content area were analyzed. Below are the responses that different content teachers provided regarding the implementation of CER in their classes based on their education and experiences, perceptions regarding CER training, perceptions regarding CER, their comfort level, and practicing CER opportunities that they provide to their students before the district test.

Teachers' Education and Experience. A teacher's educational background, teaching experience and writing experience during his/her college years could be one of the factors that play a role in the implementation of CER. In the interviews, teachers were asked to describe their teaching experience, teaching certification, college majors, languages, and writing skills that they practiced during their academic years. Below are the responses accumulated by content area teachers. (It is noted that Biology is offered at

9th grade, Chemistry is being provided at 10th grade, and Physics is offered at 11th or 12th grade.)

Three chemistry teachers participated in interviews. From their descriptions of educational background, work experience, and writing experience during their academia, it was found by comparing their educational background and experience that, the pre-AP teacher C1 from school A the most teaching experience, at 29 years and had earned a doctorate degree in Environmental Toxicology; teacher C2 from school A had 20 years' experience and had earned a college degree in Biology. Since teacher C2 had a composite certification, she was able to teach both Physics and Chemistry. In this research, their CER students' samples are analyzed and discussed in the section "comfort level of implementing CER" to understand how they implement CER in their classrooms. Regarding the writing experience, teacher C1 reported,

> My writing experience in science includes creating my lecture handouts for the students and designing laboratory applications on all levels of academia. As a graduate student, I created and compiled a reference manual for undergraduate and graduate students. I am certified by the State of Texas in Chemistry.

Based on her seven years of teaching at the university level and her writing experience during her academia, she reported that she was very comfortable in implementing CER in her classroom. On the other hand, the newly hired chemistry teacher, who had a probationary certification, had a college degree in chemistry, but did not have prolonged writing experience during his academic study, felt less comfortable in implementing CER in his classroom. Further analysis is described in the results at the end of the major themes. Similarly, the responses shared by the biology teachers from school A, who were experienced teachers, and had pretty solid writing experience during their academic years, reported that they feel comfortable in implementing CER in their classrooms. Notably, the newly hired Biology teacher from school B, based on his writing experience at the doctorate level, had overcome the challenges that he experienced in the implementation of CER in his classroom as a first-year teacher. His implementation of CER and how he overcame his obstacles are described and analyzed in this research also.

Another interesting fact was noted from all nine teachers, three from school B had zero-to-three years of teaching experience, and these teachers were not as comfortable in implementing CER as the six more experienced teachers from school A. Therefore, it may be concluded that teachers' educational background, teaching experience, and writing experience during their academia impact the implementation of CER in their classrooms.

In summary, these responses shared by the interviewees illustrate their educational background and experiences. It is noted that the educational level of these teachers ranges from a Doctorate level to the graduate level. Teaching experience ranges from 29 years to zero years. Four out of the nine teachers had education or teaching experiences from other states or countries as well as Texas. Every teacher had a Texas teacher certification in their corresponding content, or composite certification except newly hired teachers who had Intern/Probationary certification. Every teacher had some writing experience from lab reports to the research and curriculum writing in their academic years. Because of this, it could be concluded that the teachers who had a higher educational background, more teaching experience, and extensive writing experience during their academic years might feel more comfortable than the less experienced teachers in implementation of CER in their science classroom. Next, I describe the interviewee's perceptions of CER training.

Perceptions regarding CER training. Based on teacher's interview responses regarding their perceptions about CER training, the majority of the teachers found the CER training valuable. Four out of nine teachers rated the CER training as 5, [on a scale of 1-5; 5 is the highest and 1 is the lowest]. One teacher rated 4 ½, two teachers rated 4, and two teachers did not rate it.

A pre -AP Chemistry teacher C1 from school A, described her perception about the CER training in these words, "I loved the training; I am rating it as a 5 because it has inspired me to include this literacy component in the current laboratory application that I recently designed." Likewise, a biology teacher, B2 from school A passionately described her perceptions regarding CER.

> I was extremely impressed by the training and benefitted greatly from it. I am rating it as 5 because it has helped me in fine-tuning my lectures to help students grasp the concepts quickly and has resulted in an overall increase in the students' pass percentage in the EOC test results. (It is noted at the high school level, in science, only Biology EOC test by the state is required). I have attended several in house CER Writing Professional Development (PD) sessions at my school under the leadership of my Science Supervisor. I have benefitted greatly by being a part of these trainings and have been able to customize and fine-tune my writing skills after attending these trainings. I have been able to convey my message to the students as a consequence, eloquently.

Additionally, an AP physics teacher, P1 from school A, who rated the training as 4, commented,

> I have attended a science PLC at my campus, where we discussed CER writing strategies in science and looked at student samples. In addition, we have considered CER writing strategies, lessons, and topics in AP Environmental

Science PDs during district early dismissal trainings.

She rated the training as 4 is not surprising, because the district training is set for the implementation of CER for on-level students. She is teaching mostly AP classes except two regular physics classes, and for AP students she had to add another component of CER known as “rebuttal”. She was not comfortable implementing rebuttal with CER, and she thought there was a lack of this component in the training. Therefore, she rated it as a 4. However, in this study, “rebuttal” is not included since not all participants taught AP courses and this aspect would not apply them. A “rebuttal” describes a misconception a student had and uses evidence and reasoning to refute the misconception. For example, what did the student originally think was going to happen to the temperature? How has the student’s thinking changed now?

In summary, the comments shared by interviewees indicate the teacher’s perception of the CER training showed that the majority of them liked the training and training materials. The training benefitted them greatly in customizing and fine-tuning their writing skills. During training, teachers got a chance to discuss CER writing strategies in science and looked at peer’s and students’ samples, grading CERs as a norming process. In short, they were impressed by the training, and it inspired them to implement CER in their science classrooms. It is concluded that teachers’ perceptions regarding the CER training have high impact in the implementation of CER in their classrooms. Next, I describe the interviewee’s perceptions of CER.

Perceptions about CER. Based on teacher’s interview responses regarding their perceptions about CER, the majority of the teachers had a positive perception about the CER strategy. For example, a newly hired chemistry teacher, C1 from school B, expressed his perceptions, “I believe that the CER strategies are beneficial for students because it gives the teacher more opportunities to make sure that students are able to express their thinking about scientific processes by actually writing them out in a structured format.” In addition, he reflected upon his practices and perceptions regarding CER and described, "I believe that CER strategy improves teacher's practices because it once again gives more opportunity for students to get their points across and gives them another outlet for students to do so." It is noted here that this teacher had a positive perceptions regarding CER, but he had less teaching experience and less writing experience during his academic years compared to the experienced chemistry teachers C1 and C2 from school A. This could be a potential factor for not feeling comfortable in implementing CER in his classroom as he mentioned in his interview. Similarly, a biology teacher B2 from school A expressed her perceptions regarding CER in a reflective way:

> I like the CER strategy. It benefitted me greatly to customize and fine-tune my writing skills. In addition, this will allow my students to have a deeper understanding of the key concepts of Biology and perform better in grades 10, 11, and 12. My students will also be familiar with the CER when they take the District CBAs. I believe CER is a good check for understanding. It helps to strengthen the use and understanding of Academic vocabulary. It helps to understand the scientific concepts and writing the lab reports.

In addition, an AP physics teacher, P1 from school A, narrated her perceptions regarding CER and valued it as an effective instructional practice,

> I believe CER is a valuable tool for structuring and encouraging thought and writing across disciplines, but especially in science. It follows a logical thought process, provides a framework, and with a rubric, sets high expectations. I think that using the CER framework makes incorporating writing into science, especially for students with different writing and language abilities, much easier. I

> have found that this structure is usable by students who may struggle with other assignments, especially writing, and these student generally excel at CER writing in my class, maybe because they know exactly what is expected of them because of the structure and rubric.

The viewpoints regarding perceptions of CER that the AP -Teacher mentioned above are similar to the viewpoints that another physics teacher, P2 from school A, mentioned, and she added, “CER is a very powerful and effective tool for incorporating writing in a science classroom. It is a good check for understanding, it helps to make lab reports, and strengthening the use of academic vocabulary to understand scientific concepts.”

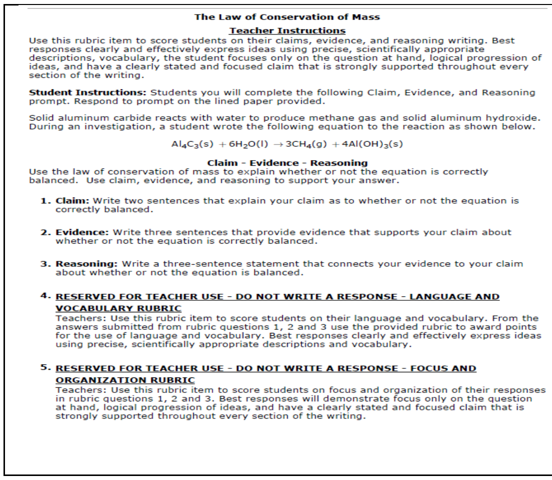
In summary, the comments shared by interviewees showed that teacher's overall perception regarding CER literacy strategy is very reflective and positive. The majority of them liked the various aspects of the strategy, using it as a lab report, a structured framework for writing, and a check for understanding science concepts, understanding vocabulary, make students think critically, and a more in-depth understanding of the key concepts in their science content. They considered the CER strategy as a logical thought process that provides a structured framework of writing with a rubric that sets high expectations. Teachers also expressed how it benefitted them in the implementation of CER in their classrooms, such as teacher B2 from school A, who mentioned that CER implementation in her class would make her students familiar with the strategy before they take the district test. It also benefitted her in fine-tuning her own writing skills. A conclusion can be drawn that as the teachers' perceptions regarding CER are high, or they see the benefit of the strategy, there is a higher chance of its implementation in their classrooms. The evidence of application of CER in science classrooms in the form of students CER samples are described and analyzed in the next section where the researcher explains the teachers' comfort level of implementation for CER in their science classrooms.

Comfort Level of Implementing CER. I establish a claim that if a teacher's comfort level of implementation of CER is high, it is evident that teacher is implementing CERs in their classrooms. The students' CER samples collected from the teachers' classroom are show how they are implementing CERs in their classrooms. The teachers' interview responses regarding their comfort levels of implementing CER in their classrooms is relatively high. Four out of nine teachers rated their comfort level as 5 [on scale 1-5; 5 is the highest and 1 is the lowest]; three rated 4, one rated 4.5, and one rated 3. For example, a pre – AP chemistry teacher, C1 from school A, stated her comfort level regarding the implantation of CER in her classroom in these words,

> I rate my comfort level as 5. I use CER in my classroom, mostly as a lab report. For example, I included this literacy component in the current laboratory application that I recently designed. This allows my students to practice and engage in writing from lab data that they generated. Additionally, my students will also be familiar with the CER when they take the District CBAs.

She also shared the district CER prompt and a student's CER sample. As she mentioned that she has been using laboratory based CER practices in her classroom, it is evident from this sample that her students have written a CER with a clear claim, provided evidence with data and reasoning connected with the science concept as shown in Figure4.1

Figure 4.1. District Chemistry CER Prompt and Student's Writing CER Sample



The Law of Conservation of Mass

Teacher Instructions

Use this rubric item to score students on their claims, evidence, and reasoning writing. Best responses clearly and effectively express ideas using precise, scientifically appropriate descriptions, vocabulary, the student focuses only on the question at hand, logical progression of ideas, and have a clearly stated and focused claim that is strongly supported throughout every section of the writing.

Student Instructions: Students you will complete the following Claim, Evidence, and Reasoning prompt. Respond to prompt on the lined paper provided.

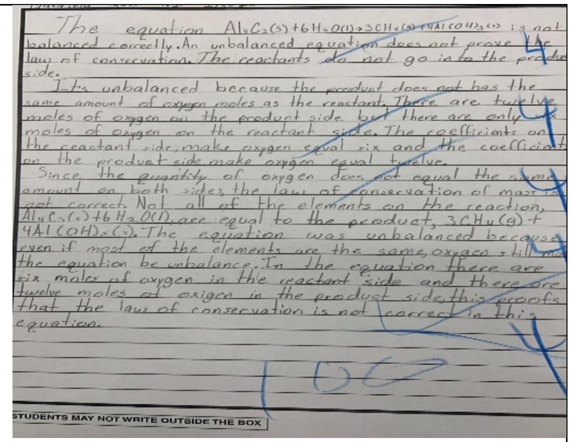
Solid aluminum carbide reacts with water to produce methane gas and solid aluminum hydroxide. During an investigation, a student wrote the following equation to the reaction as shown below.

$$Al_4C_3(s) + 6H_2O(l) \rightarrow 3CH_4(g) + 4Al(OH)_3(s)$$

Claim - Evidence - Reasoning

Use the law of conservation of mass to explain whether or not the equation is correctly balanced. Use claim, evidence, and reasoning to support your answer.

1. **Claim:** Write two sentences that explain your claim as to whether or not the equation is correctly balanced.
2. **Evidence:** Write three sentences that provide evidence that supports your claim about whether or not the equation is correctly balanced.
3. **Reasoning:** Write a three-sentence statement that connects your evidence to your claim about whether or not the equation is balanced.
4. **RESERVED FOR TEACHER USE - DO NOT WRITE A RESPONSE - LANGUAGE AND VOCABULARY RUBRIC**
   Teachers: Use this rubric item to score students on their language and vocabulary. From the answers submitted from rubric questions 1, 2 and 3 use the provided rubric to award points for the use of language and vocabulary. Best responses clearly and effectively express ideas using precise, scientifically appropriate descriptions and vocabulary.
5. **RESERVED FOR TEACHER USE - DO NOT WRITE A RESPONSE - FOCUS AND ORGANIZATION RUBRIC**
   Teachers: Use this rubric item to score students on focus and organization of their responses in rubric questions 1, 2 and 3. Best responses will demonstrate focus only on the question at hand, logical progression of ideas, and have a clearly stated and focused claim that is strongly supported throughout every section of the writing.



The equation $Al_4C_3(s) + 6H_2O(l) \rightarrow 3CH_4(g) + 4Al(OH)_3(s)$ is not balanced correctly. An unbalanced equation does not prove the law of conservation. The reactants do not go into the product side.

It's unbalanced because the product does not has the same amount of oxygen moles as the reactant. There are twelve moles of oxygen on the product side but there are only six moles of oxygen on the reactant side. The coefficients on the reactant side, make oxygen equal six and the coefficients on the product side make oxygen equal twelve.

Since the quantity of oxygen does not equal the same amount on both sides, the law of conservation of mass is not correct. Not all of the elements on the reaction, $Al_4C_3(s) + 6H_2O(l)$, are equal to the product, $3CH_4(g) + 4Al(OH)_3(s)$. The equation was unbalanced because even if most of the elements are the same, oxygen still make the equation be unbalance. In the equation there are six moles of oxygen in the reactant side and there are twelve moles of oxigen in the product side, this proofs that the law of conservation is not correct in this equation.

Note. Permission granted by the participating school district

Figure 4.1. Shows the sample provided by the chemistry Teacher C1 from school A. When I analyzed the sample provided by Teacher C1, I found that this student builds a claim that the equation given in the prompt is not balanced because the product does not have the same amount of oxygen as the reactant. He further elaborated with counting the number of atoms of oxygen before and after the reaction. The reactant has six oxygen atoms, and the product has 12 oxygen atoms. In reasoning, he connected his evidence of the equation's counting number of atoms of each element with the law of conservation of mass (the total number of atoms of the reactants should be equal to the total number of atoms of the products). He explained that for this given equation, the law of conservation of mass is not correct. Therefore, the equation is not balanced. This student also met the district CER sentence requirements, two-sentence for a claim, three for evidence, and three for reasoning.

A conclusion can be drawn from this sample that if this teacher had not been using or was not comfortable (she rated her comfort level 5) with using CERs in her classroom, her students would not have attempted the district CER comparatively well. On the contrary, a chemistry teacher, C2 from school A, who teaches regular and ELs chemistry and physics, stated her comfort level regarding implementation of CER and rated her comfort level a little differently based on her students need. She stated,

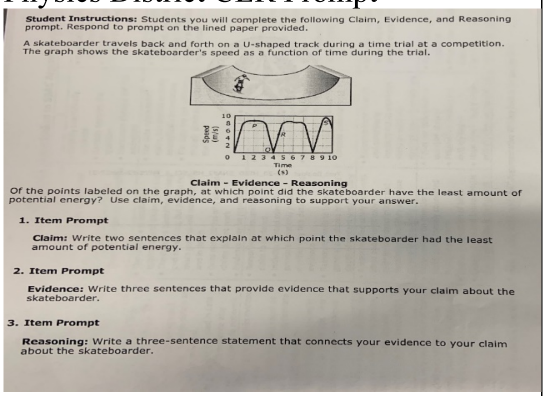
> I am comfortable with it. My scale would be a 5, but because I have to factor in my students reading and writing levels, I'll reduce it to a 3, to accommodate them

at the beginning and middle of the year. I will step it up during the 2nd semester as they improve.

She also shared a student's sample from the physics CER (see Figure 4.2)

Figure 4.2. District Physics CER Prompt and Student's Writing CER Sample

Physics District CER Prompt


Student Instructions: Students you will complete the following Claim, Evidence, and Reasoning prompt. Respond to prompt on the lined paper provided.

A skateboarder travels back and forth on a U-shaped track during a time trial at a competition. The graph shows the skateboarder's speed as a function of time during the trial.

Claim - Evidence - Reasoning

Of the points labeled on the graph, at which point did the skateboarder have the least amount of potential energy? Use claim, evidence, and reasoning to support your answer.

1. Item Prompt

Claim: Write two sentences that explain at which point the skateboarder had the least amount of potential energy.

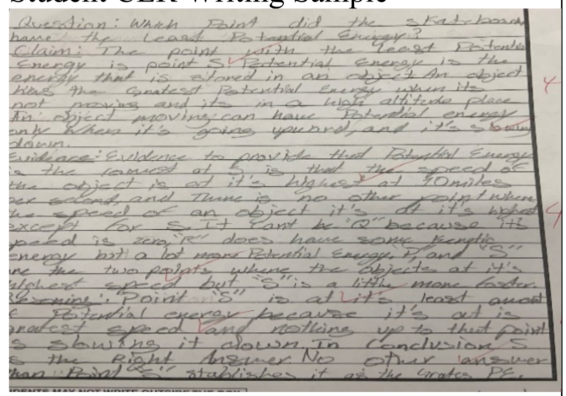
2. Item Prompt

Evidence: Write three sentences that provide evidence that supports your claim about the skateboarder.

3. Item Prompt

Reasoning: Write a three-sentence statement that connects your evidence to your claim about the skateboarder.

Student CER Writing Sample


Question: Which Point did the skateboarder have the least Potential Energy?
Claim: The point with the least Potential Energy is point S. Potential energy is the energy that is stored in an object. An object has the Greatest Potential Energy when it's not moving and it's in a high altitude place. An object moving can have Potential energy only when it's going upward, and it's slowing down.
Evidence: Evidence to provide that Potential Energy is the lowest at S is that the speed of the object is at it's highest at 10 miles per second, and There is no other point where the speed of an object it's at it's highest except for S. It can't be "Q" because its speed is zero, "R" does have some kinetic energy but a lot more Potential Energy. P, and "S" are the two points where the objects at it's highest speed but "S" is a little more faster.
Reasoning: Point "S" is at it's least amount of Potential energy because it's at is greatest speed and nothing up to that point is slowing it down. In Conclusion S is the Right Answer. No other answer than "Point S" establishes it as the Greates PE.

Note. Permission granted by the participating school district

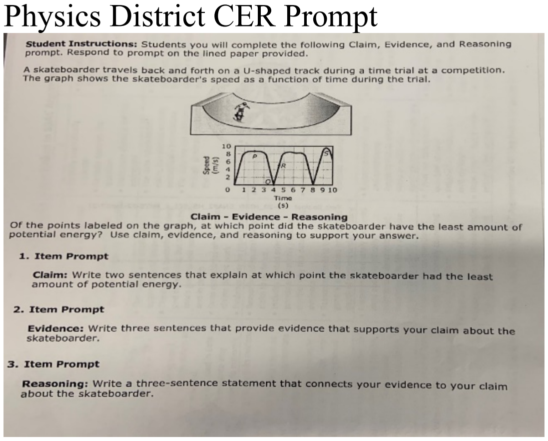
Figure 4.2. Shows the sample shared by the chemistry teacher C2 from school A. The analysis of this sample shows that the student has clearly described her claim that point "S" has the lowest potential energy. She also defined that potential energy is related to height or altitude, and kinetic energy is related to speed. She also provided evidence that point "S" has the highest speed, so it has the lowest height and thus had the lowest potential energy. She provided evidence clearly, but she was not able to connect her evidence with the scientific concept, such as the law of conservation of energy. Though she wrote a full-page CER with its requirement of two sentences for a claim, three sentences for evidence, and three for reasoning, the reasoning part was not justified. This shows that this student is struggling in the reasoning component of the CER.

This sample supports the teacher's response that she rated her comfort level of implementing CER in her classroom as 3 because her students are at this moment struggling in the reasoning part of the CER. But, she is implementing CER in her class. She also mentioned that she would provide more CER practice opportunities to her students in the second semester.

An interesting result was obtained when a comparative analysis of the above teacher's student's sample was done with another Physics teacher, P1, from school A's student's sample, as shown in Figure 4.3. Though this teacher has the advantage that she is also teaching pre-AP and AP physics, the sample she shared is from her regular physics class student. It is evident from this sample that her students are writing a quality CER with its requirement. She rated her comfort level in implementing the writing framework CER in her classroom as 5.

Figure 4.3. Physics District CER Prompt and Student's Writing CER Sample

Physics District CER Prompt



Student Instructions: Students you will complete the following Claim, Evidence, and Reasoning prompt. Respond to prompt on the lined paper provided.

A skateboarder travels back and forth on a U-shaped track during a time trial at a competition. The graph shows the skateboarder's speed as a function of time during the trial.

Claim - Evidence - Reasoning

Of the points labeled on the graph, at which point did the skateboarder have the least amount of potential energy? Use claim, evidence, and reasoning to support your answer.

1. **Item Prompt**

   Claim: Write two sentences that explain at which point the skateboarder had the least amount of potential energy.

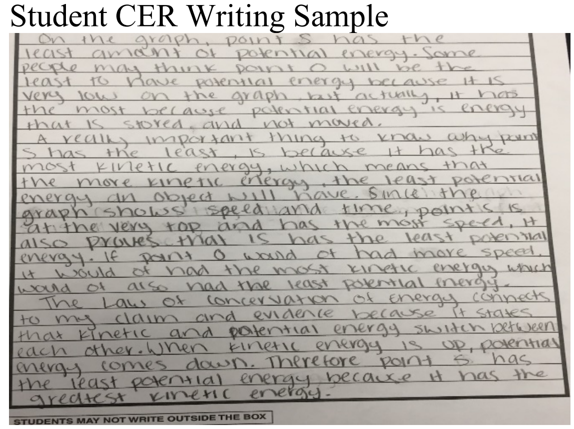
2. **Item Prompt**

   Evidence: Write three sentences that provide evidence that supports your claim about the skateboarder.

3. **Item Prompt**

   Reasoning: Write a three-sentence statement that connects your evidence to your claim about the skateboarder.

Student CER Writing Sample



On the graph, point S has the least amount of potential energy. Some people may think point O will be the least to have potential energy because it is very low on the graph, but actually, it has the most because potential energy is energy that is stored, and not moved.
A really important thing to know why point S has the least, is because it has the most kinetic energy, which means that the more kinetic energy, the least potential energy an object will have. Since the graph shows speed and time, point S is at the very top and has the most speed, it also proves that S has the least potential energy. If point O would of had more speed, it would of had the most kinetic energy which would of also had the least potential energy.
The Law of conservation of energy connects to my claim and evidence because it states that kinetic and potential energy switch between each other. When kinetic energy is up, potential energy comes down. Therefore point S has the least potential energy because it has the greatest kinetic energy.

STUDENTS MAY NOT WRITE OUTSIDE THE BOX

Note. Permission granted by the participating school district

Figure 4.3. Shows this student has written a full-page CER. He demonstrated a great explanation of his claim, evidence with data like point "S," point "O" etc. H clearly explained why point "S" has the least potential energy because it has the highest kinetic energy at this point. He made a connection from the graph. He explained that by looking at the speed-time graph, point "S" has the greatest speed. Therefore, at this point, its kinetic energy is highest. He also made the connection from the speed-time graph that point "S" has the highest speed, so it has the highest kinetic energy at this point, and when the kinetic energy of an object is greatest, then it's potential energy will be the lowest. In the reasoning part, he also connected his evidence with the science concept "the law of conservation of energy." He also had fulfilled the sentence requirements for each part of the CER.

The analysis of this CER sample offers support to the teacher's comfort level and the comments that she provided in the perceptions regarding CER section:,

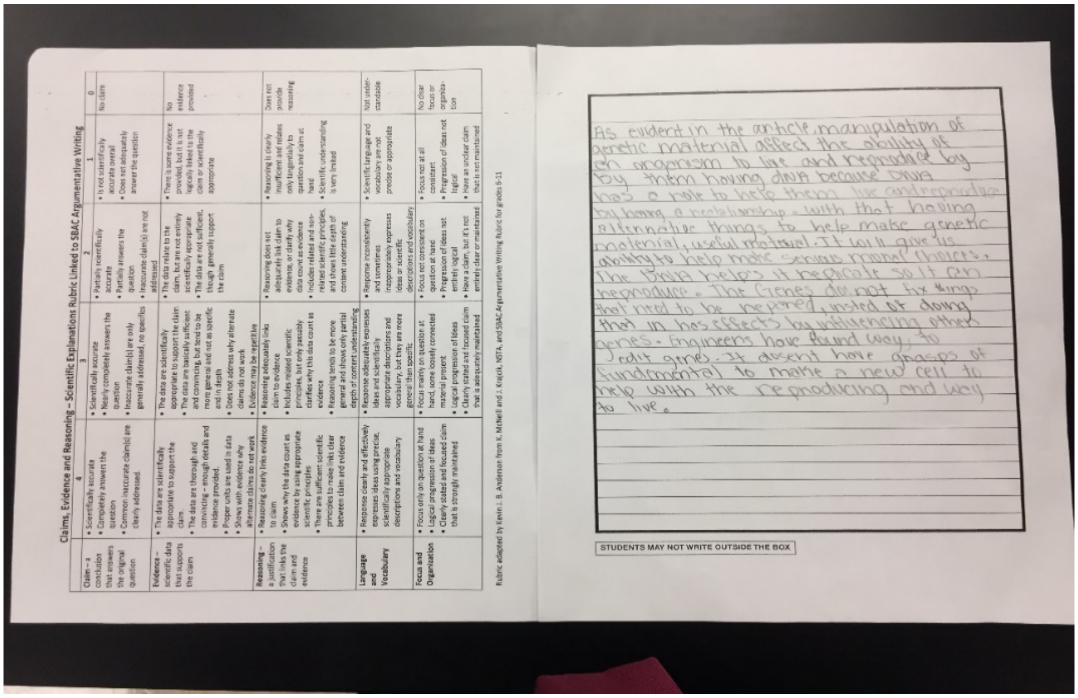
> I have found that this structure is usable by students who may struggle with other assignments, especially writing, and these student generally excel at CER writing in my class, maybe because they know exactly what is expected of them because of the structure and rubric.

In a similar way, a biology teacher, B1 from school A, regarding her comfort level and how she implemented CER in her classroom, responded,

> I rate myself a four and ½ in implementing the CER writing framework in my instructional practices. Requiring students to use textual based evidence have sharped student's literacy skills as they identify and write claims, find evidence, and conclude reasons in their thought process, which are reflected in their scientific writings. Students are also engaged in constructing data to integrate into their lab reports coupled with transferring CER knowledge into the District CBAs.

She also shared a student sample practice of writing CER using the district CER rubric as shown in Figure 4.4

Figure 4.4. A Genetics Textual-Based Biology CER Student's Sample



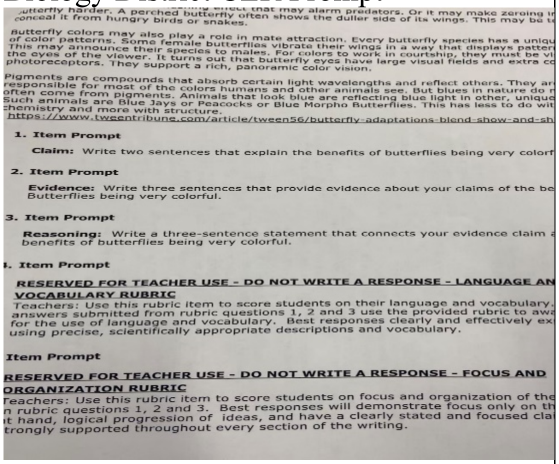
Note. Permission granted by the participating school district

Figure 4.4. It is evident in the picture that this teacher is using the district CER rubric and providing her student's textual – based CER practice opportunity before the district CER. This student has written a CER in an open-ended response format. This student wrote more than a half-page as required by the teacher. In this sample, the student is completing textual - based writing. The student responded to the writing question, based on the article that "manipulation in genetic materials affects the ability of an organism to live and reproduce, ---- DNA holds a role for organisms to live and reproduce, --- etc." This shows the student's understanding of the science concept through textual – based writing.

This biology teacher also shared an example of the district biology prompt-based CER. The district prompt and a student's CER sample is shown in Figure 4.5.

Figure 4.5. District Biology CER Prompt and Student's Writing CER Sample

Biology District CER Prompt



utterfly harder. A perched butterfly often shows the duller side of its wings. This may be t conceal it from hungry birds or snakes.

Butterfly colors may also play a role in mate attraction. Every butterfly species has a uniqu of color patterns. Some female butterflies vibrate their wings in a way that displays patter This may announce their species to males. For colors to work in courtship, they must be vi the eyes of the viewer. It turns out that butterfly eyes have large visual fields and extra co photoreceptors. They support a rich, panoramic color vision.

Pigments are compounds that absorb certain light wavelengths and reflect others. They ar responsible for most of the colors humans and other animals see. But blues in nature do n often come from pigments. Animals that look blue are reflecting blue light in other, unique Such animals are Blue Jays or Peacocks or Blue Morpho Butterflies. This has less to do wit chemistry and more with structure.
https://www.tweentribune.com/article/tween56/butterfly-adaptations-blend-show-and-sh

1. Item Prompt

Claim: Write two sentences that explain the benefits of butterflies being very colorf

2. Item Prompt

Evidence: Write three sentences that provide evidence about your claims of the be Butterflies being very colorful.

3. Item Prompt

Reasoning: Write a three-sentence statement that connects your evidence claim a benefits of butterflies being very colorful.

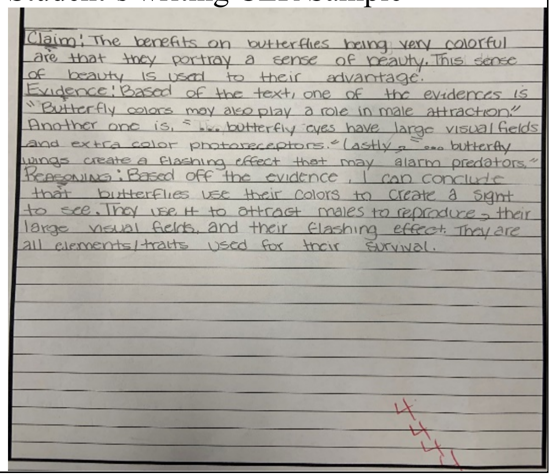
4. Item Prompt

RESERVED FOR TEACHER USE - DO NOT WRITE A RESPONSE - LANGUAGE AN VOCABULARY RUBRIC
Teachers: Use this rubric item to score students on their language and vocabulary. answers submitted from rubric questions 1, 2 and 3 use the provided rubric to awa for the use of language and vocabulary. Best responses clearly and effectively ex using precise, scientifically appropriate descriptions and vocabulary.

Item Prompt

RESERVED FOR TEACHER USE - DO NOT WRITE A RESPONSE - FOCUS AND ORGANIZATION RUBRIC
Teachers: Use this rubric item to score students on focus and organization of the n rubric questions 1, 2 and 3. Best responses will demonstrate focus only on th t hand, logical progression of ideas, and have a clearly stated and focused cla trongly supported throughout every section of the writing.

Student's writing CER Sample



Claim: The benefits on butterflies being very colorful are that they portray a sense of beauty. This sense of beauty is used to their advantage.
Evidence: Based of the text, one of the evidences is "Butterfly colors may also play a role in male attraction." Another one is, "... butterfly eyes have large visual fields and extra color photoreceptors." Lastly, "... butterfly wings create a flashing effect that may alarm predators."
Reasoning: Based off the evidence, I can conclude that butterflies use their colors to create a sight to see. They use it to attract males to reproduce, their large visual fields, and their flashing effect. They are all elements/traits used for their survival.

Note. Permission granted by the participating school district

Figure 4.5. shows though this student did not write the whole page, she clearly demonstrated the specific content understanding with the district CER prompt requirements of two sentences for the claim, three sentences for evidence, and three sentences for reasoning. In this prompt-based CER, she established her claim that benefit on butterflies being very colorful are they portray a sense of beauty. This sense of beauty is used to their advantage. She provided three evidences from the text, such as "butterfly colors may also play a role in male attraction; butterflies' eyes have a large visual field, etc. Then she justified her evidence with science concepts like "butterflies use their colors to create a sight to see, attract a male to reproduce, etc.

Both the samples that she shared offer support to her comments that she required her students to use textual based evidence to sharpen their literacy skills as they identify and write claims, find evidence and conclude reasons in their thought process, which are reflected in their scientific writings. From these samples, it is evident that she is implementing the CER writing framework in her instructional practices as a textual based, and prompt-based writing.

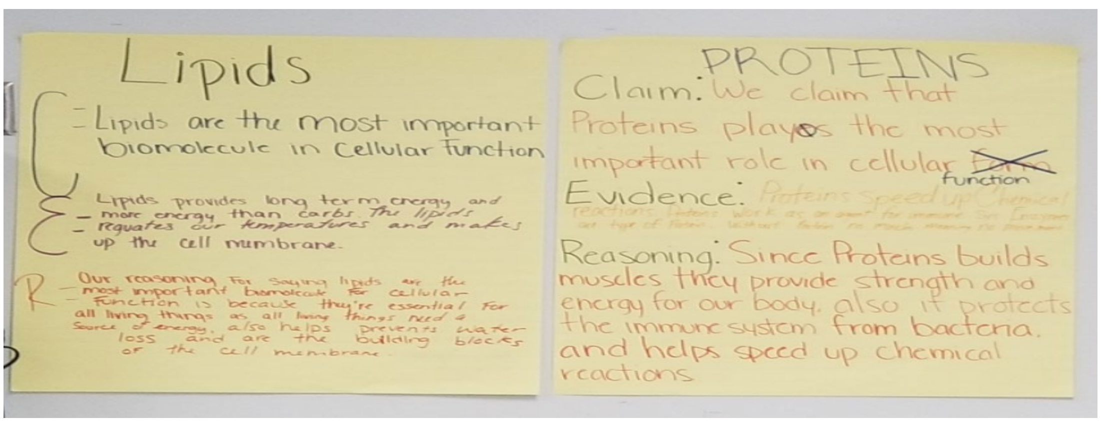
Another Biology teacher, B2 from school A, responded regarding her comfort level and how she implemented CER in her classroom in these words:,

> I am rating it as a 5 because I have been using the CER practices in my classroom in different formats, prompt-based writing, a gallery walks of mini CERs,

question annotation format, and district CER format. It helped my students grasp the concepts quickly and resulted in an overall increase in the students' pass percentage in the STAAR Biology End of Course (EOC) test results.

In addition to the biology district CER sample, she also shared writing mini CER samples regarding understanding biomolecules (as shown in figure 11). In this sample, she posed CER questions regarding each biomolecule, such as, "Is lipid an essential biomolecule for our body? If so, why? She also modified the sentence requirement for mini CERs as one sentence for the claim, one or two-sentence for evidence, and one or two sentences for reasoning. Figure 4.6 is showing a mini CER sample created by her students as a Biology Gallery Walk CER for Biomolecules.

Figure 4.6. Biology Gallery Walk Poster - Student's Writing Mini CER Sample



Note. Permission granted by the participating school district

Figure 4.5. Shows that this student is claiming lipids are the essential biomolecule in a cellular function. The evidence she provided – lipids provide long term energy, regulates our temperature, and makes cell membrane. The reasoning she explained was connected with the scientific concept that lipids are essential for all living things as all living things need energy; they are building blocks of the cell membrane, and they help to prevent water loss.

This sample shows the student's clear understanding of lipids in the form of mini CER writing. I wish the teacher would have asked her students to include some examples of the biomolecule to make it more relevant. However, this sample provides evidence of the implementation of CER in her classroom in the form of a gallery walk. The quality of the sample offers support to the teacher's comments that she has been using the CER practices in her classroom in different formats, such as prompt-based writing and a gallery walk of mini CERs and rated her comfort level of implementing CER as 5.

The data collected in this section, provide a closer insight into the teacher's work and their students' CER samples as evidence of their implementation of CER in their classrooms based on their comfort levels. A pattern was noted that the teachers who rated their comfort level high, were mostly highly experienced, and they had extensive writing experience during their academic years. Their perceptions regarding CER and CER training was also high. For example, the Pre-AP chemistry teacher, the two biology teachers, and the two physics teachers (including AP teachers) from school A had extensive teaching and writing experience. They also provided comparatively more CER practices to their students for the implementation of CER in their classrooms. Another pattern was noted: the quality of their students' CER samples was comparatively better, as evident in the shared samples. In conclusion, it is noted that if a teacher's comfort level of implementation of CER is high, it is evident that the teacher is implementing CERs in his/her classrooms. The students' CER samples collected from teachers' classrooms are showing how teachers are implementing CERs in their classrooms based on their comfort levels. They are using CERs as a laboratory-based summary, a check for understanding, prompt-based writing, textual-based writing, or mini CER galley walk writing in their classrooms.

Next, I describe the interviewee's responses regarding providing practicing CER opportunities to their students.

Practicing CER. This theme is connected with the previous theme:- teachers' comfort level of implementing CER. A claim is established here that if teachers are comfortable in implementing CER in their classroom, then they must have provided practice CER opportunities to their students more than one time per semester. The analysis of the interviewees' responses indicated that five out of nine teachers provided their students practicing CER opportunities more than one time per semester, and four out of nine teachers provided at least one practicing CER per semester before the district test. Each teacher's interview responses regarding their providing opportunities for practicing CER and how they are using them in their classrooms are described below.

The AP chemistry teacher, C1 from school A, responded,:

> I used a similar CER practice component often, which was a summary at the end of the experiment; the summary allowed the student to describe what was learned based on the objective, laboratory findings, and evaluate the lab data in a written form.

So, this teacher is using CER in her classroom as a laboratory-based summary as a routine. Similarly, a regular chemistry teacher, C2 from school A, responded, "I've used the CER so many times in my instruction since the training. I use it in formative assessments, question annotations, and checks for understanding." Another biology teachers, B2 from school A, who implemented CER in a similar way as the pre-AP chemistry teacher mentioned above, reported, "I provided practicing CER more than three times before the district test. I have used CER Practices as a prompt-based writing, mini CER Gallery walks in addition to laboratory-based CER " The AP physics teacher, P1 from school A, stated, "My team of teachers usually does two CER writing practices for students each semester, before the district curriculum-based assessments (CBAs). We continue to use the structure even after the district assessments."

These comments shared by the interviewees illustrate that every teacher has either provided practicing more than once (in different forms as mentioned above), or at least one practicing CER opportunity to their students before the district test, as an implementation of CER in their science classrooms. A result can be concluded that if the teachers are providing more incidents of practice CER opportunities to their students, the more comfortable they are in the implementation of CER in their classrooms.

Next, I describe the interviewee's responses regarding the second major themes, *how teachers grade student's CER responses* while implementing CER in their classrooms.

Grading CER

Grading CER, as term, was chosen because it incorporates the common practice that teachers use to measure the students' achievement. The interviewees were asked about their comfortability of using the district CER rubric for grading CER. It is noted from the interviewees' responses that four out of nine teachers are using the district CER rubric with no modification, whereas five out of nine teachers are using the district CER rubric with some modification based on their students' needs found out by grading CERs. It is noted that the district CER rubric is designed for on-level students. Teachers are allowed to make some adjustments or modification based on their students need. The teacher's interview responses regarding their comfort levels of using the district CER rubric for grading CERs are given below.

It is analyzed based on the interviewees' responses that a pre- AP chemistry teacher, C1 from school A, an AP – physics teacher P1 from school A, a pre-AP biology teacher B1 from school A and another biology teacher B2 from school A, are using the district

CER rubric with no modification. All four teachers provided a similar response and rated their comfort level in using the district CER rubric for grading CERs as 5. Here is one quote from the pre-AP chemistry teacher, who responded regarding the comfort level of using the district rubric in grading CER:,

I am very comfortable grading my students' papers using the grading rubric. My rating is a 5 because I include the CER in my lab write-ups. I use the rubric as presented in the standard form, but I assign grades that are aligned to the rubric

4= 100% 3 = 80%   2 = 60%   1 = 40%.

An interesting response was noted from a physics teacher P1 from school B**,** who also teaches ELs, she stated:,

> I used the district provided template for writing CER, but I did not use the district 1, 2, 3, 4 Rubric, I modified it. I used it based on the completion of each section of the CER. If students provide one sentence for the claim, provide two or more sentences for evidence-based on the data points, and two or more sentences for reasoning, then they get a completion grade. That's how it helps me grading my students' CER.

These comments, shared by the interviewees' regarding their comfort level in using the district CER rubric in grading CER indicate that only four teachers are utilizing the district CER rubric with no modification. Whereas, the rest are modifying the district CER rubric based on their students' needs and their comfort level.

To draw a generalized result based on interviewees responses, with a more in-depth analysis, the researcher compared the responses of a newly hired biology teacher B1 from school B, with a newly hired chemistry teacher, C1, from school B:, it is noted that a teacher's writing and grading experience during and throughout academic years may play a significant role in being comfortable in grading and implementing CER in the classroom. For example, the newly hired biology teacher B1 stated regarding grading CER, "I am comfortable in grading CER because I had the experience of grading over 200 lab reports at the collegiate level as a teaching assistant using a similar rubric." In contrast, the newly hired chemistry teacher C1 responded regarding grading CER, "I am not comfortable with being able to grade students CER's accurately because I feel that I did not have the amount of time to be able to grade 150-200 written essays (CERs) with precision and accurately." He also mentioned that his writing experience during his collegiate level was not a prolonged experience. Based on this comparison, it is concluded that even less experienced or first year teachers feel comfortable in grading and implementing CERs if they have writing and grading experiences during their collegiate level and the implementation strategies learned in the district CER training.

In summary, based on the interview responses of the participating teachers regarding grading CER, it is concluded that the majority of teachers are comfortable in grading their students' CER. Still, they are not fully using the district provided CER rubric. They modified it based on the needs of their students or the teacher's comfort. It is noted that the teachers who are teaching regular, pre-AP, or AP classes such as the teacher C1 from school A, the teachers B1 and B2 from school A, and the teacher P1 from school A, are using the district grading rubric with no modification. Whereas, the chemistry teacher C2 from school A and physics teacher P1 from school B are modifying the rubric based on their students' needs as they are teaching to regular and ELs.

Based on the analysis of interviewees' responses, it is concluded that the teachers' educational background, teaching experiences, and especially their writing experiences during their academic years, play a significant role in the implementation of writing and grading CER in their classrooms. It is also concluded that the teachers loved the CER training. They have overall positive perceptions regarding the CER strategy. The majority of the participating teachers are comfortable in implanting CER in their classrooms. They are implementing CERs in their classrooms as a lab write up (summary), open-ended response form, question annotation, textual-based writing, mini CER Gallery walks, and prompt-based writing, but their opinion regarding grading CER differed.

A more in-depth analysis of teachers' responses indicates how the teachers' education and experience, especially writing experience, their perceptions regarding CER and CER training, their comfort level of implanting CERs, and the number of opportunities of practicing CER provided to their students, are the factors that influence teachers in implementing CER in their classrooms. For example, when the researcher examined the pre- AP chemistry teacher, who implement CERs as a laboratory-based summary, consider this: she has 29 years of teaching experience, has a doctorate and had various levels of teaching and writing experience during her academia; her perceptions regarding CER and CER training is also high; her comfort level regarding implementing CER is five (the highest); and she provided many opportunities of practicing CERs in her classroom. The researcher claimed these factors would have benefited her in the implementation of writing CERs in her classrooms. In contrast, it is argued that the newly hired chemistry teacher would have challenges in the implementation of CERs in his class, as his writing experience and skills during the college-level were minimal. However, his perception regarding CER is high, but his comfort level of implanting CER is 3, and he had provided only one opportunity of practicing CER to his students before the district test. I triangulated these qualitative data of the same teachers, their peer reviews, and their quantitative data from table 4.7. The result showed that the pre-AP chemistry teacher's students' average CER score was 79.4%, and the CBA score was 59.8%. Correspondingly, the newly hired chemistry teacher's students' average CER score was 44.6%, and the CBA score was 42.6%.

In the same way, an analysis of biology and physics teachers' implementation of CER in their classrooms showed similar results. For example, the experienced biology teacher, B1 from school A,'s students' average CER score was 43.8%, and the CBA score was 44.9. Correspondingly, the less experienced teacher B2 from school A's students' average CER score was 34.7%, and the CBA score was 33.5%. In the same way, experienced physics teacher, P1 from school A,'s students' average CER score was 51.0%, and CBA average score was 45.6%. Correspondingly, less experienced physics teacher P2 from school A,'s students' average CER score was 45.6%, and CBA average score was 44.9%. See the table 4.10.

Table 4.10

Comparative Data of Experienced Vs Less Experienced Teacher by content

Content Teacher	Experience/ Writing Experience during college level (Yrs.)	Comfort level in grading CER (n)	Students' Ave. CER Score (%)	Students' Ave. CBA Score (%)
Chemistry Teacher C1 from School A	29 / 7	5	79.4	59.8
Chemistry Teacher C1 from School B	0 / 2	3	44.6	42.6
Biology Teacher B1 from School A	17 / 4	5	43.8	44.9
Biology Teacher B2 from School A	7 / 2	4	34.7	33.5
Physics Teacher P1from School A	7 / 4	5	51.0	45.6
Physics Teacher P2 from School A	3 / 2	4	45.6	44.9

Based on these analyses a conclusion can be drawn that teachers' education and experience, especially writing experiences, perceptions regarding CER and CER training, comfort level, and opportunities of providing practicing CERs to their students, are the factors that influence how the teachers implement CER in their classrooms or showed how comfortable they are in implementing CER in their classrooms.

In summary, overall, the analysis of interviewees' responses illustrate that they liked the district CER training, they loved the strategy, and they firmly believe its implementation in their classrooms is worthwhile. They are using this strategy authentically with some modifications and adjustments based on their students' needs. Their perceptions regarding CER and CER training is high. Their overall comfort level of implementing CER in their classroom is high, as evidenced by the number of practicing CER opportunities that they provided to their students.

This concludes discussion of the two major themes, *how teachers implement CER in their classrooms, and how teachers grade student's CER responses* for research question four. Next, I describe the interviewees' responses regarding teachers' perceptions of the obstacles to the implementation of CER in their classrooms.

Research Question Five

Research question five, *What are teacher's perceptions of the obstacles to the implementation of CER in their classrooms?,* was answered based on the data collected from the participating teachers' interview responses. The collected qualitative data was analyzed using an inductive coding process using NVivo. From the interviews, responses were assigned into one theme. The theme was, *teachers' perceptions of the obstacles to the implementation of CER in their classrooms.*

Now, teachers' perceptions of the obstacles to implement CER, is discussed and analyzed.

Teachers' Perceptions of Obstacles in implementing CER

Based on interviewees' responses, it was found that each teacher faced a different type of challenges or obstacles in implementing the CER writing framework in their classrooms. An inductive thematic coding process using NVivo derived this theme into additional themes: (a) students' ability-based obstacles, and (b) students' perceptions - based obstacles. A pattern was noted that when the majority of the teachers described their obstacles or hindrances, they also provided the ways they try to overcome those obstacles in the current and future implementation of CERs in their classrooms. Next, I describe the interviewees' responses regarding students' ability-based obstacles they experienced.

Students' ability-based obstacles. Based on the responses from the newly hired chemistry teacher C1 from school B, chemistry teacher C2 from school A, physics teacher P1 from school B, and the newly hired biology teacher B1 from School B, it was found that these teachers were having similar obstacles, which is themed as student ability-based obstacles. For example, the teacher C2 described her perceptions of obstacles to implementing CER in these words, "The hindrance is working with students with low reading and writing abilities, some of whom may not find the exact part of the literature that answers the question." Similarly, the physics teacher P1 from school B stated,

> The reasoning part gets confusing for my students. They have writing challenges, language barriers and I just tried to accommodate these barriers by giving them points for putting their efforts as they completed their lab and tried to complete their CER. I gave them credit for participation.

Regarding accommodation in grading, a CER training-based accommodation and modification was noted by the newly hired biology teacher B1from school B who described his obstacles and possible solution in these words:,

> My students have difficulty expressing their thoughts in written composition. When guided through each step of a CER, they were capable of explaining to me their claim, evidence, and reasoning acceptably. However, putting their words to paper was an obstacle.

He further explained how he overcame this obstacle, “I used sentence starters or sentence stems that guide students to put their thoughts in writing, and for my ELs learners, I provided visuals as a designated support.” Additionally, “my experience of writing lab reports helped me in implementation of CER writing in my classroom.” He also shared the example of the practice CER that he used with his students. He stated:,

> I had the students write a CER, based on a sample electron micrograph to have them practice writing a claim (whether they thought the cell was prokaryotic or eukaryotic). I asked them to provide support to your claim with evidence (what organelles they saw in the micrograph), and reasoning (which organelles they would expect to find in a eukaryotic cell that would not be present in a prokaryotic cell). I know my students have difficulty expressing their thoughts in written composition. Therefore, I provided these type of sentence stems with visuals of prokaryotic and eukaryotic cell:
>
> I claim that the cell I observed is prokaryotic because it has ----------
>
> I claim that the cell I saw is eukaryotic because -------
>
> My evidence is -----------
>
> The organelle I found in this cell ---------, therefore, I claim --------

This showed a concrete example of the implementation of CER in a biology classroom and the strategies used to overcome the obstacles. This biology teacher tried his best to overcome the obstacle that he experienced with his students for the implementation of CER in his class. It is noted that the use of CER strategies learned during inhouse district CER training and his lab writing experience helped him in implementing CER in his classroom as a first-year teacher. A study conducted by Jackson, Durham, Dowell, Sockel, and Boynton (2016) concluded that CER sentence stems help students become familiar with and comfortable using the scientific discourse they will encounter when speaking, reading, or writing about science. It is also important to mention here that “sentence starters or sentence stems” strategy was modeled and shared with teachers during the district CER trainings, especially for ELs. This is another evidence that teachers not only liked the district CER training, but they are using some of its strategies that were modeled and shared during the training to overcome the obstacles they faced based on students’ ability levels. Next, I describe the interviewees’ responses regarding students’ perceptions-based obstacles they experienced.

Students’ perceptions - based obstacles. A pre-AP chemistry teacher C1 from school A and a biology teacher B2 from school A described their obstacles and hindrances regarding the implementation of writing CER based on students’ perceptions. Both expressed a similar response. Here the researcher describes the response of biology teacher B2,

Since the CER was a relatively new concept, it took some time for the concept to resonate with the students as they were used to conventional methods of writing. As I continued to use the CER concepts practices, students started understanding the benefits of breaking the information down into the CER format as it helped them in expressing their understanding of the key concepts and make a connection. With this continued CER practice, students have finally realized that they must learn to express their thoughts and information learned into the writing format to relay the information effectively.

This comment showed that this teacher considered her students' initial perception regarding CER as an obstacle because her students were accustomed to traditional writing, and CER writing was a challenge in the beginning as breaking down the information into a structure format writing. But, she overcame this obstacle by the implementation of continued practices of CER with her students, and finally, they understand the benefit of breaking down information into the CER format and get familiar with this structured writing. It is noted that this teacher has used CER practices in different forms, such as prompt-based writing and mini CER Gallery walks, in addition to the laboratory-based writing. (This response from her was described in the previous research question). A similar pattern was noted by the response of a pre-AP chemistry teacher, regarding the obstacle she faced in the implementation of CER in her classroom, she wrote,:

> At the beginning, my students did not see the need to break the information down into the CER format because young scholars tend to move their thought patterns away from the objective. By continued practices of CER in the form of laboratory-based and prompt-based writing, they do understand that the ultimate goal of the CER is to make a connection; they finally learn to express their thoughts and information learned into the writing format.

On the contrary, a newly hired chemistry teacher C1 from school B stated, "One of the main obstacles is getting students to understand that science/math classes still require you to write about the topic or subject. They believe that the only time they need to write is in English classes." By comparing the above responses, a result may be concluded that teachers first described their students' initial perceptions regarding CER as their obstacles, and by implementing continued CER practices in their classrooms, they overcame this obstacle. It is noted that they not only described their obstacles but also described the possible solution that they have used. It is also pointed out that the above two experienced teachers' comfort level of implanting CER was 5. Whereas the newly hired chemistry teacher's comfort level was 3, and he just described his students' perceptions regarding writing as an obstacle, but he did not describe what he could have done to resolve his hindrance. It is also noted that he has provided only one CER practice per semester. He has not provided continued CER practices to his students as an implementation of CER in his classroom. Therefore, it may conclude that students' perceptions regarding CER as an obstacle can be resolved by implementation of the continued CER practices in the classrooms.

In summary, the responses from the teachers are not surprising regarding their perceptions of obstacles they faced during the implementation of the CER writing framework in their classrooms. It is noted that the majority of the teachers not only described their obstacles or hindrances, they also provided possible methods they tried or will try to overcome the obstacles they experienced in the current and future implementation of CERs in their classrooms. A conclusion can be drawn that students' CER perceptions-based obstacles that teachers faced in the beginning of implementation of CER could be resolved by the continued practices of CER in different forms such as prompt-based, textual-based, mini CER Gallery walk or laboratory-based writing CERs in their science classrooms.

Summary of Findings

The results obtained from the qualitative data analysis of teacher interviews were triangulated with peer review, members checking and quantitative data. This triangulation validates the quantitative results obtained using Pearson Product Moment Correlation (r) that there is a significant relationship between students writing CER scores and their CBA scores. As students' CER scores increases so does the CBA score:, thus the students' science achievement increased. If students are doing well on CER, evidently the teachers are implementing the CER writing framework in their class. Therefore, it is concluded that the teachers have positive perceptions regarding this strategy as evident in their interview responses.

Conclusion

This chapter presented the analysis of qualitative and quantitative data collected from the researcher's school district data system, interviews, and processes of answering each research question. Overall, the teacher demonstrated positive perceptions regarding the implementation of the CER writing framework in their classrooms. Results of Pearson (r) Correlations showed that a relationship exists between a students' ability to write a CER and their scores on the CBAs. For example, data represented in Table 4.6, 4.7, 4.8, and 4.9 indicated the correlation between the student's ability to write a CER and their scores on the CBA. As students' CER scores improve, CBA scores improve in conjunction with CER scores. The analysis of qualitative data also supports quantitative data findings. Teachers' interview responses and students' samples CERs showed the teachers' implementation of CER in their classrooms varied with their comfort levels. Therefore, the researcher concludes that if the teachers have high perceptions regarding the CER training, high perceptions regarding the CER writing framework, and provide more practice CER opportunities to their students, thereby helping to overcome on the student obstacles to implement CER, then the implementation of CER in their science classrooms is high, and their students are writing quality CERs. It is also concluded that teachers' education and teaching experiences also play a vital role in the implementation of CER in their classrooms.

In the next chapter, findings will be presented to compare what was found through this study with existing literature. Implications of this study in education and future research will be discussed.

CHAPTER V:

SUMMARY, IMPLICATIONS, AND RECOMMENDATIONS

The purpose of this study was to examine the relationship between science writing and student science achievement and how teachers implement the writing strategy claim, evidence, and reasoning (CER) in their science classrooms. Many studies have analyzed the role of writing in the learning process, demonstrating that writing, in conjunction with other activities such as reading and hands-on experiences, contributes to greater critical thinking, thoughtful consideration of ideas, and better concept learning. In other words, the use of writing in science makes thinking visible (Miller & Calfee, 2004). This study supported the previous research in the area of science writing, writing to learn (WTL), learning science through the process of science writing, science-specific argumentative writing, and writing a scientific explanation. Within this chapter, the findings of this study are contextualized in the larger body of research literature. Furthermore, implications and limitations are discussed, and recommendations for future research will conclude the chapter.

To quantify the relationship between science writing and students' science achievement, this mixed methods study collected data from a purposeful sample of high school students and their respective science teachers within a large urban school district located in southeast Texas. The district writing CER and curriculum-based assessment (CBA) data for 25 teachers from the five participating High schools, grades 9-12, were generated from the district data system "OnTrack" for the analysis and answer the quantitative research questions. Nine teachers (3-biology, 3-chemistry, and 3-physics teachers) participated in the semi-structured interview to respond to the qualitative research questions. Quantitative data, collected from the CER writing framework and the CBA, were analyzed using Pearson's product moment correlations (r). The analysis determined the relationship between students' CER scores and CBA scores. The qualitative data from the teacher interview responses were analyzed by an inductive coding process using NVivo to determine how teachers are implementing CER in their classrooms and what their perceptions of the obstacles are in its implementation. The qualitative data analysis found that the implementation of CER in teachers' classrooms depends on these factors: (a) Teacher's education and experience, (b) Teachers' perception regarding CER training, (c) Teachers' perceptions about CER, (d) Teachers' comfort level of implementing CER, (e) Teachers providing practice CERs to their students, (f) Teachers' comfort level using the CER rubric in grading CER, and (g) Teachers' perceptions of obstacles in implementing CER.

Summary

This study specifically addressed the following five questions in contributing to the field of science writing and students' achievement. The research questions addressed whether there was a relationship between science writing and student science achievement. The first three questions are the quantitative research questions. The focus of these question is to examine the relationship between students' science writing and their science achievement by each content area: biology, chemistry, or physics. The contextual analysis of these three questions with literature will be discussed after the discussion of all three content areas' results.

Research Question One

Research Question One, focused on whether there was a relationship between students' Biology writing CER scores and their achievement on the Biology district CBA. Quantitative analysis of the data collected from the district assessment revealed there was a statistically significant positive relationship that existed between students' Biology CER writing scores and their Biology CBA scores. As a student's biology CER writing score increased, so did the student's achievement on the biology district CBA.

Research Question Two

Research Question Two asked whether there was a relationship between students' Chemistry writing CER scores and their achievement on the Chemistry district CBA. Quantitative analysis of the data collected from the district assessment indicated there was a statistically significant positive relationship that existed between students' Chemistry CER writing scores and their Chemistry CBA scores. As a student's Chemistry CER writing score increased, so did the student's achievement on the Chemistry district CBA.

Research Question Three

Research Question Three focused on whether there was a relationship between students' Physics writing CER scores and their achievement on the Physics district CBA. Quantitative analysis of the data collected from the district assessment indicated there was a statistically significant positive relationship that existed between students' Physics CER writing scores and their Physics CBA scores. As a student's Physics CER writing score increased, so did the student's achievement on the Physics district CBA.

For all 25 science teachers' students' (n = 1,754) the average CER score was 47.4%, and the CBA score was 46.3%. This data showed that as students' science CER score increased, so did their science achievement on the district assessment CBA. By comparing all three content areas' CER and CBA scores, the researcher found that the Biology average CER and CBA scores were comparatively lower than the Chemistry and Physics average CER and CBA scores. This may be an indication that Biology district assessment was comparatively more rigorous though all these three subjects are entirely different and have no commonality. Therefore, comparing their scores will be like comparing apples to oranges. Anyway, each content area result showed that there was a statistically significant positive relationship that existed between students' science CER writing scores and their science CBA scores. These results are in agreement with the findings of a previous study conducted by Shaw, Lyon, Stoddart, Mosqueda, and Menon, (2014). The findings of the previous study showed a statistically significant relationship between the integration of science language and literacy practices and the improvement of English language learners' (ELLs') achievement scores in science. The previous study examined the relationship between science language and literacy practices and the achievement scores of only ELLs. Whereas, the current study examined the relationship between science writing CER (one of the literacy components) and students' science achievement in general, including ELLs. The present study also supported the findings of the study conducted by Glogger, Schownke, Holzapfel, Nuckles, and Renkle, (2012). The results showed in two parts; first, students who apply cognitive and metacognitive strategies during writing, learn more than students who do not. Second, the experimental study found that prompting students to use cognitive and metacognitive strategies in their writing significantly increases their learning. The CER writing may be classified as one of the cognitive and metacognitive argumentative writing strategies because this structured literacy process of teaching can improve students' conceptual understanding by using claim, evidence, and reasoning to support scientific explanation, referred to as the CER framework (Zembal-Saul, et al., 2013). It is also aligned with a WTL literature conclusion that argumentative writing was the most effective among other writing activities such as journal writing, summary writing or synthesis-discourse writing (Klein et al., 2016).

The current study used a district modified CER rubric (as shown in appendix E). The study concluded that using rubrics allow teachers to determine students' strengths and weaknesses, which can inform teachers to modify or re-design their future instruction. Krajcik and McNeill (2006) is the pioneer of the CER writing framework. Their research was related to the CER writing framework and student achievement similar to the current study. In that study, Krajcik and McNeill developed a writing instructional framework and broke down the scientific explanation into three components: claim, evidence, and reasoning (CER). In an attempt to analyze students' writing assignments in science, McNeill and Krajcik's team developed a base explanation rubric for scoring their scientific explanation of the written assignments (as shown in appendix A).

The current study also supports a similar study conducted by Sampson, et al. (2013), which was a quantitative study that examined the relationship between students' understanding of core ideas and their science-specific argumentative writing skills. For this study, they used the Argument-Driven Inquiry (ADI) instructional model. The ADI model is student-centered and involves argumentative writing based on laboratory instruction. The length of the study was one school year, during which students participated in a series of science experiments or labs designed based on the ADI instructional model. The study collected and analyzed data using a set of paired-samples t-tests to determine whether the students' scores on the content assessments changed in each course (life science, physical science, biology, or chemistry) at the end of the first and second semesters of instruction. The study concluded that the students' science-specific argumentative writing skills and their understanding of core scientific ideas improved throughout the intervention.

The benefit of using the CER framework in science classrooms can be determined by comparing and contrasting the previous and the current studies. The previous study used an intervention model ADI with science-specific argumentative writing (no structured format). In contrast, the current study used a structured science writing CER framework and student district CBA to examine the relationship between students' writing CER scores and their CBA scores to measure students' science achievement. The CER framework of the current study provides students practicing opportunities in various open-ended forms such as laboratory-based writing, prompt-based writing, textual – based writing, etc.; but, the ADI model was limited to laboratory-based argumentative writing. Also, the current study used a standardized CER rubric for grading students' CERs, but the ADI study did not use any standardized grading rubric. Therefore, the results obtained in the current study generate more credentials and reliability for future studies in science literacy and student's science achievement.

The current study can also be compared with a study conducted by Huerta and Spies (2016). The study suggested that one practical way for educators to simultaneously build students' conceptual understanding and academic language in science is to integrate science inquiry with writing. Additionally, by engaging students in this inquiry practice, students can improve their ability to justify their own written claims (McNeill et al., 2006). The study used the 5E (engage, explore, explain, elaborate and evaluate) model lesson (Bybee et al., 2006) as an inquiry model, one of the teaching methods, which has been used successfully in intervention studies with English Language Learners (ELLs) in the science classroom (Tong et al., 2014). In this elementary-level study, Huerta and Spies (2016), used notebooks as a writing tool. (In the current study the researcher used the CER writing framework as a science literacy writing template, or tool.) The study concluded that integrating literacy activities such as writing in science using journals and inquiry-lesson models improved students' conceptual understanding and academic language, which is similar to students writing in science and students' conceptual understanding or student's achievement. As in this study, students' science conceptual understanding improved by integrating writing and inquiry-lesson models. Similarly, the current study showed that as a student's CER writing score increases, so does the student's science achievement score. Therefore, the benefits of these findings recommend teachers to implement CER writing in their science classrooms to develop students' science concepts and increase the achievement scores in their science content specific standardized tests.

Research Question Four

Research Question Four studies how science teachers implement the CER literacy writing framework in their science classrooms; it was answered using an inductive thematic coding process using NVivo based on the interview responses obtained from nine teachers (three teachers from each content areas: biology, chemistry, and physics) from two participating schools of a large urban school district located in southeast Texas. Responses were organized into two major themes: *Implementation of CER*, and *Grading CER.* A contextual analysis of qualitative data collected from the interview's responses from each teacher's description of implementation of CER writing is described below.

Implementation of CER

The interview responses from the participating teachers regarding *implantation of CER* were organized into four subthemes themes: (a) Teachers' Education and Experiences, (b) Teachers' Perceptions regarding CER Training, (c) Teachers' Perceptions regarding CER, and (d) Teachers' Comfort level of implementing CER in science classrooms.

Teachers' Education and Experience. Teachers' responses to the interview questions pertaining to their educational background and experiences, especially their writing experiences during collegiate level having any impact in implementing CER in their classrooms, were varied across all participants. Feedback from the participants indicated that the teachers with higher educational background and having extensive writing experiences at the collegiate level were more comfortable in implementing CER in their science classrooms compared to less experienced science teachers. For example, five out of nine teachers, who had a doctorate or master's degree, had teaching experience in the range from 7 to 29 years, and had an extensive writing experience during their academia, rated their comfort level 5, the highest. Four out of nine teachers, who had a graduate degree, had teaching experience ranges from 0 to 3 years, rated their comfort level of implementing CER between 3 and 4. Responses from teachers indicated that experienced teachers provided more CER practices (three or more per semester) to their students compare to the less experienced teachers (provided at least one CER practice per semester). Therefore, a conclusion was drawn that teachers' education and experience may play a role in how often and how effectively teachers implement CER writing in their classrooms. If a teacher's education and experience are high, then there is a greater chance of implementing CER in their classroom more often or vice versa. The findings from the current study confirm and align with the research conducted by Rice (2010). The result showed that, on average, teachers with more than 20 years of experience are more effective than teachers with no experience but are not much more effective than those with 5 years of experience.

Teachers' perceptions regarding CER training. When examining the factors that influence writing in science and student achievement, teacher training is considered to be essential. Many studies have demonstrated that effective teachers have a high correlation with student success (Brown, 2010; Hamel & Merz, 2005; Marchant, 2004). Therefore, to improve students' achievement at levels demanded by the high standards, accepted by states and districts, teachers would have to help them reach these levels. Consequently, students' performance depends on the qualifications and effectiveness of teachers. As a result, professional teacher training is a significant focus of districts' systemic initiatives (Vangrieken, Meredith, Packer, & Kundt, 2017). In the current research, the district CER training was required for teachers to participate in the interview responses regarding the implementation of CER in the science classrooms. Overall responses shared by the interviewees indicated the teacher's perception of the CER training was positive. The majority of the participants liked the training and training materials. Therefore, a conclusion can be drawn that if the teachers' perceptions regarding the CER training are high, then there are greater chances of the CER implementation in their classrooms. A common response was noted that the CER training benefitted them greatly in different ways, such as customizing and fine-tuning their writing skills and the means of implementing CERs in the classrooms. During training, teachers were able to discuss CER writing strategies in science and looked at peer's and students' samples, grading CERs as a norming process. In short, teachers were impressed by the training, and it inspired them to implement CER in their science classrooms.

Teachers' Perceptions regarding CER. Teachers' responses to the interview questions pertaining to the perceptions regarding CER were frequent and consistent across all participants. Overall teachers' perceptions regarding CER were positive. The findings showed that if the teachers see the benefit of CER strategy or have positive perceptions regarding CER, there are higher chances of CER implementation in teachers' classrooms. The analysis of teachers' perceptions regarding CER was similar to the results found in the literature. For example, a biology teacher stated, "CER requires students to use textual-based evidence that sharpen student's literacy skills. As they identify and write claims, find evidence, and conclude reasons in their thought process, which are reflected in their scientific writings." This quote is mirroring the writing perspective explained by the National Center of Education Statistics (NCES, 2012) that requires students to use writing to predict, describe, explain, and draw conclusions about science topics or concepts. These comments are in agreement with the previous study conducted by Zohar and Nemet (2002), which reported that writing helps students learn science concepts in a constructivist approach: they found that student content knowledge increased when they created, supported, and evaluated claim statements. Additionally, these findings are aligned with the literature review that defines CER as an instructional writing framework that helps students write to support scientific explanations (Zembal-Saul, et al., 2013).

Overall, teachers expressed positive perceptions regarding CER that impacted its implementation in their classrooms. The teachers' beliefs relating to CER summarize that the CER framework is a valuable tool for teaching, writing, and thinking, especially in science, and can be used for any topic and skill level. CER is a good check for understanding in concept development in science and strengthening the use and understanding of academic vocabulary, in lab investigation, in science exploration, and it also builds scientific conceptual understanding. These comments support the conclusion of Zembal-Saul, et al. (2013) that CER writing framework is a literacy integration method that can improve students' conceptual understanding.

The current study's qualitative results of teachers' perceptions regarding CER that impacted its implementation in science classrooms, are in the form of an investigation-based, prompt-based, textual-based, and laboratory-based writing CERs that support the previous research conducted by Huerta, and Spies (2016). The study suggested that one practical way for educators to simultaneously build students' conceptual understanding and academic language in science is to integrate science inquiry with writing. The findings of the study showed that student's science conceptual understanding improved by integrating writing and inquiry-lesson models.

Similarly, the current study showed that if the teachers' perceptions regarding CER was high, then teachers' implementation of CERs in their science classrooms were evident in the form of laboratory-based, investigation-based writing, etc. Consequently, the qualitative findings of the study support the quantitative results:, “Based on teachers' implementation of CER in science classrooms, as the student's CER writing score increases, so does the student's science achievement score."

Comfort Level of implementing CER. Based on teachers' responses pertaining to the comfort level of implementing CER, a conclusion can be drawn that if the teacher's comfort level of implementation of CER is high, then the teacher must be implementing CERs in their classroom. As evidence, students' collected samples of CERs were analyzed to see how the teachers implemented CER in their classrooms. The findings showed that overall, the teachers' interview responses regarding their comfort levels of implementing CER in their classrooms were relatively high. Based on closer examination of the teacher's work and students' CER samples, a conclusion can be drawn that teachers are implementing CER in their classrooms based on their comfort levels and in different formats such as a laboratory-based summary, prompt-based writing, textual-based writing, or mini CER galley walks.

Grading CER

The interview responses of the participating teachers grading CER concluded that the majority of teachers were comfortable in grading their students' CER. Based on the teachers' responses, a result was found that some teachers were not entirely using the district provided CER rubric during CER practices and the district CBA time. The teachers modified the district CER rubric based on the needs of their students or the teacher's comfort level. The findings also showed that the experienced teachers who teach regular, pre-AP, or AP classes used the district grading rubric with no modifications.

Whereas, the less experienced teachers who teach regular and ELLs modified the district CER rubric based on their students' needs and implemented some modifications that they learned during the district CER training such as using visuals and sentence stems or sentence starters, especially for their ELL students to help them put their thoughts in writing.

Furthermore, with regards to how teachers implemented the CER writing in their science classrooms, a conclusion can be drawn based on the analysis of the teachers' responses:, the findings showed that the teachers' educational background, teaching experiences, and especially their writing experiences during their academic years, played a significant role in the implementation of writing and grading CER in their classrooms. The findings also showed that the teachers loved the CER training, and their perceptions overall regarding the CER strategy was positive. The majority of the participating teachers were comfortable in implementing CER in their classrooms. The teachers implemented CERs in their classrooms as a lab write up (summary), open-ended response form, as question annotation, textual-based writing, mini CER Gallery walks, and prompt-based writing, but their opinions regarding grading CER differed. Teachers modified their students' CER grading based on the students' needs.

Research Question Five

Research Question Five regarding teachers' perceptions of the obstacles to the implementation of CER in their classrooms, was answered using an inductive thematic coding process using NVivo based on the semi-structured interviews with science teachers from the two schools of a large urban school district located in southeast Texas. Responses were organized into one major theme that revealed subthemes: (a) Teachers' perceptions based on students' ability-based obstacles and (b) Teachers' perceptions based on students' perceptions - based obstacles. From the interviewee's responses, a positive aspect was noted that the majority of the teachers did not only describe their obstacles or hindrances; they also provided the possible ways they tried to overcome those obstacles. Some teachers, especially less experienced, who struggled in overcoming the obstacle they faced during CER implementation, made commitments to use some modification strategies they learned during district CER training and provide more CER practices opportunities to their students in the future implementation of CERs in their classrooms. A contextual review of the interviewees' responses regarding students' ability-based obstacles that they experienced is described below.

Students' ability-based obstacles. Four out of nine teachers responded regarding the challenges they faced based on working with students with low reading and writing abilities. During the CER writing, teachers' students were having difficulties finding the exact part of the literature that answers the CER question. Teachers also mentioned that during the reasoning part, students get confused about making connections with scientific facts or concepts. This comment is aligned with the findings of a previous study conducted by Loch (2017) with 9th-grade biology students. Loch reported that, in the survey, when asked what the most challenging part of writing a scientific explanation was, 27% of students (N= 41) mentioned that providing reasoning was most difficult. Therefore, teachers need to model more on how to make a connection of a claim and evidence with the scientific concepts or principles to create reasoning.

Furthermore, some teachers claimed their students' reading level was four or five grades below their current grade level. Therefore, they had to modify the district CER grading rubric. The district CER grading rubric was designed for on-level students, and teachers are allowed to make adjustments and modifications based on their students' needs. Some teachers, to overcome the language reading and writing barriers accommodated their grading based on the completion and efforts of students in writing

CER. Some teachers made modifications and adjustments in their instructions based on the district CER training recommended strategies. For example, a biology teacher made modifications and adjustments in his CER writing and grading based on his students' needs. The biology teacher noted that his students experienced difficulty in expressing their thoughts in written composition. Though, students were able to understand and explain the process of writing CER when guided through each step of a CER. However, putting their words to paper was an obstacle. To overcome this obstacle, the teacher used sentence starters or sentence stems that guide students to put their thoughts in writing, especially for his ELLs learners. The teacher also provided visuals related to content vocabulary based on the CER question as designated support. Additionally, the teacher shared the example of the students' practice CER and the adjustment or modification that he made. The teacher provided students sample sentence stems and the visuals as designated support. The teacher asked students to write a CER, based on a sample electron micrograph observation of a cell. During students practice writing a CER based on the electron micrograph cell observation lab, the teacher provided question stems for each part of the CER. For example, to establish a claim, the provided question prompt was, “Do you think the cell is prokaryotic or eukaryotic?” For the evidence part, the teacher provided a question prompt, “What organelles do you see in the micrograph?”, And for reasoning, “Which organelles would you expect to find in a eukaryotic cell that would not be present in a prokaryotic cell?” Since the teacher knew his students are struggling to put the words in composition, he provided the following sentence starters (sentence stems):

I claim that the cell I observed is prokaryotic because it has ----------

I claim that the cell I saw is eukaryotic because -------

My evidence is -----------

The organelle I found in this cell ---------, therefore, I claim --------

The researcher compared his accommodation with literature and found alignment with a previous study conducted by Jackson, Durham, Dowell, Sockel, and Boynton (2016). The study concluded that CER sentence stems help students become familiar with and comfortable using the scientific discourse students will encounter when speaking, reading, or writing about science. During the district CER training, the "sentence starters or sentence stems" strategy was modeled and shared with teachers, especially for ELLs. Based on this example, the teachers' responses regarding students' ability-based obstacles and how to overcome the obstacles, a conclusion can be drawn that teachers were using the research-based strategies to overcome the obstacles that they faced regarding their students' ability based in the implementation of writing CER in their science classrooms.

Students' perceptions - based obstacles. Three out of nine teachers described their perceptions regarding their students' attitude towards CER as an obstacle. Since the CER was relatively new to the students, the acceptance of CER framework was a challenge. For students, to understand and integrate the CER process with the conventional methods of writing would take some time for them to adjust. Therefore, teachers tried to overcome with this obstacle by continued practicing CER concepts in the classrooms, until students started understanding the benefits of breaking the information down into the CER format, since it helped them express their understanding of key concepts and make a reasoned connection. With continued CER writing practice, students have finally realized that they must learn to express their thoughts and information learned into the writing format to relay information effectively. Students finally understand that the ultimate goal of the CER is to make a connection; they must learn to express their thoughts and information learned into the writing format. Based on these comments, a conclusion can be drawn that students' perception-based obstacle towards

CER as a new concept could be overcome by teacher's continued providing CER practice opportunities to their students for effective implementation of CER in their science classrooms. Another obstacle regarding students' attitude towards writing was that a majority of the students believe that the only time they need writing is in English class; math/science classes don't require them to write about the topic or subject. This aspect of students' attitude towards writing in science could also be corrected by a continued practicing CERs in science classes.

Implications

As a result of this study's findings of the science teacher's perceptions regarding CER implementation and the relationship between students CER writing and students' science achievement, several implications for administrators, teachers, and students emerged.

Implications for Administrators

For administrators, this research revealed a critical need for leaders to understand, that teachers need a supportive environment to learn new approaches to instruction and assessments (Asghar, 2014). Additionally, school administrators play a critical role in influencing the school climate, which affects the classroom climate through vision, mission, and belief system (Ball, & Cohen, 1996). School administrators are primarily responsible for developing and leading the vision for a school community. Administrator support is essential to create an environment that encourages teachers to learn new approaches, take risks and try new strategies and techniques like the CER literacy strategy. A supportive environment involves providing professional development opportunities to teachers to improve their practice (Asghar, Ellington, Rice, Johnson, & Prime, 2012). School administrators are the leaders of a school, and their vision impacts the school's academic program. In addition, school administrators are responsible for providing teachers with effective and engaging professional developments. Based on the findings of the study, in addition to the district training, administrators should provide teachers purposeful training that emphasizes the importance of literacy integration, such as implementation of writing framework CER in science classrooms for students' science achievement and how teachers can overcome the obstacles that they face in the implementation of CER in the science classrooms. Furthermore, district and school administrators also need to review the district CER rubric, which can be standardized for all learners and monitor the modification in the rubric based on students need under the district guidelines and CER training based recommended strategies especially for ELLs.

Implications for Teachers

For teachers, the findings provide support for their perceptions regarding CER and its implementation in the science classrooms. The study revealed that teachers have a significant influence on the success of CER implementation and its impact on students. Teachers have witnessed that the study had shown the positive relationship between students' CER writing and students' science achievement. The current research shows that when teachers are implementing CER in their science classrooms, as the students' science content CER writing score increases, their achievement score on the district assessment increases. The findings of the study show the implications for teachers to align with the guidance recommended for teachers by Krajcik and McNeil (2005). According to Krajcik and McNeil (2008), secondary school students find constructing their scientific explanations particularly challenging. Therefore, it is essential for teachers to reinforce the CER framework, especially regarding when, how, and why it can be used. To do so, teachers can explicitly explain each part of the CER to help students understand the importance of each component. Not only must students understand what a CER framework explanation is, but they must also understand how the CER framework can construct a scientific explanation. The study also uncovered the need for teacher professional development that emphasizes how to increase implementation of CER and how teachers can overcome the obstacles in the implementation of CER in science classrooms.

Lastly, this study highlights the importance for teachers to model how to construct scientific explanations using the CER framework. Additionally, the students will be able to witness examples of what a well-written explanation is and be able to analyze what writing is appropriate and effective (Sutherland, Krajcik, McNeil, & Colson, 2006). Qualitative interviews revealed that teachers had modeled and provided sample CER practices to their students before students participated in the district CER writing. This is in alignment with the research recommendation that students need opportunities to make claims based on available evidence and then use science concepts to justify why the evidence supports the claim (Novak and Treagust, 2018)

Implications for Students

The findings of this study also highlight the importance for students to see the benefit of using the CER writing framework as a life-long learning skill to understand the science concept by applying critical thinking and structured cognitive writing. This is aligned with the literature that recommends middle and high school students not only meet the expectation of general reading and writing competencies but also to master literacy skills and strategies to unlock and convey content knowledge within a given discipline such as science (NRC, 2012). According to Mathis (2018), the CER model can be scaffolded for all writing and speaking levels. In Mathis (2018) study, the CER model was implemented at the elementary school level. One of her students commented, “the CER model taught me how to make an argument I can support when my ideas conflict with others. I use this method any time I have to write a paper or make a presentation.”

Therefore, students need to take the ownership of the CER writing framework as their lifelong writing skills in order to be successful in their future learning and acquire the skills for work/career success; and also to increase the likelihood that they will actively participate as citizens of a literate society (Graham, Harris, & Hebert, 2011).

Recommendations for Future Research

Several recommendations are suggested for future research. First, replicating this study in similar districts would provide additional data to develop the contributions of this work. Second, take the current data and apply other parameters to isolate specific populations such as Hispanic, African American, etc. and see the impact of the implementation of the CER writing on their science achievement score. Since this study was limited to five schools, expanding research to include more schools in the district and also to analyze the outcomes of why certain teachers in the district implemented CER in their science classrooms and why certain teachers did not. Therefore, the study of greater magnitude would give a larger sample size to increase the potential for finding even more significant results. The third recommendation would be comparative research with the inclusion of a control group versus the CER implementation groups of schools. Furthermore, this information could assist in identifying what stakeholder groups need to be targeted to improve the overall perception of the CER writing framework and its implantation in classrooms, not only in science but in other content areas, too, for the overall improving and strengthening students' writing skills.

The findings of the current study showed that teachers are still struggling to implement CER, especially with their ELL students. Therefore, future research may focus on teachers' CER training that should include specific strategies to support ELL students' CER writing. Another future recommendation is that CER writing could be introduced at the lower grades both elementary and middle school levels, so when students come in

High schools, they feel comfortable using CER writing and show more improvement in their science achievement scores in the standardized tests. The final recommendation for future research would be to investigate how gender and ethnicity of students impact their science achievement based on their CER writing. This type of research could provide more insight in regard to the implementation of CER in science classrooms and its impact on students' science achievement.

Conclusion

The purpose of this study was to examine the relationship between science writing and student science achievement and how teachers implemented the CER writing strategy in their science classrooms. The ultimate focus was to determine the teachers' perceptions regarding CER, district CER Training, teachers' comfort level, teachers' perceptions of obstacles of implementation of CER, and how teachers are implementing CER in their science classrooms. From this study, the school district will have a better idea about what factors influence the CER implementation in science classrooms for improving students' writing skills and students' science achievement. The findings of the study would also allow the district to assess the effectiveness of teachers' professional development on CER writing and student achievement. The district could also then use this data to assess changes needed in professional development training. The findings, implications, and recommendations from this study contribute to the ongoing efforts to develop better and more effective methods for promoting CER implementation in science classrooms.

As indicated in the literature review, writing is a critical tool for scientific literacy and inquiry (Yore & Treagust, 2006). Developing literacy skills in students has become an international goal of schools' science education programs in the past few decades. (Bybee, McCrae, & Laurie, 2009). One instructional writing framework which may address this need and the international goal is known as the CER writing framework, a process of teaching students how to write to support scientific explanations (Zembal-Saul, McNeill, & Hershberger, 2013). Therefore, this framework was used in this study. The findings supported the need and goal described in the literature. The study had provided significant results of students' achievement in science by the implementation of writing CER in science classrooms. In summary, teachers who continue to improve students' science achievement and their critical thinking to support scientific explanations are more likely to engage students in CER writing in their science classroom.

In conclusion, the findings of the current study are in the alignment of the new Common Core Standards (CCS) that requires students to write arguments to support claims with clear reasons and relevant evidence (Kuhn, Hemberger, & Khait, 2017). Therefore, according to Zembal-Saul, McNeil, and Hershberger (2013), teaching students to use CER to support scientific explanation improves students' writing skills, which also supports the idea that it is not just an option for our students to write well; it is a necessity because possessing excellent writing skills is an indicator of educational achievement and an essential requirement of the life-skills needed for participation in civic life and the global economy (Graham & Perin, 2007).

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APPENDIX A:

INTERVIEW QUESTIONNAIRE COVER LETTER

University of Houston Clear Lake

September 2018

Dear Science Teacher:

Greetings! You are being solicited to participate in the Interview Questionnaire regarding the implementation of writing framework claim, evidence, and reasoning (CER) in your classrooms. The purpose of this Interview Questionnaire is to examine the relationship between science writing and student science achievement and how does the implementation of science writing affect teachers' pedagogical beliefs and practices.

Please try to answer all the questions. It will take approximately 20-25 minutes to participate in the interview or writing your responses to the interview questionnaire form. All of your responses will be kept completely confidential. No obvious undue risks will be endured, and you may stop your participation at any time. In addition, you will also not benefit directly from your participation in the study.

Your cooperation is greatly appreciated and your willingness to participate in this study is implied if you proceed with participation in the interview questionnaire. Your participation in the *Interview Questionnaire* is not only greatly appreciated, but invaluable. If you have any further questions, please feel free to contact me at your convenience. Thank you!

Sincerely,
Muhammad Abid
UHCL Doctoral candidate
832-633-7562
Abidm4388@uhcl.edu

APPENDIX B:

INFORMED CONSENT TO PARTICIPATE IN RESEARCH

You are being asked to participate in the research project described below. Your participation in this study is entirely voluntary and you may refuse to participate, or you may decide to stop your participation at any time. Should you refuse to participate in the study, or should you withdraw your consent and stop participation in the study, your decision will involve no penalty or loss of benefits to which you may be otherwise entitled. You are being asked to read the information below carefully and ask questions about anything you don't understand before deciding whether to participate.

Title: Correlation of Claim, Evidence, and, Reasoning as a Writing Framework and Students' Success Rates in High School Science District Standardized Tests

Student Investigator(s): Muhammad Abid

Faculty Sponsor: Brenda Weiser, EdD.

PURPOSE OF THE STUDY

The purpose of this research is to examine the relationship between science writing and student science achievement and how does the implementation of science writing affect teachers' pedagogical beliefs and practices.

PROCEDURES

The research procedures are as follows: The participants will be asked to meet at a convenient time and location to participate in an interview. The participants will be asked open-ended questions about their implementation of Writing Framework claim, evidence , and, reasoning (CER) in their science classroom and how does it affect their pedagogical beliefs and practices. The responses will be recorded for accuracy.

EXPECTED DURATION

The total anticipated time commitment will be approximately 25-30 minutes.

RISKS OF PARTICIPATION

There are no anticipated risks associated with participation in this project.

BENEFITS TO THE SUBJECT

There is no direct benefit received from your participation in this study, but your participation will help the investigator(s) better understand the use of social media by teachers and its influence on professional growth.

CONFIDENTIALITY OF RECORDS

Every effort will be made to maintain the confidentiality of your study records. The data collected from the study will be used for educational and publication purposes, however, you will not be identified by name. For federal audit purposes, the participant's documentation for this research project will be maintained and safeguarded by the Student Investigator for a minimum of three years after completion of the study. After that time, the participant's documentation may be destroyed.

FINANCIAL COMPENSATION

There is no financial compensation to be offered for participation in the study.

INVESTIGATOR'S RIGHT TO WITHDRAW PARTICIPANT

The investigator has the right to withdraw you from this study at any time.

CONTACT INFORMATION FOR QUESTIONS OR PROBLEMS

If you have additional questions during this study about the research or any related problem, you may contact the Student Researcher, Muhammad Abid, at phone number 832-633-7562 or by email at abidm4388@uhcl.edu.

SIGNATURES:

Your signature below acknowledges your voluntary participation in this research project. Such participation does not release the investigator(s), institution(s), sponsor(s) or granting agency(ies) from their professional and ethical responsibility to you. By signing the form, you are not waiving any of your legal rights.

The purpose of this study, procedures to be followed, and explanation of risks or benefits have been explained to you. You have been allowed to ask questions and your questions have been answered to your satisfaction. You have been told who to contact if you have additional questions. You have read this consent form and voluntarily agree to participate as a subject in this study. You are free to withdraw your consent at any time by contacting the Principal Investigator or Student Researcher/Faculty Sponsor. You will be given a copy of the consent form you have signed.

Subject's printed name:____

Signature of Subject: ____

Date: ____

Using language that is understandable and appropriate, I have discussed this project and the items listed above with the subject.

Printed name and title: ____

Signature of Person Obtaining Consent: ______________________________

Date: ____

APPENDIX C:

INTERVIEW QUESTIONNAIRE

Interview Questionnaire

The following represents a list of questions for the participants in the oral, written or telephonic interview. Since the questions will be asked in the context of a dynamic conversation, the following list provides an outline of the interview. The wording of questions during live interviews may differ slightly or there may be follow up questions based on a participant's answer.

1. Have you attended district-wide CER Writing Professional Development (PD) or similar PD in any other district? What are your beliefs regarding this literacy strategy?

2. Describe your teaching experience, your college majors, languages and writing experience that you were having during your academic years, your teaching certification and aptitude towards writing in science.

3. On scale 1-5 (5 being the most and 1 being the least), how comfortable you are to implement the writing framework CER in your classroom after attending the district training? Why did you give that rating? OR Justify your rating.

4. On scale 1-5 (5 being the most and 1 being the least), how comfortable you are in grading students CERs after practicing grading sample CERs in the district training? Justify your rating.

5. How did you grade your students CER, explain the process? Show your sample and explain why your student scored the way you graded?

6. How often have you used CER writing practices with your students in your classrooms before students participating in the district curriculum-based assessments (CBAs) in semester 1 and in semester 2? Can you provide some sample?

7. What are the hindrances or obstacles you faced in implementing writing claim, evidence and reasoning (CER) in your classrooms?

8. How does the use of writing framework CER in science affect teachers' pedagogical beliefs and practices?

APPENDIX D:

BENCHMARK RUBRIC

Science Benchmark Lab Rubric

Subject____________LabName____

Component	Level			
	0	1	2	Feedback
Claim – A conclusion that answers the original	Does not make a claim or makes an inaccurate claim.	Makes an accurate but incomplete claim	Makes an accurate and complete claim	
Evidence – Scientific data that supports the claim. That data needs to be appropriate and sufficient to support the claim	Does not provide evidence, or only provides inappropriate evidence. (Evidence that does not support the claim)	Provides appropriate, but insufficient evidence. May include some inappropriate evidence	Provides appropriate and sufficient evidence to support claim	
Reasoning – A justification that links the claim to the evidence. It shows why the data counts as evidence by using appropriate and sufficient scientific principles.	Does not provide reasoning, or only provides reasoning that does not link evidence to claim	Provides reasoning that links the claim and evidence. Repeats the evidence and/or includes some scientific principles, not sufficient.	Provides reasoning that links evidence to claim. Includes appropriate and sufficient scientific principles.	

Claim Evidence and Reasoning (K. McNeill and J. Krajcik, 2005 Basic Rubric)

APPENDIX E:

SCIENTIFIC EXPLANATIONS RUBRIC

Claims, Evidence and Reasoning – Scientific Explanations Rubric Linked to SBAC Argumentative Writing

	4	**3**	**2**	**1**	**0**
Claim – a conclusion that answers the original question	• Scientifically accurate • Completely answers the question • Common inaccurate claim(s) are clearly addressed.	• Scientifically accurate • Nearly completely answers the question • Inaccurate claim(s) are only generally addressed, no specifics	• Partially scientifically accurate • Partially answers the question • Inaccurate claim(s) are not addressed	• Is not scientifically accurate overall • Does not adequately answer the question	No claim
Evidence – scientific data that supports the claim	• The data are scientifically appropriate to support the claim. • The data are thorough and convincing – enough details and evidence provided. • Proper units are used in data • Shows with evidence why alternate claims do not work	• The data are scientifically appropriate to support the claim • The data are basically sufficient and convincing, but tend to be more general and not as specific and in depth • Does not address why alternate claims do not work • Evidence may be repetitive	• The data relate to the claim, but are not entirely scientifically appropriate • The data are not sufficient, though generally support the claim	• There is some evidence provided, but it is not logically linked to the claim or scientifically appropriate	No evidence provided
Reasoning – a justification that links the claim and evidence	• Reasoning clearly links evidence to claim • Shows why the data count as evidence by using appropriate scientific principles • There are sufficient scientific principles to make links clear between claim and evidence	• Reasoning adequately links claim to evidence • Includes related scientific principles, but only passably clarifies why this data count as evidence • Reasoning tends to be more general and shows only partial depth of content understanding	• Reasoning does not adequately link claim to evidence, or clarify why data count as evidence • Includes related and non-related scientific principles, and shows little depth of content understanding	• Reasoning is clearly insufficient and relates only tangentially to question and claim at hand • Scientific understanding is very limited	Does not provide reasoning
Language and Vocabulary	• Response clearly and effectively expresses ideas using precise, scientifically appropriate descriptions and vocabulary	• Response adequately expresses ideas and scientifically appropriate descriptions and vocabulary, but they are more general than specific	• Response inconsistently and sometimes inappropriately expresses ideas or scientific descriptions and vocabulary	• Scientific language and vocabulary are not precise or appropriate	Not under-standable
Focus and Organization	• Focus only on question at hand • Logical progression of ideas • Clearly stated and focused claim that is strongly maintained	• Focus mainly on question at hand, some loosely connected material present • Logical progression of ideas • Clearly stated and focused claim that is adequately maintained	• Focus not consistent on question at hand • Progression of ideas not entirely logical • Have a claim, but it's not entirely clear or maintained	• Focus not at all consistent • Progression of ideas not logical • Have an unclear claim that is not maintained	No clear focus or organiza-tion

Rubric adapted by Kevin J. B. Anderson from K. McNeill and J. Krajcik (2005), NSTA, and SBAC Argumentative Writing Rubric for grades 6-11