2019

Explicitly Teaching Scientific Argumentation: Using Action Research to Study High School Science Readiness and Detracking

Ami Lefevre

LOYOLA UNIVERSITY CHICAGO

EXPLICITLY TEACHING SCIENTIFIC ARGUMENTATION: USING ACTION RESEARCH TO STUDY HIGH SCHOOL SCIENCE READINESS AND DETRACKING

A DISSERTATION SUBMITTED TO

THE FACULTY OF THE GRADUATE SCHOOL OF EDUCATION

IN CANDIDACY FOR THE DEGREE OF

DOCTOR OF EDUCATION

PROGRAM IN CURRICULUM AND INSTRUCTION

BY

AMI LEFEVRE

CHICAGO, ILLINOIS

AUGUST 2019

ACKNOWLEDGEMENTS

I would like to express my profound appreciation to Dr. Lara Smetana, dissertation chair and mentor, for all her wisdom and encouragement. Dr. Smetana, your knowledge and insight about science education research taught me how to conduct research, as well as how to construct a deeper understanding of science curriculum and instruction. Your questions challenged my own thinking and made me reflect on my own learning experiences. Because of you, I transformed as a learner, educator, and leader. I treasure the hours of conversation we had about science pedagogy and current research. It is a rare opportunity to find someone like you who can speak the same scholarly science education language! Thank you so much for your guidance and patience as I moved through the stages of research.

I would also like to offer special thanks to my dissertation committee members: Dr. Leanne Kallemeyn and Dr. Elizabeth Ferrell. Dr. Kallemeyn, you provided invaluable support and feedback about my research, and within my coursework. You enriched my understanding of qualitative research and the practical use to assess data driven decision-making. I learned about research methodology and the evaluation process, but more importantly how to be critical thinker. You can analyze and systemically identify how to improve our learning. Dr. Ferrell, thank you so much for volunteering your time to participate on my dissertation committee. I was amazed at how you balanced your full time teaching job and dedication to doctoral students. You are a role model for all

educators and represent a true academic scholar. Because of you, I can see the power of building knowledge through scholarly discourse. I cannot express enough how much I appreciate your feedback and grammar lessons!

Dr. David Ensminger, you were my trusted advisor for four years and became a voice of reason for me. Your words of wisdom and deep probing questions guided my study and provided confidence in myself. The IRB process was a challenge, but with your guidance, I was able to move forward with my study. I am extremely grateful for all your assistance. Thank you so much for teaching me to be a reflective researcher. I am particularly grateful for the assistance given by the dedicated teachers who spent countless hours improving instructional practices through our action research study. Our goal was to eliminate inequitable practices by detracking students of color. Michele, your background in reading and literacy was critical to our growth as a team and the development of curriculum. You provided deep insight to how we could improve instruction as well as student learning. During our meetings, you provided a fresh perspective and made me think deeper about what we could do differently. Thank you for all the time you spent in the ECP classroom. You really went beyond what was expected. Anthony, you were transparent about the challenges associated with the work. At times when you thought, we needed to move in a different direction you spoke up, and continued to support our work. You are in the trenches each day and work very hard to prepare our students to be successful in future courses. We all recognize how much you care for students and their well-being. John, I also appreciate your candor about our work. You were dedicated to the work and often initiated new ideas on how to change lessons. It is mentally draining to teach ECP day in and out, but you persevered and

made a difference with students. It was amazing to see how your actions moved the class forward in learning. To the team, please know this dissertation study would not have been possible without you. Thank you for this experience and all you have done to help me grow as an educator.

For the past five years, I have balanced my role as an administrator, doctoral student, mother, daughter, and wife. Keeping balance was only possible with my loving family. Bob, my love and best friend, you have always supported my wishes and desires. I am forever grateful for your understanding and for being so reliable. You are always there when I need you. During my academic journey, you have waited patiently and provided constant encouragement. Thank you for taking care of me, without you I would never have reached my goal.

William and James, my boys, this accomplishment also involves you. You gave me the drive to achieve my goal. The more we know the more we grow as a family. There is never a time to stop learning. I hope you set your goals high and finish what your start. Live your life to the fullest!

Kikue, my mother, you may not realize the life lessons you have taught me over the years. In 1965, you came to this country faced with many challenges. Through the culture shock and lack of acceptance, you persevered. You were a role model for me as I engaged in this research with a social justice lens.

In conclusion, I would like to acknowledge Martin John Foley, my father. You are with me in spirit and affect who I am down to my soul. Your words of wisdom are still with me and inspire me to be a lifelong learner. I know you would be proud.

TABLE OF CONTENTS

APPENDIX

LIST OF TABLES

LIST OF FIGURES

Figure Page

ABSTRACT

Access to advanced-level science courses can be difficult for those students who start in a tracked system. Tracking is an educational practice where students are assigned to different classes based on ability level. African American and Hispanic students are most at risk since most minority students are found in the lower level track (Burris, 2014; Mehan, 2015; Oakes, 2005). This investigation used an action research approach to determine how explicitly taught elements of scientific argumentation would influence student mastery of argument skills and influence instructional practices by a professional learning community. A mixed method study collected qualitative and quantitative data with an action research approach. A professional learning community collected data through cycles of actions research. The professional learning community collected evidence to make claims about how to instructional practices. The findings revealed how the process of action research influenced instructional practices, and improved student written and verbal understanding of elements of argument. The results of this study added to science education research related to scientific argumentation in the science classroom.

CHAPTER I

INTRODUCTION

Background and Statement of the Problem

The mission statement of District 2 School Township (2017) publically stated, “the purpose of District 2 is to provide an equitable, student-focused learning environment where every student graduates prepared and ready for college” (p.1). The emphasis on college readiness in the mission statement influenced curricular decisions and change to science course scope and sequence. Reform efforts were set in place to detrack students so they would all be college ready. Top-down decisions stemmed from the No Child Left Behind (NCLB) Act, which required each school district to report results of student achievement and to disaggregate the results by demographic subgroups. In 2016-2017, the Illinois Report Card posted disaggregated data about District 2 African American and Hispanic students and found students of color performing below average on all standardized test scores (Illinois State Board of Education, 2018). On the 2018 Illinois State Science Assessment, 80% of African American students and 53% of Hispanic students scored in the “not proficient” category. The majority of White and Asian students scored in the “proficient” category. The trend in test result disparity was a call for action by our school district as well as school districts across the nation (Bookwalter, 2019; Burris, 2010; Darling-Hammond, 2010). District 2 administration followed federal mandates with a sense of urgency. Swift decisions were made to implement detracking reforms with a goal of lessening the achievement gap for students of color. Administrators were concerned with the low scores on standardized ACT tests and the number of students of color in lower-level core subject courses. The goal was to make all students college ready. The implementation of detracking efforts had a goal of preparing students for higher-level college preparation courses. The detracking effort included the elimination of basic level (lowest level) science courses. Freshmen students had two course options: a regular or honors level freshman Biology course. This detracking reform effort magnified inequality among students, particularly our students of color. Course enrollment data collected from one high school, NW High School, in District 2 confirmed the inequality. Over a three-year period, trends in data revealed students of color moving into the lower level science courses. The detracking efforts by District 2 had the opposite intention of moving students into higher-level science courses.

The case of detracking in District 2 is not alone. Other school districts, such as Evanston High School, removed the lowest-level freshman science course as well. In 2017, Evanston High School reported positive results for regular level students moving into Advanced Placement courses. In 2010, the high school removed the lowest level freshman English, history, and Biology courses for the vast majority of students (Bavis, 2017, p. 37). The goal was to eliminate achievement and opportunity gaps. Prior to the removal of the lowest level course, Evanston High School students enrolled in honors, mixed-honors, mixed-regular, and regular tracks based on a single standardized test score from 8th grade. Evanston found great variability in course expectations, assessments, and semester exams. The school eventually eliminated all levels of Biology and created an "honors credit model". The honors credit model allowed students to take a series of assessments to earn honors credit while still enrolled in the one level Biology course. If students passed these exams, they earned honors credit for the Biology course. Students with low reading and math levels do not take a science course during their first year of high school. Instead, they move into alternative science courses during their sophomore year.

Evanston believed that this form of detracking caused an increase in the percentage of students taking AP courses during their junior year (Bavis, 2017, p. 39). Evanston reported more "regular-level" students enrolled in honors level and AP courses. Recently, Bookwalter (2019) reported that Evanston High School has seen an increase in AP enrollment and test scores. Data presented to the Evanston District school board found there is still a distinct performance gap between black and white students (Bookwalter, 2019, para. 6). Students of color are not taking more AP courses. One school board member stated that there are more societal issues causing the achievement gap and that these are issues out of the schools' control.

According to Hugh Mehan (2015), there are schools who successfully detracked without eliminating course levels. For example, the Preuss School in San Diego instituted academic and social supports such as an advisory period during the school day and enrolled every student in a college prep course. They also extended the school year to provide more time for building trusting relationships. In another successfully detracked school, Gompers Preparatory Academy in San Diego incorporated longer school days, Saturday Academy, school uniforms, professional development plans for teachers, research, evaluation, governance expertise, and college student tutors. In both situations, more academic and social support systems were implemented to raise student academic achievement. A school wide united front was instituted for the betterment of the academic experience.

At NW High School, removing the lowest level freshman science courses increased failure rates in the regular level Biology course, and magnified tracking in science courses across a three-year period. NW High School is one of two high schools in District 2 where this study took place. According to the course enrollment data collected from the NW High School database, 10% of all students in enrolled in the 2014-2015 Biology (regular level) course failed. In year prior, the average percentage of failures was around 3%. NW High School science teachers anecdotally describe the students who failed Biology course as being disengaged and unmotivated to learn. These same science teachers reported failing students struggled to understand the science content and they gave up on learning. Disheartened students failed the course, or received at most a D as a letter grade. The failing students moved on to repeat Biology or placed in a low-level physical science course. Credit recovery was difficult for students who failed Biology during freshman year. High school students attend school for four years. Many of these students ran out of time in school to make up the credit. NW High School students must earn one year of life science (Biology) credit and two years of physical science credit to graduate.

The increase in number of student failures magnified the tracking pathway and increased the risk of students dropping out of high school. Evidence of magnified tracking appeared in the 2017-2018 school year when the lowest level science course, called Science Topics, more than doubled in student enrollment. The majority of students who failed Biology eventually placed into the lowest level science course, Science Topics, as juniors. If removing our lowest level freshman science course was successful, we should see these students move into Conceptual Physics 10-20 or Conceptual Chemistry 10-20 by their junior year. Both of these courses are higher-level science courses than Science Topics. Students in the Science Topics course tend to be struggling learners who read at a 5^{th} grade level and have not mastered Algebra. The researcher collected STAR reading scores from the NW High School database to determine the average reading level of Science Topics students. In addition, the researcher looked at transcripts of each enrolled Science Topic student to see which math course they reached.

Table 1 shows data with the percent of students enrolled in each junior year science course. The researcher collected the data found in Table 1 from District 2 databases. Course enrollment data for all science courses was through the NW High School database. The data presented in this table is concerning. During the years following the removal of the lowest-level freshman science course, we noticed an increase in Science Topic student enrollment and a decrease in Physics 10-20 and Chemistry 10-20. The trend in data show how students moved toward the lowest level science course. The data proves the removal of the lowest level freshman course was counterintuitive to intent of the detracking reform. Unfortunately, over a three-year period the opposite result occurred. Removing the lowest level Biology course, as intended by District 2 administration, did not detrack students toward higher-level courses. *Table 1* shows the trend of students enrolled in a junior level science course from 2015 to 2018. The number of students taking the basic level science course, Science Topics, moved from 70 students to 133 students while the next higher-level science course, Physics 10-20, dropped in student enrollment from 129 to 90. Chemistry 10-20 also experienced a drop in student enrollment from 171 students to 136. The trend showed an increase of student enrollment toward the lowest level Science Topics course.

Table 1

NW High School Course Enrollment from 2015 to 2017

NW High School Course Enrollment from 2015 to 2017 (% of students enrolled in course out of total student population)						
Science Course Junior Year	**2015-2016**		**2016-2017**		**2017-2018**	
	# Students Enrolled	**% Enrolled**	**# Students Enrolled**	**% Enrolled**	**# Students Enrolled**	**% Enrolled**
Science Topics (basic)	70	2.66%	87	3.32%	133	5.29%
Physics 10-20 (basic)	129	4.91%	112	4.27%	90	3.58%
Chemistry 10-20 (basic)	171	6.51%	140	5.34%	136	5.41%
Physics 12-22 (regular)	286	10.89%	305	11.63%	296	11.78%
AP Physics 1 (honors)	139	5.29%	106	4.04%	134	5.33%

Disaggregated course enrollment data over the three-year period brought up another concern: the lack of students of color in higher-level science courses. There is a higher percentage of African American and Hispanic students found in lower level science courses. There was a disproportionate percentage of students of color in our lower level science courses. In *Table 2*, the data shows a higher percentage of African American and Hispanic students in comparison to the total population of students enrolled in Science Topics course. In 2015-2016, the total student population in the school was 6% African Americans and within the Science Topics course, 17% of the students were African American students. Hispanic students experienced similar trends. In 2015-2016, NW High School had 15% Hispanic students in the total student school population and 26% of all students enrolled in Science Topics were Hispanic. As the difficulty level of the science course increased, the percentage of Hispanic students enrolled in the course decreased (26% Hispanic in Science Topics, 30% Hispanic in Chemistry 10-20, 22% Hispanic in Physics 10-20, 17% Hispanic in Physics 12-22, and 6% Hispanic in AP Physics 1). The percent of students of color in higher-level science courses did not represent the percent of African American and Hispanic students found in the total student population. *Table 2* lists the junior year (or third year) science course options and percentage of students in each course by race. Additional course enrollment data from the past three years is in Appendix A.

Table 2

NW High School Course Enrollment by Demographics from 2015 to 2017

NW High School Course Enrollment by Demographics from 2015 to 2017 (% of Student by Ethnic Group out of the total students in the course)						
	# Students Enrolled	**% 2015-2016**	**# Students Enrolled**	**% 2016-2017**	**# Students Enrolled**	**% 2017-2018**
Total Population						
African American	147	6	105	4	121	5
Asian	840	32	866	32	834	33

Hispanic	394	15	420	16	377	15
White	1224	47	1186	45	1105	44
Science Topics (basic level)						
African American	12	17*	6	7	8	6
Asian	14	20	16	18	32	24
Hispanic	18	26	26	30	35	26
White	25	35	38	44	56	42
Chemistry 10-20 (basic level)						
African American	15	9	7	5	11	8
Asian	36	21	38	27	29	21
Hispanic	50	29	29	21	41	30
White	68	40	62	44	52	38
Physics 10-20 (basic level)						
African American	9	7	8	7	7	8
Asian	31	24	24	21	25	28
Hispanic	23	18	34	30	20	22
White	66	51	47	42	37	41
Physics 12-22 (regular level)						
African American	9	3	18	6	9	3
Asian	77	27	116	38	101	34
Hispanic	49	17	40	13	50	17
White	152	53	131	43	127	43
AP Physics 1 (AP level)						
African American	1	1	3	3	1	1
Asian	70	50	52	49	66	48
Hispanic	10	7	4	4	8	6
White	60	43	48	45	62	45

* 17% of African American students in 2015-2016 decreased to 6% in 2017-2018 due to the increase of total number of students in the course.

Solution to the Problem

Detracking by the elimination of the lowest level science course will not solve the problem of inequitable practices associated with tracking at NW High School. Rubin and Noguera (2004) support this argument with this statement, “Put more simply, it is not enough to ‘just take them out’ of the track” (p. 99). Changes to curriculum and pedagogy that provide access, interest, challenge, and relevance would better serve our students when trying to detrack students in the high school. Deliberate lesson planning by teams of teachers with the support of professional development and resources from administrators are necessary components of the curriculum changes that lead to successful detracking. District 2 recognized tracking as an inequitable practice, but only eliminated the lowest level science course as a means for reform. This was not the right approach, as evidenced by the data. I would argue for detracking by means of interventions built into a low level course rife with scientific argumentation skill building, so those students can access more challenging curriculum in future years.

Numerous research studies have stated inequitable learning experiences in lower track courses cause students to fall behind academically and remain in lower level courses (Oakes, 2005; Burris, 2014; Darling-Hammond, 2010; Hallinan, 2004). In a meta-analysis study, Jeannie Oakes (2005) observed tracked lower level courses and found these courses to have lower expectations and scant curriculum. These learning conditions limited the ability of students to succeed in future courses. Thus, a solution to the problem of inequitable learning conditions would be to provide interventions that maintain high expectations and quality science curriculum that maximize student academic growth. Irubine (2010) believed “building students’ skills of analysis and critique” is one best practice to use when detracking students (p. 9). Academically at-risk high school freshmen would benefit from interventions that develop thinking skills, reasoning, and problem solving. Designed curriculum that explicitly teaches elements of scientific argumentation as an intervention will improve student critical thinking skills, student dialogic skills, and empower student voice. The mastery of argumentation skills leads to successful detracking as students move to future courses.

In the 2017-2018 school year, a new freshman-level science course, called Exploratory Chemistry and Physics (ECP), began at NW High School to teach scientific practices of argumentation and other science practices that develop critical thinking skills. A goal of the ECP course is to develop critical thinking skills by mastery of argumentation skills. Exploratory Chemistry and Physics is a physical science course with an emphasis on developing fundamental science practice skills for future science courses such as regular level Biology.

Windschitl, Thompson, Braaten, and Stroupe (2012) state, “Of all factors linked with student achievement in schools, the day to day practices of teachers exert the most powerful influence on learning” (p.879). In 2017-2018, ECP science teachers and a literacy coach (professional learning community, PLC team) started an action research study at NW High School. The purpose of that action research study was to see the impact of argumentation-based curriculum on students’ academic achievement. The PLC team identified scientific argumentation as an area to focus on within the ECP curriculum. Scientific argumentation is a common skill needed by all subjects across the school. Common Core English Language and Arts, Common Core Math, and the Next Generation Science Standards have objectives related to this skill. Mastering scientific argumentation skills would have the greatest impact on skill building across all courses. In addition, NW High School Biology teachers noticed that struggling students in years past often isolated themselves from group work. Scientific argumentation involves verbal discourse in groups, and thus the PLC team felt this skill set might build confidence in students while working with peers. Scientific argumentation builds critical thinking skills in writing as well. Students learn how to collect evidence, write claims, justify with reasoning, and rebuttal findings. Scientific argumentations have multifaceted layers of critical thinking involved.

The results of the pilot study found a need for explicitly teaching elements of argument in both verbal and written students discourse. Results indicated the majority of students could write a claim and list evidence, but found it very difficult to justify their reasoning with evidence. Students really struggled with verbal discourse since they did not understand the elements of argumentation. In this action research study, designed curriculum will explicitly teach elements of argument and identify the impact of this curriculum on student argument skills. We hope to see ECP students develop stronger science argumentation abilities, since science argumentation is such as critical component of science education, we hope strengthening these core science practices will prepare them to also successfully advance into higher level Biology, Chemistry, and Physics science courses.

Statement of Purpose

The purpose of this action research study is to investigate how the process of action research influences our instruction of scientific argumentation and, subsequently, student mastery of elements of argument. We hope the explicit focus of scientific argumentation during lessons will promote student development of critical thinking skills and student readiness for upper level science courses. Our theory of action is to develop argumentation curriculum that results in changes to instructional practices, which thereby leads to improved student outcomes in the science classroom. The process of action research and the products that came from the development of the ECP curriculum influenced other science courses. The action research approach and argumentation model acted as a framework for other science courses at our school. The team hoped students would use their prior knowledge and learn more deeply about argument from one year to the next.

The designed curriculum will focus on developing scientific argumentation skills. The National Research Council (NRC)'s *A Framework for K-12 Science Education* (National Research Council, 2012) and the related Next Generation Science Standards (NGSS) (NGSS Lead States, 2013) describe argumentation as a core scientific practice students should progressively master through school. Scientific argumentation is the process by which scientific explanations and engineering solutions progressively achieve over the span of K-12 grades. Within the context of K-12 science education, the NGSS standards for argumentation states:

> Engaging in argument from evidence in 9–12 builds on K– 8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to

> defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science (National Association of Science Teachers, 2014, p.7).

This statement provides an expectation for student learning related to argumentation in high school. The progressions of science and engineering practice skills involves the ability of students to construct an argument with evidence to support a claim. Students from kindergarten to senior year in high school build up their knowledge about scientific argumentation. Argumentation is the means by which students present their ideas and engage in science sense making. The process of argument requires social interaction between students. Yerrick and Gilbert (2011) recognize the social dynamics, they state "As a part of current national science education reforms, students are now being asked to construct scientific argument and teachers are currently being challenged to prepare their students to construct and reflect upon scientific knowledge instead of simply receiving it" (p. 69). Science educators should plan more than delivering science content. Building a community where students construct their understanding of science content is critical for learning.

Curriculum for this research study was designed by the NW High School literacy coach and researcher to explicitly teach elements of scientific argumentation. The lessons were scaffolded to teach the elements of argument: claim, evidence, reasoning, and counter arguments. The goal is for students to show progressive mastery of these elements through written work and dialogue. The instruction will emphasize the importance of argumentation as socioscientific skill, which requires communities of learners to communicate scientifically. The study will examine the ways students generate and evaluate components of scientific arguments, and accurately utilize argument from the science perspective through verbal and written student discourse.

A focus on scientific argumentation has the potential for a myriad of benefits. Eduran and Jimenez-Aleixandre (2011) argue that students who are engaged in argument have many benefits such as learning science concepts, science discourse, altering scientific views of science, and assist in socioscientific decision making. Additionally, constructing scientific argument requires teachers to relinquish control over the classroom dialogue and allow students critical examination of their own thinking. Students are empowered by their voice during argument. Seiler (2011) describe student voice in the classroom as “where students had freedom to participate in science using their own ways of speaking and sense making, that is when they were not asked to leave who they are at the school door” (p. 375). Quaglia and Corso (2014) observed student voice as the process where students proactively participate in the greater good of learning. Teachers ask for student opinions and listen to what students share, and incorporate students into the leadership of the classroom (Quaglia & Corso, 2014, p. 2). In addition to examining the curricular impact on student ability with this scientific practice, this research study will also gain insight into the role verbal discourse has on students during argument.

In summary, this study hypothesizes that the benefits of learning about and engaging in written and verbal scientific argumentation using evidence may positively influence student learning and success in the ECP course, increasing the likelihood of successful matriculation into higher-level science courses at NW High School. After freshman year, the goal is for students in our lowest level science course, Exploratory Chemistry and Physics, to move into higher levels of Biology, Chemistry, and Physics science courses. Research studies have shown that argumentation promotes student critical thinking skills and construction of scientific knowledge (Kuhn, 1991; Osborne, 2010; Osborne, Erduran, & Simon, 2004; Sampson & Clark, 2008). Ultimately, acquisition of argumentation skills will build science knowledge and dialogic skills, which may lead to detracking science course placement.

Research Questions

The guiding research questions in this action research study will examine how the action research process influenced instructional practices and how students' understanding of the elements of scientific argumentation change over time. Collaboration during this action research study occurred between the members of a professional learning community (PLC) team: researcher (who is also a practitioner), NW High School science teachers, and the NW High School literacy coach. One goal of the PLC team was to develop argumentation curriculum that explicitly taught elements of argument so students could improve and master argumentation skills. Collectively, the PLC team took action to improve instructional practices and curriculum. There are three primary questions (RQ1, RQ2, and RQ3) that guide this action research study:

- Research Question 1 (RQ1): How does the process of action research influence our instruction of scientific argumentation in a high school science course?

- Research Question 2 (RQ2): How does a student ability to write scientific argument develop over time?
- Research Question 3 (RQ3): What role did verbal discourse play in students developing understanding of elements of argument?

The research questions are both technical and adaptive in nature. The mastery of scientific argumentation through written and verbal discourse may appear to be technical, but the basis for argumentation involves social interactions as well. The success of student understanding depends on how well the students construct knowledge in a group setting, and then apply what they learn as individuals. Social interactions in small groups can enhance a student's understanding of claim, evidence, and reasoning.

Rationale and Significance

The research questions will produce findings that will inform the professional practices of the PLC team. NW High School science teachers learn how to collaborate as a team and modify instructional strategies to promote argumentation as a scientific practice. The entire PLC team learns more about the deeper meaning of argumentation, and creates curriculum to help students master the practice of argument. Changes to the ECP curriculum and the products produced from this action research study will have a lasting impact on future ECP students. On a personal level, this study will deepen my own understanding of how to lead a PLC team, and affect other stakeholders, such as the science department, school, district, and network of educators.

This action research study can be used as a model for science educators trying to implement argumentation as a science practice in their classroom. Interested science educators may find the developed argumentation curriculum, rubrics, student work templates, and other instruments useful. Many science educators are still trying to make meaning of the NGSS three-dimensional approach, as well as the implementation of the NGSS science practices (NGSS Lead States, 2013). Developing curriculum and assessments relating to science practices is a challenging and complex process. The *Science ECP Student Questionnaire* used in this study may reveal beliefs and values about group dynamics and student voice. Argumentation is associated with science practice, but may also influence student empowerment of voice through discourse. The classroom should be a place where meaningful dialogue allows students to construct scientific knowledge. "As Paulo Freire (1970) put it, to empowering students to understand the society around them and their own capacity to transform it" (Jimenez-Aleixandre & Erduran, 2007, p. 8). The tools used in this study, such as the use of the claim, evidence, and reasoning (CER) rubric, can help others understand the elements of argumentation and application in the classroom. However, the tools should not be used alone to improve argumentation. The rubric serves its purpose as a tool for measuring quality argument. It does not consider the importance of social interaction to construct knowledge.

Action research can contribute to positive changes on a local level, as well as act as a model for other schools using the same approach. The collaborative approach in action research empowers teachers to solve problems and is a source of learning for the group. The researcher and the literacy coach began the action research cycle by teaching lessons that are explicit to components of argumentation. Science teachers continued to teach ECP and adjusted their lessons to what we learned through the action research PLC meetings. Participants in action research studies collaborate to produce critical knowledge aimed at social transformation (Pine, 2009, p. 54). However, in this action research the PLC team was focused on how to make instructional changes to improve student understanding of argumentation as a science practice. The long-term goal of the PLC team is used to create meaningful work that emancipates oppressive practices and barriers. The findings of this study will not include the long-term impact, but it ongoing work to make systemic change. This will contribute to the field of science education with a lens for equity pedagogy.

Overview of the Subsequent Chapters

Chapter II explains the meaning of tracking from a systemic and classroom perspective. A broad review about tracking practices, the debate over whether to detrack courses, and the history of tracking provides context for this action research. Interwoven in this discussion is the connection of equitable practices that lead to detracking. Next, the review of literature narrows the focus of the research to interventions that may support successful detracking reforms within the high school. The definition of argumentation is stated along with reasons for why argumentation was selected as a science practice. Chapter II concludes with an analysis of curriculum design frameworks used to measure elements of argumentation.

Chapter III presents the goals of action research and the significance of the approach in this study. The details of the action research plan with the three cycles are shared. The methodology used in this study is qualitative and uses the sociocultural theory as a conceptual framework. Data collection tools and explanations of how the data was analyzed is included.

Chapter IV introduces the findings of the action research study through visual displays and narrative data that connect findings from the problem, research questions, and design of study. The chapter explains the rationale for data organization and analysis along with a report of the main findings of the qualitative study. The reflective and narrative writing used in this chapter is in line with action research because of the lived experiences that align within the process.

Chapter V will synthesize and discuss the patterns and themes that emerge from the findings and my own reflection as it relates to the literature review and conceptual framework. The chapter will conclude limitations of the study and recommendations for future research.

CHAPTER II

LITERATURE REVIEW

Introduction

Discriminatory practices of tracking accumulate over time and may influence student success in high school and the opportunity to attend college (Mehan, 2015). Lewis and Diamond (2015) argue, “even single instances of discrimination at a key decision point can have long-term cumulative effects” (p. 115). The impetus for this action research study came from the analysis of data related to tracking in a local setting. Evidence from NW High School course enrollment data supported a sense of urgency to transform the oppressive system of tracking. Ironically, actions of detracking reform from prior years increased the number of students tracked into lower level courses. In 2017-2018, new detracking reforms were implemented with the goal of improving literacy skills needed to succeed in higher-level science courses. The success of students of color were of particular interest because of the high percentage of tracked students in lower level science courses.

The scope of this literature review begins with general information about the origins of tracking, the educational connection to tracking, and the debate over whether to detrack. The background information about tracking gives context to the broader issues of oppressive systems in education and as well as to multiple methods of detracking. Rubin (2006) states “a curriculum that provides multiple entry points and is accessible to students working at a variety of levels is essential for detracking" (p. 9). Curriculum that has culturally relevant pedagogy, flexible approaches to grouping, and builds student skills of analysis and critique are all considered best practices for detracking. Eliminating the lowest level course alone will not lead to successful detracking.

The rest of the literature review attempts to show the connection between culturally relevant pedagogy and empowerment of student voice through the use of argumentation skills. Designed curriculum that improves argumentation skills is central to science practice (Osborne, Eduran, & Simon, 2004). Argumentation skills may be associated with an emancipatory process of knowledge production and improve student voice in the science classroom. Very few research studies associate the development of scientific argumentation skills with equity pedagogy. The majority of scientific argumentation research focuses on task design and analytical frameworks.

Review of Literature

Tracking

Tracking is an educational practice where students are assigned to different classes based on ability level. Oakes (1985) defines tracking as a sorting of students where they are separated in a public manner by intelligence and accomplishments, labeled by learning type (high ability, low achieving, slow, average), defined by others, and have a different schooling experience. Tracking comes in many different forms related to the classroom and within the larger system. Tracking within the classroom may relate to ability grouping where teachers place students in groups according to perceptions of their capacity to learn. Within the larger school system, schools may track students by the course scope and sequence year to year. Wheelock (1994) defines tracking as the “practice of sorting secondary school students into different programs of study, often called college preparatory, general, or vocational” (p. 1). Research studies have concluded that the practice of tracking will negatively affect students. Students in the lowest track never catch up to the average performing student because of slow-paced curriculum and low expectations.

Historically, students are separated by race, socioeconomic status, gender, and academic ability. Hallinan (2004) opposed all forms of tracking since “critics argued that tracking, especially in practice, created greater learning opportunities for high-performing students at the expense of their lower-performing peers” (p. 74). One common finding in tracking practice has been the overwhelming percentage of minorities and low socioeconomic students found in low tracks and the under representation of the same students in advanced levels. Oakes (2005) conducted multiple research studies that show how poor and minority students were disproportionately placed in low performing tracks. The lowest tracks in the science course scope and sequence at NW High School is no exception to Oakes statement. There is a high percentage of African American and Hispanic students in the lowest level science courses. Unfortunately, students enter high school unprepared for high school expectations. Research by Rubin and Noguera (2004) state “that once children are placed in lower track classes (in some places this may begin in elementary schools with the creation of reading groups), they are more likely to encounter lower teacher expectations, a watered-down curriculum, and inferior instructional materials” (p. 93). High schools need to prepare for lower performing students and provide a quality education with interventions, challenging curriculum, and high expectations. Many school districts are implementing detracking reforms to counter the inequitable systems of tracking. Rubin (2006) defines detracking as "a reform in which students are placed intentionally in mixed-ability heterogeneous classes" (p. 4). The single course of rigorous instruction in a heterogeneous mix of ability level is not the answer to countering inequitable systems. Detracking is not a technical change in the course guide. It is a cultural change in belief systems and requires academic and social supports.

School districts implementing detracking reforms to counter the inequitable systems of tracking should be wary of what and when is detracked. I would argue that the timing of moving students into higher-level courses, implementation of support systems, and availability of academic interventions are critical to the success of detracking students. Timing when to detrack students within the organizational structure should be addressed in a collaborative evidence-based manner. Incoming high school students need fundamental skills and knowledge in both reading and math to be successful in high school science courses. Unfortunately, many students enter high school without the necessary skills to succeed in an on-level science course. Therefore, one should be careful of when freshman-level science courses are detracked. Oakes (2008), a proponent of detracking, makes a comment about the appropriate time to detrack courses. Oakes (2008) writes:

> the Finns and other 'high achieving' societies (e.g. the other Scandinavian countries, Canada, Hong Kong-China, and Japan) have apparently concluded that

> tracking (at least prior to age 15) is fundamentally inconsistent with having all students meet the same high academic standards and perform well on the same tests (p. 702).

Great consideration should be given to the quote from Oakes (2008) that states, "…at least prior to age 15". If schools decide to detrack it may best to do so before students are 15 years old or essentially before high school. Burris and Garrity (2008) state, "Detracking should begin where tracking begins. If your elementary school tracks, that is the place to start. If tracking is delayed until the middle school years, begin there" (p.26). A decision to remove lower level science courses in high school should be thoroughly investigated. Rubin and Noguera (2004) state further studies need to be done to determine whether detracking efforts will be successful so late in high school.

Removing lower level courses is not a quick fix to issues related to tracking. A collaborative action research study in one urban public high school detracked two lower level Biology courses in order to provide equitable opportunities to the growing disadvantage and minority population (Caro-Bruce, Flessner, Klehr, & Zeichner, 2007). The two lowest level Biology courses were eliminated from the science program. This research study hypothesis stated:

> if the biology and special education staffs embrace change by heterogeneously grouping students and by implementing inclusive strategies and other practices consistent with the objectives set forth in the National Science Education Standards, it will result in a successful experience for all students and staff as measured by increases in student attendance and grade point averages among

> lower achieving students and increase positive attitudes on surveys administered to all biology students, the biology staff, and the special education staff (Caro-Bruce et al., 2007).

The results of this study show higher attendance rates, but the grades of the heterogeneous grouping of students did not improve. Evidence from this study results in positive changes related to behavior, but does not improve student academic achievement. The question of whether students are too far out of their zone of proximal development to be successful remains. Rubin and Noguera (2004) suggest conducting more studies that determine which organizational and structural supports are needed to successfully detrack courses. Also, an "honest and informed discussion must take place over the issue of whether some subject areas (for example math and science) are too complex and dependent on previous preparation for detracking" (Rubin & Noguera, 2004). An example would be upper level science courses, such as Chemistry and Physics, which require students to apply prior knowledge math skills. If students do not understand how to isolate out variables in equations, then they tend to struggle with computational skills in science.

Tracking-Detracking Debate

The majority of research studies report that tracking can have a negative impact on student performance, particularly those students of low socioeconomic status and African American and Hispanic ethnicity. However, several studies support the tracking practice. In 1998, an influential report written by the Thomas B. Fordham Foundation supported the norms of tracking curriculum. This report concluded that tracking did not cause impoverished students to inferior schooling nor did it support adoption of detracking (Duflo, Dupas, & Kremer, 2009). In 2005, the International Child Support Africa funded a study about tracking and found that teachers could best tailor instruction to help student needs when they were tracked. Duflo, Dupas, and Kremer (2009) examined whether tracking could improve student learning. Two school systems were analyzed in Kenya. The design of the first experiment included 140 schools. Half of the schools were tracked and the other half not tracked. Student achievement was measured using test scores. The results found that students in tracked schools performed higher than students in heterogeneous groups. The reason tracking worked was due to focus of on teaching and greater teacher effort. Pickens and Eick (2009) investigated motivational strategies used in tracked science courses. Strategies used in the higher tracked classroom included enthusiasm in presentations, promoting non-threatening environments, and implementing everyday applications. In the lower track, the teachers used strategies such as increasing dialogue, using practical applications, building confidence, and using hands-on activities. This case study approach investigated the effect of motivational strategies presented by two experienced science teachers. Each teacher taught differently tracked students. One teacher taught the advanced level and the other the general level. Interviews, classroom observations (field notes), debriefing conversations, focus group interviews, student survey, and researcher reflection were used to analyze the results. The summary and implications of this case study turned out as one would predict. The students in both levels benefited from the positive learning environment. The positive learning climate and teaching style in this study made an impact on student learning despite the tracked system. The one criticism to this study is the lasting impact tracking has on these students in all the studies described. Academic performance in the study was compared within the cross-sectional time period. It is questionable whether these students have been challenged enough to move to a higher track and succeed. One question remains about the lasting impact of tracking on these students as they move on in school.

Educators who support tracking believe students learn better, when they are amongst peers who have the same academic abilities and it is easier for teachers to accommodate individual differences in homogeneous groupings. Oakes (1985) states, "we have virtually mountains of research evidence indicating that homogeneous grouping doesn't consistently help anyone learn better" (p. 7). She concluded there are no consistent benefits of homogeneous groupings, but recognized studies that show the brightest students learn more when in homogeneous groupings. In addition, Oakes (1985) states that "some studies have found that learning of students identified as being average or low, has not been harmed by their placement in homogeneous groups" (p.7). Oakes is an advocate for detracking school curriculum, but also recognizes there are limited studies that show a neutral position. Argys, Rees, and Brewer (1996) examine the impact of tracking on student achievement by use of the National Education Longitudinal Study student survey. They control teacher and classroom characteristics with empirical calculation models. Results from the study conclude that below average math classes benefited from detracked classes, but the average and above average classes were harmed.

Research studies have concluded that tracking negatively affects students. Grouping and placing students in a low academic track is concerning since this placement will affect student performance beyond the current grade. Students never catch up to the average performing student because of slow paced curriculum and the decline of learning expectations in lower level courses (Burris, 2010; Oakes, 1990; Solorzano & Ornelas, 2004). Homogeneous ability grouping is problematic for students who are in the lowest track because student track movement occurs far more frequently toward the lower track than towards the higher track (Burris & Garrity, 2008). In addition, access to advanced level science courses can be difficult for those students who start in a tracked system. Mastery of higher learning standards is difficult for students to attain if they are not prepared nor expected to learn as much at the lower level.

The number of research studies that support detracking clearly outweigh the number of studies supporting tracking. The effects of detracking have been documented to increase student achievement overall and lessen the achievement gap. Guyon, Maurin, and McNally (2012) investigated whether increasing the size of a higher detracked course could improve student achievement. Administrative data sets were used from the Department of Education in Northern Ireland to analyze how detracking influenced students. The basic research question was whether detracking of grammar school admission would improve college-entrance exam results. The results show the mid-ability group who would not normally attend the elite secondary school benefited the most from detracking.

Hyland (2006) examined tracking and detracking in various subject areas. The author emphasizes the need for heterogeneous grouping in social studies classes because all students need a solid foundation of understanding democracy. In order to make changes and influence policy all citizens need to be able to dialogue about history and policy. Hyland found research studies that support detracking. Low performing students scored five percentage points higher on their achievement tests in their heterogeneous math class.

Watanabe, Nunes, Mebane, Scalise, & Claesgens (2007) present their qualitative research study about detracking chemistry courses at Highlander High School. The high school moved from four levels to two levels. Highlander High School is a low socioeconomic status public school in California that implemented a detracked Chemistry curriculum. This high school eliminated lower tracks and moved from four levels to two levels. The theoretical framework is grounded in the interpretive framework, and highlights how classroom curricula are socially constructed. The teachers and students interact to create the learning experience. Interviews with teachers, interviews with students, classroom observations, teacher inquiry group observations, and teacher journals were used to analyze whether four essential components influence the success of detracking. The author pointed out that this study is rare since there are not many science-course detracking studies available. Grounded theory was used to build the theory based on the results of this study. The research study found heterogeneous chemistry classrooms were most successful when teachers believed students develop in their learning, focus on inquiry-based pedagogy with real world context, focus on science study skills, and have a strong sense of community in the classroom. The Wallace and Brand research study found similar social constructs; teacher social awareness will influence instructional practice.

Rockville Centre School District in New York incorporated detracking reform movements throughout all disciplines in their high school. South Side High School was the first high school in the district to gradually start detracking courses. The rigors of the International Baccalaureate (IB) program became the curriculum for all 9th and 10th grade students. Burris (2010) noted that "after detracking 95% of African American and Hispanic students earned a Regents diploma- up from 37% before detracking- 87% of the students took at least one IB course" (p. 30).

Corbett and Garrity (2008) found "lower-achieving students who were placed in a higher-level math course by mistake increased their chances of successfully completing a college prep course of math study" (p. 24). Early in high school, students accidentally placed in a higher math track were found to be successful in college prep math courses later on. Detracking is a practice worth examining if it can raise academic expectations and increase the representation of minorities in advanced level science courses. However, one must be careful with the conclusions of this accidental study. These results should not be the sole reason for detracking.

The opportunity to learn from a challenging individualized curriculum with high learning standards should be provided to all students. A free and appropriate public education should include the examination of individual student needs, so students are not just passed through the school system.

Equity and the Achievement Gap

Tracking in schools is thought to be an inequitable practice since it places many low income and minority students into lower tracked courses. Homogeneous academic ability grouping has systematically oppressed African American and Hispanic student populations. According to Oakes (2005), tracking has a significant impact on the African American-White achievement gap. African American and Hispanic students are most at risk since most minority students are found in the lower level track. Rubin and Noguera (2004) state "Upper tracks, including honors, gifted, and advanced placement courses have disproportionate numbers of students from affluent backgrounds, while the lower tracks, especially remedial and special education courses are filled with poor and economically disadvantaged students" (p. 93). This disparity is due to the lack of representation of minority students in higher-level science courses. It is questionable as to whether our lower tracked education paths provide college readiness skills necessary for academic success.

Grouping and placing students in a low track will affect student performance beyond the current year in school. Access to advanced level science courses can be difficult for those students who start in a lower tracked system. Unfortunately, these students never catch up to the average performing students because of the slow paced curriculum and decline of learning expectations (Oakes, 2005). When advancing to the next level course students have difficulty understanding higher level learning standards. African American and Hispanic students are most at risk of failing courses since most minority students are found in the lowest track early in their schooling. Oakes, Ormseth, Bell, & Camp (1990) explain, “while not all students have the interests of aptitude to become scientists or mathematicians, the disparities for African American and Hispanic minorities is undoubtedly being lost from these groups” (p. 2). This disparity is due to the lack of representation of minority students in higher-level courses. The opportunity to learn from a challenging curriculum with high learning standards are not available to all students.

High schools should be concerned with the lack of minority students enrolled in higher-level science courses. African American, Hispanic, and American Indian students participate less in advanced level science courses, such as the Advanced Placement (AP) program, than any other racial group. According to the *AP Equity Policy (2014)*, the College Board encourages schools to abide by the principle of making AP classes accessible to all. The *AP Equity Policy (2014)* includes three main goals:

- Eliminate barriers that restrict access to AP for students from ethnic, racial, and socioeconomic groups that are traditionally underserved.
- Make every effort to ensure their AP classes reflect the diversity of their student population.
- Provide all students with access to academically challenging coursework before they enroll in AP classes (“Achieving Equity,” 2014, para 1).

Tracking students in the lower levels limits the opportunity of a student to take Advanced Placement courses. Klopfenstein (2004) states, “the academic culture provided by the AP program can be particularly beneficial to minority students who may not be exposed to a culture of learning in other places” (p. 1). The disparities found are in the lack of access to science and math knowledge, less materials or resources, less qualified teachers, and the judgment of these students who have perceived low ability (Oakes et al., 1990). In one Texas school study, Klopfenstein found African American students did not even have access to AP courses. In addition to this finding, the study also found that African American and Hispanic boys felt pressured to work outside of school, which prevented these students from taking AP courses (Klopfenstein, 2004). Socioeconomic status causes students to select easier courses, so they can work and support their families. African American and Hispanic students do not have equal access to AP programs even with Advanced Placement courses in the school. Klopfenstein (2004) reported that three quarters of all African American and Hispanic students come from low-income families. He also reports many students of low income do not participate in the AP program because the schools they attend do not offer AP courses or have less AP availability.

Research shows that students who succeed in rigorous coursework, such as Advanced Placement courses, develop college readiness skills while in high school ("Achieving Equity," 2014). Enrolling in Advanced Placement STEM courses is a preliminary and important step toward college preparation. The School Superintendents Association (2016) recently published the *National College and Career Readiness Indicators* that redefine the meaning of college readiness. Established indicators of college success include: GPA 2.8 out of 4.0 and one or more of Advanced Placement exam (3+), Advanced Placement Course (grade of C or better), Dual Credit College English and/or Math (grade of C or better), Developmental English and/or Math (grade of

C or better), Algebra II (grade of C or better), International Baccalaureate Exam (4+), and minimum ACT scores (English 18, Reading 22, Science 23, and Math 22). These indicators are research-based metrics that guide school district curricular decisions, but are not all accessible to all students (School Superintendents Association, 2016). Students who struggle to meet these standards may be denied admission into colleges. Corbett and Garrity (2008) state the decision to deny students to access AP courses will affect their candidacy to competitive colleges.

National Science Education Standards and Equity Pedagogy

The National Research Council (NRC) Executive Summary (2007), Taking Science to School, stated proficiency in science is multifaceted, thus requires a range of experiences that support students' learning. The NRC Executive Summary (2007) define proficiency in the four strands. If interwoven successfully they support science learning:

- Knowing, using, and interpreting scientific explanations of the natural world.
- Generating and evaluating scientific evidence and explanations.
- Understanding the nature and development of scientific knowledge.
- Participating productively in scientific practices and discourse. (p. 2)

One of the recommendations from the NRC Executive Summary (2007) was to develop curriculum and standards that "present science as a process of building theories and models using evidence, checking them for internal consistency and coherence, and testing them empirically" (p. 5). The use of evidence to support a claim through justification or reasoning is at the core of argument. Mastery of scientific argumentation skills is an important socioscientific skill for scientific literacy. Argument is communal in nature where there is student-to-student interaction and the ability to counter argument and analyze another claim. The social interactions within the community of learners create a power dynamic and opportunities to exercise student voice.

In 2013, the National Research Council (NRC) finalized the Next Generation Science Standards (NGSS) to serve as the National Science Education Standards. The NGSS standards evolved from the NRC's *Framework for K-12 Science Education* three dimensions of instruction- eight science and engineering practices, crosscutting concepts, and disciplinary core ideas. The NGSS framework also identifies proficiency in science with the combination of three dimensions of science learning: Science Engineering Practices (SEP), Disciplinary Core Ideas (DCI), and Crosscutting Concepts (CCC). All three dimensions of learning should be used in the development of curriculum and the execution of a lesson. The three dimensions of learning differs from the traditional methods of teaching where the focus was more on core concepts and ideas. Today, the use of NGSS three dimensions requires a shift in teacher mindset toward a student centered classroom. Science Engineering Practices (SEP) investigate phenomena, build models and theories, and formulate a problem that can be solved through design for solution. Disciplinary Core Ideas (DCI) are ideas related to core concepts progressed over grade levels and include interests and experiences of students. Crosscutting Concepts (CCC) link different domains of science where students learn about patterns, cause and effect, scale, quantity, and proportions. In addition, Cross Cutting Concepts (CCC) relate knowledge from other disciplines in an integrated approach. Common Core standards from Math and English Language Arts (ELA) are integrated with NGSS standards. The standards are scaffolded to build from Kindergarten to grade 12.

All students at each grade level should receive equitable learning opportunities. Science curriculum should prepare students to be scientifically literate with proficiency in scientific practices (including equity) and science core content. The NGSS Framework lists eight science practices in *Appendix F Science and Engineering Practices*:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information (NGSS Lead States, 2013, p.1)

Rodriguez (2015) criticizes the Next Generation Science Standards for not including a fourth dimension of learning and believes there should be a fourth dimension called Engagement, Equity, and Diversity. Similar to the Hernandez five component model, Rodriguez believes quality science curriculum should include cultural content, student choice and voice, groupings, and relevant student experiences. Rodriguez (2015) uses the socio transformative constructivist theoretical framework to merge cross-cultural education with social constructivism. Dialogic conversation, authentic activity, metacognition, and reflexivity describe elements of equitable opportunities and success for all students.

Dialogic conversation involves a deep conversation and exchange of ideas so a learning community develops with all identities and cultural experiences. Authentic activity is relevant to everyday life, inquiry based, and minds-on. Metacognition is the learner's awareness and ownership of learning. Reflexivity is a critical awareness of how one's own cultural background, beliefs, values, and skills influence learning. These four components act as a framework for equity-based classroom strategies. Although, Rodriguez criticizes the NGSS Framework for not including a dimension about equity, he also describes how NGSS is an improvement over past national science standards. Rodriguez recognizes how the National Research Council took a strong stand for equity by publishing the NGSS document called *All Standards, All Students*. This document provides a position statement about how all science classrooms should teach to the NGSS framework, but with an equity lens. The *All Standards, All Students* document provides specific strategies and examples of equitable opportunities for non-dominant student groups. Curriculum and pedagogy for detracked science courses is most successful when it is relevant to student experiences, includes culturally responsive practices, has challenging and integrated curriculum, and asks students to construct meaning about the content. The NGSS position about curriculum is validation for improving student learning through an interdisciplinary approach. According to the NGSS framework, the convergence of Common Core Math and English Language Arts standards and NGSS are beneficial for non-dominant student groups. "Students develop mastery of crosscutting concepts through repeated and contrastive experiences across curricula" (Next Generation Science Standards, 2013, p. 3). All students build fundamental skills in areas of science literacy. "Students are expected to engage in argumentation from evidence, construct explanations; obtain, synthesize, evaluate, and communicate information; and build a knowledge base through content rich texts across three subject areas" (Next Generation Science Standards, 2013, p. 4). Building scientific argumentation skills can improve their understanding of content by engaging in a practice most used through all subject areas.

Why Teach Argumentation?

Argumentation is defined by many sources as a process where social dialogic learning occurs to justify a claim based on evidence (Duschl, 2007; Erduran, 2007; Jimenez-Alexaindre, 2007; Hsu, Chiu, Lin, & Wang, 2015; Sampson & Schleigh, 2012; Shemwell & Furtak, 2010; Venville & Dawson, 2010). Community learning is essential to the process and particular elements of argument involve collecting evidence, making a claim, justifying a claim with evidence, and providing counter critique or rebuttal. NGSS (2013) defines argumentation as the process by which explanations and solutions are achieved by engaging in argument from evidence. Hsu, Chiu, Lin, and Wang (2015) clarify that "argumentation is not a competition involving justification and debate to determine winners and losers, but rather a form of logical discourse used to extract relationships between claims and evidence" (p. 48). Shemwell and Furtak (2010) share a quote from Grootendorst and van Eemeren who define argumentation as a "verbal and social, and rational activity aimed at convincing a reasonable critic of the acceptability of a standpoint by putting forward a constellation of propositions justifying or refuting the proposition expressed in the standpoint" (p.1). Shemwell and Furtak (2010) believe there are three essential properties to scientific argumentation:

- Evidence as the basis for establishing the acceptability of knowledge claims (i.e. theories)
- Scientific argumentation is a social process predicated on differences in standpoint that are contested or contestable.
- Scientific argumentation has the purpose of building and refining generalized explanations (p. 227).

Duschl and Osborne (2002) define argumentation as "the special case when [a dialogue between two individuals] addresses the coordination of evidence and theory to advance an explanation, a model, a prediction, or an evaluation" (p. 55). In simple terms, Kuhn (1991) defines argument as "an assertion with accompanying justification" (p. 12). Duschl, Osborne, and Kuhn outline three forms of argument: analytical, dialectical, and rhetorical. Analytical argument proceeds inductively or deductively from a set of premises to a conclusion (Duschl & Osborne, 2007, p. 163). Rhetorical argument involves discursive techniques employed to persuade an audience. Dialectical, or dialogic, argument involves two opposing views where each person provides justification and counter arguments to the view. According to Duschl and Osborne (2002), dialectical and analytical arguments are more representative of quality scientific argumentation.

Argumentation requires practice and is a difficult skill to acquire. Teachers should not assume students are capable of implementing skills of argument. Sandoval and Millwood (2005) found practicing argumentation helps students construct knowledge and is a core scientific practice that students should learn. Bulgren, Ellis, and Marquis (2014) define scientific argumentation with components similar to those found in the Toulmin argument framework. The Toulmin framework (claim, evidence, warrant, and backing) is the most often cited source in argumentation research studies and used as a conceptual framework. Below is a list of argumentation components from Bulgren and Ellis (2014):

- Identifying a claim as presented in a written document or inquiry activity and analyzing the claim for qualifiers
- Identifying evidence, labeling the type of evidence, and judging the quality of the evidence.
- Identifying the reasoning that led to the claim, labeling the type of reasoning and judging the quality of the reasoning.
- Presenting rebuttals or counterarguments; and
- Drawing a conclusion about the claim, and explaining the reasoning that supported the conclusion.

This list adds to the Toulmin framework by adding the need to measure the quality of claim, evidence, and reasoning.

Argumentation can improve academic achievement across disciplines, and provide fundamental skills needed to succeed in college and in STEM careers. The recommendation to teach socioscientific skills, such as argumentation, is not a new concept to science education. In the 1960s, there was a reform movement to replace the scientific method with processes of science. According to Bybee (2011), “the processes of science shifted the emphasis from students’ memorizing five steps in the scientific method to learning specific and fundamental processes such as observing, clarifying, measuring, inferring, and predicting” (p. 13). The instructional practice from 1960 to 1990 was the scientific inquiry approach, which emphasized science concepts and skills of inquiry. Inquiry is not synonymous with science practice, but one form of science practice. According to Coleman (2014), “science education does not place enough emphasis on helping youth to understand what it means to do science, and how they might engage in science in order to bring about personal and social transformation” (p. 18). Currently, science educators emphasize teaching science concepts, and are slow to shift toward instruction that also incorporates science practices.

Teaching argumentation is beneficial to students across high school core subjects of English, Math, and Science. Integrated curriculum, or interdisciplinary curriculum, includes “a combination of subjects, an emphasis on projects, sources that go beyond the textbooks, relationships among concepts, thematic units as organizing principles, flexible schedules, and flexible student groupings” (Lake, 1994, p. 2). The integrated approach is an effective method to use to reinforce learning objectives across disciplines. A research study by Lipson (1994) found positive effects of integrated curriculum:

- Integrated curriculum helps students apply skills.
- An integrated knowledge base leads to faster retrieval of information.
- Multiple perspectives lead to a more integrated knowledge base.

- Integrated curriculum encourages depth and breadth in learning.
- Integrated curriculum promotes positive attitudes in students.
- Integrated curriculum provides for more quality time for curriculum exploration (Lake, 1994, p. 11)

The combination of lessons in different course subjects can build on elements of argumentation, as well as on student prior knowledge. Houseal, Gillis, Helmsing, and Hutchinson (2016) explain how math, science, and English Language Arts share common crosscutting concepts. Students analyze and interpret data in all three-subject areas. In science class, students produce data through engineering experiments and analyze the patterns of results. English classes use Common Core standards that require students to analyze data in a text at both the word and speech level. Math courses use Common Core standards that require students to analyze data in a model and interpret meaning from the patterns. Similar skills are needed to be successful at analyzing and interpreting data. Lake (1994) found research studies that support the positive achievement outcomes for students when an integrated curriculum approach is used. One study reported an increase in academic achievement for the majority of their students when the literature-based language arts program changed to a science-literature based program for sixth graders (Lake, 1994). Another study found success when seventh grade students were in a math and science integrated course (Lake, 1994).

Challenging content and expectations of students are part of the NGSS standards and best practices in the science classroom. The use of crosscutting concepts (CCC) encompasses an interdisciplinary approach, also known as integrated curriculum, to teaching science, math, and English language arts (ELA). The crosscutting concepts apply to different domains of science and include observing patterns, identifying cause and effect, recognizing proportions, and developing models. However, Cheuk (2015) analyzed all the Common Core and NGSS practice skills from ELA, math, and science and found an engaging in argument by use of evidence to be most common. She created the Venn diagram to show the overlap in practices. The Venn diagram found in *Figure 1* highlight the integration of Math, Science, and English Language Arts (ELA) standards of practice. In the middle of *Figure 1,* the most common practice relates to argument and using evidence to support claims. This intersection of NGSS and Common Core standards include skills related to literacy in communication. Houseal, Gillis, Helmsing, and Hutchinson (2016) would describe this intersection as a set of standards that encompass scientific literacy.

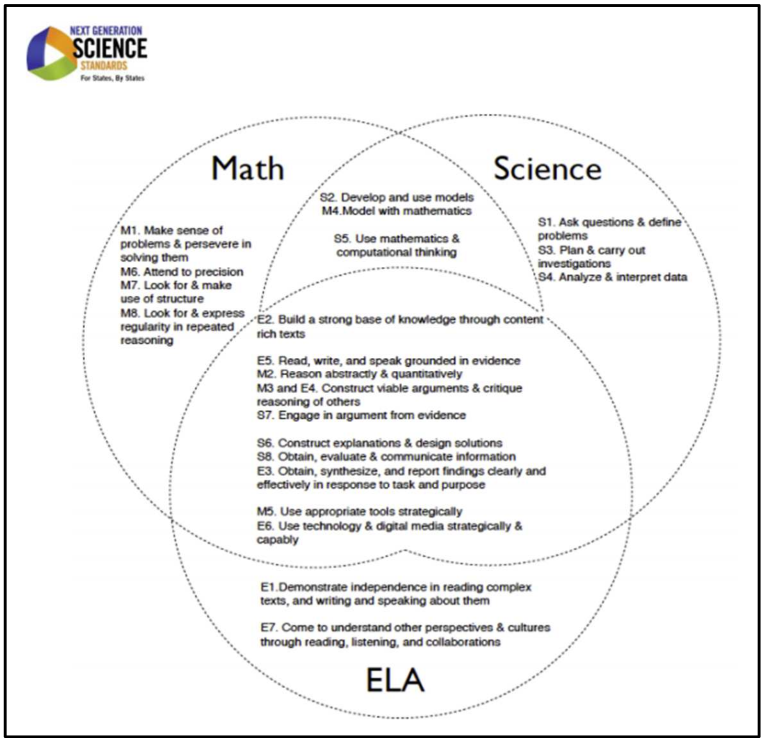


Figure 1. Common Core and NGSS Intersection of Practices (Cheuk, 2015).

The convergence of Common Core math, Common Core ELA, and NGSS science standards of practice is beneficial for all students, but particularly for marginalized groups of students. NGSS (2013) stated, “Such convergence is beneficial for students from nondominant groups who are pressed for instructional time to develop literacy and numeracy at the cost of other subjects, including science” (“All Standards, All Students”, 2013). Students of color who read below grade level and/or lack high school math skills would benefit from an integrated curriculum that develops argument skills. At NW High School, low ability freshmen students often enroll in two English and two math courses. The second course is an intervention course helps student catch up to grade level. Thus, coordination of evidence-based argumentation lessons throughout the three core courses would enhance student critical thinking skills. Engaging in argument from evidence is the science practice focused on in this action research study.

Research studies that investigate argumentation in science classrooms have found three common challenges for students. First, students have difficulty justifying their claim with evidence. Sandoval and Millwood (2005) found that students often fail to cite sufficient and appropriate evidence for their claims and explain how the connection of evidence to the claim. McNeill and Krajcik (2011) found students could not construct scientific explanations and did not know what to include in their explanations.

Second, traditional triadic dialogue where the teacher is in total control over learning has a negative impact on the student achievement. The power dynamics that exist in the classroom does not allow for student initiatives and the opportunity to talk science. Lemke (1990) describes triadic dialogue as a classroom dialogue where the teacher initiates a question, a student responds, and the teacher evaluates. The triadic dialogue is a three-part question, answer, evaluation pattern sometimes associated as IRE- initiate, response, and evaluate. Triadic dialogue is considered the most overused pedagogy that is mistaken as the best method to use to encourage maximum student participation. In many ways, it is a passive form of teaching, and even suppressive to the students in the science classroom. Yerrick and Gilbert (2011) state, "this treatment of scientific knowledge has also contributed to the deterioration of self-identity, confidence, efficacy, and agency for students' subject to this treatment of science" (p. 68). "The level of participation it achieves is illusory; high on quantity, low on quality" (Lemke, 1990, p. 168). Argumentation can have the opposite effect on learning because students are in dialogue and have control over the discussion. The social interactions of argumentation between students can improve the quality of participation and learning. Keiser and Stein (2003) explored how teaching students the skills of critique and democratic participation empowered students of color in this integrated setting (Rubin, 2006, p. 10). Teaching argumentation can empower our students of color with student voice. Jimenez-Alexaindre and Erduran (2007) believe argumentation could “be an added interest in democratic participation, which requires debate among different views rather than acceptation of authority” (p. 4). Building student ownership over their own learning requires teachers to reduce control over the classroom dialogue.

Third, teachers need to design tasks and groupings so student can practice the process involved with argumentation. “The one single change in science teaching that should do more than any other to improve students’ ability to use the language of science is to give them more practice actually using it” (Lemke, 1990, p. 160). Promoting the practice of argumentation requires the development of appropriate pedagogical approaches (Hsu et. al., 2015). Kuhn’s (1991) work highlighted the need for practice of argumentation and found valid argument does not come naturally to students. Argument is a form of discourse that needs to be explicitly taught.

Student Voice

Argumentation is a social process with community learning. Fundamentally, students must engage in dialogue to construct their knowledge about scientific principles and justify or refute their claim with evidence. Student voice during argumentation is key to constructing explanations and solutions. “Providing opportunities for student voice and choice changes the classroom dynamics and fosters different patterns of participation among marginalized youth" (Seiler, 2011, p. 378). The Glossary of Education Reform defines student voice as the "values, opinions, beliefs, perspectives, and cultural backgrounds of individual students and groups of students in a school, and to instructional approaches and techniques that are based on student choices, interests, passions, and ambitions" ("Glossary of Education Reform," n.d.). Student voice involves developing curriculum and changing instructional approaches that provide opportunities to listen to, and respond to, students. They do not have to leave their opinions, values, and culture at the classroom door (Seiler, 201). Bain (2010) also agrees that student voice is a fundamental democratic activity, which gives everyone a voice and "finds itself in harmony with an agenda for social inclusion and empowerment for all" (p. 18). The values and beliefs of students are expressed through the design of instruction. Gale Seiler (2011) identifies student voice as a best practice for developing high school science curricula. Seiler (2011) states that "when science students are able to participate using their own repertoires of practice in ways that are validated in the classroom, more promising patterns of student engagement emerge" (p.375). Instructional tasks that have relevancy to students and their everyday lives can keep students engaged in verbal discourse. Quaglia and Corso (2014) highlight eight conditions schools should consider to empower student voice: belonging, heroes, sense of accomplishment, fun and excitement, curiosity and creativity, spirit of adventure, leadership and responsibility, and confidence to take action. Students feel valued in a community when they feel a sense of belonging. Teachers should create environments where students "accept differences, of listening to one another's ideas with respect, of sharing common interests and goals, and of working together on joint projects" (Quaglia & Corso, 2014, p. 2). Students should be seen in the curriculum as well as know the relevancy of the topics.

Argumentation can promote student voice in the science classroom because it is a social process, which requires evidence-based reasoning, and counter arguments. Student discussions and debates make student thinking visible as they share ideas, opinions, sources of evidence and reasoning within the community of learners. Windschitl, Thompson, and Braaten (2018) explain the importance of student discourse, "Fostering students' discourse is important because goal-directed talk is a chance to think, and thinking is required for higher order learning" (p. 39). They list justifying claims with evidence as a way to require higher cognitive demand from students. Exploratory Chemistry and Physics students, participants in this study, can benefit from engaging in argument since this practice may build higher order thinking skills. Talking science while using an argument framework will require students to activate prior knowledge and organize ideas to further the conversation. This type of engagement "stimulates learning because translating ideas into words is not simply the 'reporting out' of what is fully formed in one's head" (Windschitl, Thompson, & Braaten, 2018, p. 40). According to Osborne, Henderson, MacPherson, Szu, Wild, and Yao (2016), a counter critique during argument…

> is somewhat more demanding requiring the cognitive operations of analysis to identify the salient elements of an argument, that is, claim, warrant, data, followed by an evaluation of the truth status of these elements or their validity while drawing on factual or conceptual knowledge, and then creating or synthesizing

> a counter-argument which is relevant to the argument that has been advanced (p. 823).

Asking students to counter argue is a challenge because of the cognitive demanding process involved. Drawing on factual knowledge and applying their understanding of the facts is a difficult task. During this study, all students in the Exploratory Chemistry and Physics course are expected to engage in argumentation practices. The researcher, science teachers, and literacy coach will explore how students engage with one another in small group discussions.

Conceptual Framework

This study is informed by both sociocultural theory and argumentation theory. Sociocultural theory stresses the interaction between social interaction of individuals and the culture in which they live. Vygotsky (1978) asserts that learning is a fundamental social process influenced by both biological and nature. According to Heineke, Ryan, and Tocci (2015), this theory recognizes "the co-construction of knowledge through participation in social and cultural activity" (p. 384). Applying sociocultural theory to this action research study provides a framework for determining whether students are able to learn components of scientific argumentation and empower students to learn within the classroom community. Elements of argumentation are taught explicitly to students in the ECP course and students will work in groups to construct meaning of those elements. Smetana and Bell (2014) stated "Knowledge construction first takes place between individuals at an interpersonal level (learning) and subsequently within the learner on an intrapersonal level (development)" (p. 483). The instructional tasks in argumentation lessons will allow students to dialogue about the elements of argument. Hopefully, student will internalize what they have learned from the group on an intrapersonal level. Vygotsky argued that "every function in the child's cultural development appears twice: first, between people (interpsychological), and then inside the child (intrapsychological)" (p. 57). This sociocultural perspective assumes social interactions between ECP students will contribute to their understanding of elements of scientific argumentation and their perception of their role within the community of learners.

For this study, sociocultural theory and argumentation theory will both be used both as a conceptual and analytical framework. Vygotsky's sociocultural theory was selected because it involves social interactions and cultural activity. Argumentation theory provided a framework to use for structural analysis of both verbal and written CER discourse. In this study, argumentation theory is used with the structural framework of Toulmin, Zohar, and Nemet argumentation schema. According to Macagno and Konstantinidou (2013), the "advantage to researchers of adopting this framework is that it can be used to assess the quality of argumentation in terms of identifying the number of components, hence the complexity of the arguments used" (p.232). In this study, three argumentation schemas, or frameworks, were combined to inform the quality of argumentation and to analyze student discourse after explicitly taught argumentation lessons were implemented. The notion of Ambitious Science Teaching (Windschitl, Thompson, & Braaten, 2018), Toulmin's Model of Argumentation, sometimes referred to as Toulmin's Argument Pattern (TAP) (Toulmin, 1958), and Zohar and Nemet's framework (Zohar & Nemet, 2002) were used for evaluating scientific argument quality. The combination of these frameworks support the analysis of argumentation mastery.

Ambitious Science Teaching

The principles of Ambitious Science Teaching (AST) principles provide insight into science practices that promote evidence based explanation with attention to equity. The goal of AST "is to help students of all backgrounds to deeply understand fundamental science ideas, participate in practices of science, solve authentic problems together, and learn how to continue learning on their own" (Windschitl, Thompson, & Braaten, 2018, p.3). Merriam and Tisdell (2016) define a theoretical framework as the "underlying structure, the scaffolding or frame of your study" (p. 85). Ambitious science teaching is a framework with four core principles, encompassed by intellectual engagement and attention to equity. Windschitl, Thompson, and Braaten (2018) analyze specific and skilled practices in science education, and include equity as an overlying lens over these principles.

> Ambitious science teaching is supported by four sets of core practices that work together throughout every unit of study. These practices start with designing units of instruction (Planning for engagement with important science ideas); they then focus on making visible what students currently know about the science being taught (Eliciting students' ideas); they help the teacher guide sense-making talk around investigations and other kinds of lab activities or readings (Supporting ongoing changes in thinking); and finally they help the teacher scaffold students'

> efforts to put everything together near the end of a unit… (Ambitious Science Teaching, 2017).

Ambitious Science Teaching represents the idea of rigorous and equitable teaching by educators. Braaten and Sheth (2016) describe how ambitious science teaching practices can work toward equitable science learning experiences for all students. Equity instruction plays a central role in ambitious science teaching which also includes the use of argumentation skills. One of the roles of argumentation is to engage in dialogue to construct one's own meaning, as well as foster science-talk and student voice. In this action research study, the AST principles guides the methodology, data collection, and analysis. The AST principles provide criteria for developing curriculum in this study. Argumentation lessons will be developed and taught in a scaffolded manner. Components of arguments, such as claim and evidence, was explicitly taught in stages over time. The curriculum was scaffolded so students can learn the basic components and then synthesize reasoning by use of claim and evidence. By the end of the argumentation, lessons the students will be able to counter argue with one another. The researcher and literacy coach will explore the impact of the curriculum on learning and student voice.

The Ambitious Science Teaching framework is more than just a checklist of practices, but a shift in pedagogy to empower students in their own learning. Braaten and Sheth (2016) state, "equity pedagogies are characterized by active involvement of students constructing and producing their own knowledge and understandings rather than passively acquiring information transmitted by authoritative sources" (p. 138). Argumentation is a science practice explicitly emphasized in the *Next Generation Science*

Standards to shift the belief away from science as a set of facts to memorize. The vision of this action research study is to transform curriculum so students engage in social practices that develop critical thinking skills through argumentation. McNeill, Katsh-Singer, Gonzalez-Howard, and Loper (2016) define argumentation as a social practice in which students should be both constructing and critiquing claims as they engage with their peers in both the sense-making and persuasive goals of this practice" (p. 2028).

Toulmin's Argument Pattern

In 1958, Stephen Toulmin published a popular book called *The Uses of Argument, which* is still used by many argumentation studies today. According to Yerrick and Gilbert (2011), many studies have turned to Toulmin's analytical framework to determine when and how evidence based argumentation are taking place in the classroom. The Toulmin argument framework seen in *Figure 2* outlines the different parts of argument. The main components of argument include claim, data, warrants, backing, and rebuttals. Venville (2010) summarizes Toulmin's element of argument as listed below:

- Claim is defined as the conclusion, proposition, or assertion.
- Data is evidence that supports the claim.
- Warrants is an explanation of the relationship between the claim and the data.
- Backings are basic assumptions to support warrants.
- Qualifiers are conditions in which a claim is true.
- Rebuttals are the conditions to discard the claim. (p. 954)

Erduran (2007) adds to the description of the elements of argument: claim is not only an assertion, but also put forward for public general acceptance; data and warrants are specific facts that support the claim; "Backings are generalizations making explicit the body of experience relied on to establish the trustworthiness of the ways of arguing applied in any particular case" (p. 57).

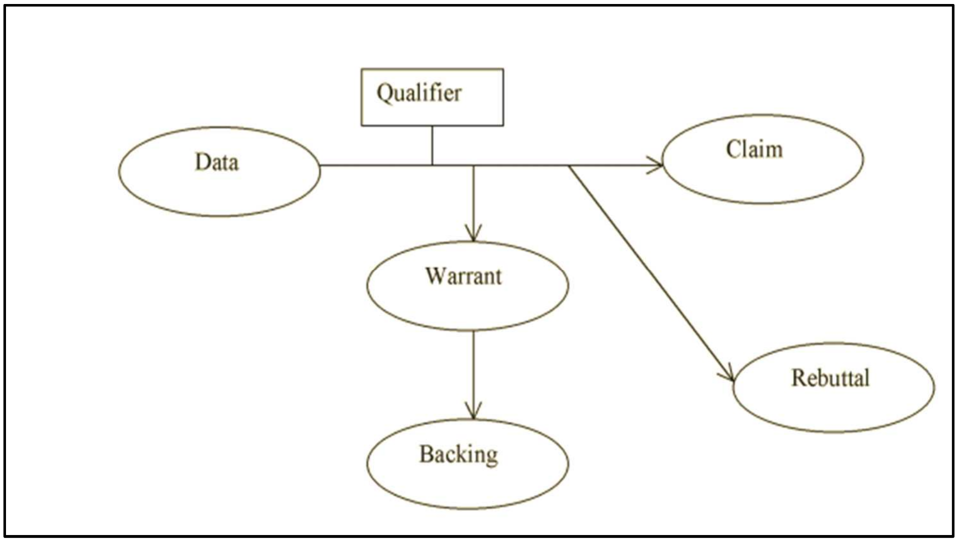


Figure 2. Toulmin's Argument Pattern (Toulmin, 1958).

The Toulmin analysis framework is a domain-general framework used to analyze argument quality in various field such as English, math, or science. However, the universality of this framework brings up issues of use in the science classroom. Osborne, Henderson, MacPherson, Szu, Wild, and Yao (2016) believe the Toulmin analysis framework plays a central role in argumentation, but it is not sufficient to use alone. "In addition to justification, the process of critique is essential to identifying flaws in arguments" (Osborne et. al., 2016, p. 826). The ability to counter critique requires knowledge of content, ability to distinguish between elements of argument, and cognitive performance of comparing and contrasting.

Sampson and Clark (2008) found issues with interrater reliability where researchers found it problematic when they had to identify a claim, evidence, and reasoning while students were engaged in science talk. Recognizing the accuracy of science content while students were in dialogue was a difficult task. They found the Toulmin's analysis framework to be strong in structure, but challenging when they had to identify the accuracy of science content. "Unfortunately, because the majority of the research using Toulmin's argument framework has focused on the field-invariant features of an argument, we know very little about how well arguments constructed by students adhere to the criteria shared by the scientific community for judging quality" (Sampson & Clark, 2008, p. 452). In our spring of 2018 pilot action research, study the researcher and the co-researchers found the same conclusion. The results of this pilot study showed progress in student understanding of claims and evidence, but lacked the accuracy of science content. Thus, the researcher felt it was important to use both the Toulmin framework and the Zohar-Nemet framework for evaluating scientific argument quality (Zohar & Nemet, 2002) for this action research study.

Quality Criteria for Scientific Arguments

Zohar and Nemet created a domain-specific framework that focused on aspects or criteria of argument specific to science content. The domain-specific framework included "students' ability to formulate arguments, alternative arguments, and rebuttals to justify them" (Zohar & Nemet, 2002, p. 43) A scoring system (0-2) was used to determine the quality of the argument. The number of justifications in the argument and the structure or branching of justification in the argument determined the score. Zohar and Nemet (2002) only accepted arguments that: "(a)…were supported by justifications (as opposed to simple assertions) and (b) accepted only justifications whose content was indeed adequate for supporting the conclusion (as opposed to pseudo-reasons)" (p. 45). Their study examined the outcomes of a human genetics unit that integrated explicit teaching of general reasoning patterns into specific science content. The results of the study showed the instruction contributed to improved student scores on argumentation tests. Zohar and Nemet (2011) state "results of the analysis of both written tests and transcripts of group discussions support the conclusion that integrating explicit teaching of argumentation into the teaching of dilemmas in human genetics enhances performance in both biological knowledge and argumentation" (p. 57). Zohar and Nemet's framework focus on both the strength of the justification and accuracy of science content.

ECP Argument Analytical Framework

In this action research study, there are four investigate constructs. The three constructs are accuracy of science content in argument, elements of argument, and the nature of justification. The effectiveness of explicitly taught argumentation lessons in the ECP course were measured by four indicators. *Figure 3* illustrates the constructs of the framework. The argumentation schema and interest in improving instructional practices are based on these constructs.

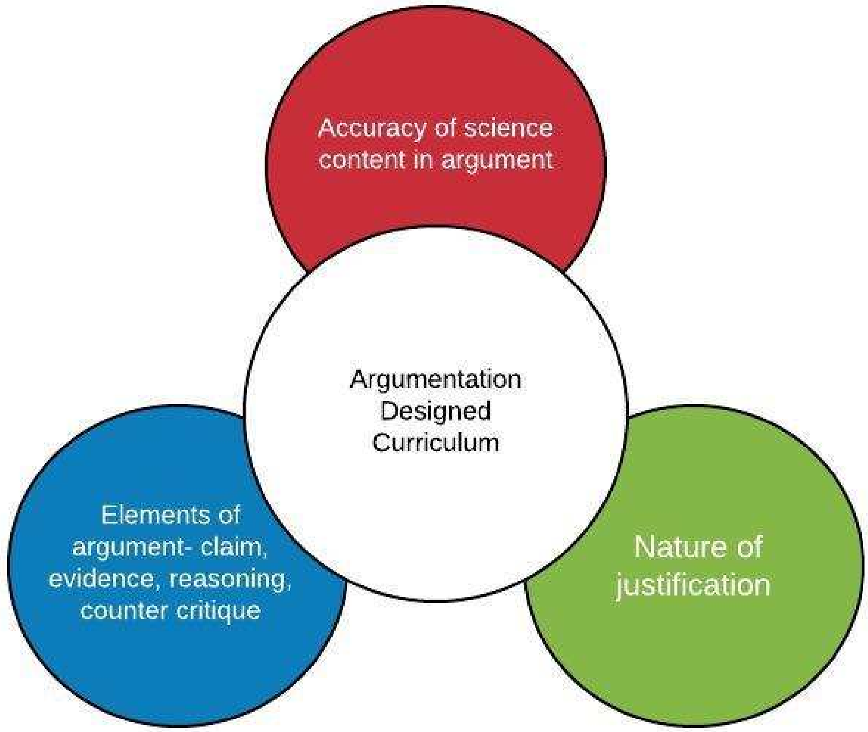


Figure 3. Constructs of Conceptual Framework.

Summary

The practice of tracking results in inequitable opportunities for our students of color. Science course enrollment data show a higher percentage of students of color in lower level courses and less students of color enrolled in advanced level science courses. Systemic issues of inequity continue to perpetuate the cycle of tracking and the achievement gap. This chapter reviews the history and debate over tracking and presents solutions for reform. Sections of the review of literature propose interventions to lessen the achievement at NW High School in the Science Department and point out the need for empowerment and transformation. Teaching argumentation skills to students in lower level science courses may be one intervention that can break the cycle of tracking. Preparing students with argumentation skills through an interdisciplinary approach during their freshman year may build a foundation for movement into more advanced science courses.

CHAPTER III

METHODOLOGY

Introduction

The identified problem at NW High School was the inequitable tracking system of students of color in the science program and the increase in number of students failing the freshman level Biology course. The researcher gathered four years of science course enrollment data and found a disappointing trend. Students of color in the NW High School science program were moving from a regular level Biology course down into a lower level science course. Starting in 2014-2015, the science department found more students failing Biology than had ever failed in the past. Approximately 10% of freshmen taking the regular level Biology course failed. In years past the average percentage of students, failing Biology was around 3%. The purpose of this action research study is to investigate how the process of action research influences our instruction of scientific argumentation and student mastery elements of argument. This action research study investigates how explicitly teaching scientific argumentation changes instructional practices and influences student mastery of elements of argument. The overarching goal is to detrack students so they have a skill set that will improve their critical thinking and place them in higher-level science courses. Three primary questions (RQ1, RQ2, and RQ3) guide this action research study.

- Research Question 1 (RQ1): How does the process of action research influence our instruction of scientific argumentation in a high school science course?
- Research Question 2 (RQ2): How does student ability to write scientific argument develop over time?
- Research Question 3 (RQ3): What role did verbal discourse play in students' developing understanding of elements of argument?

The timeline for implementation of this action research study follows the *2018-2019 Argumentation Action Research Plan*. The first cycle (highlighted in blue in *Figure 4*) introduced the basic elements of claim and evidence. The second cycle (highlighted in yellow in *Figure 4)* focused on how to identify and generate quality reasoning. Lastly, the third cycle (highlighted in pink in *Figure 4*) will introduce counter argument and how to analyze competing theories. During the first semester, lessons from cycle I and II were taught. Second semester will continue with explicit teaching of reasoning and include lessons from cycle III. Appendix E contains the action plan in full.

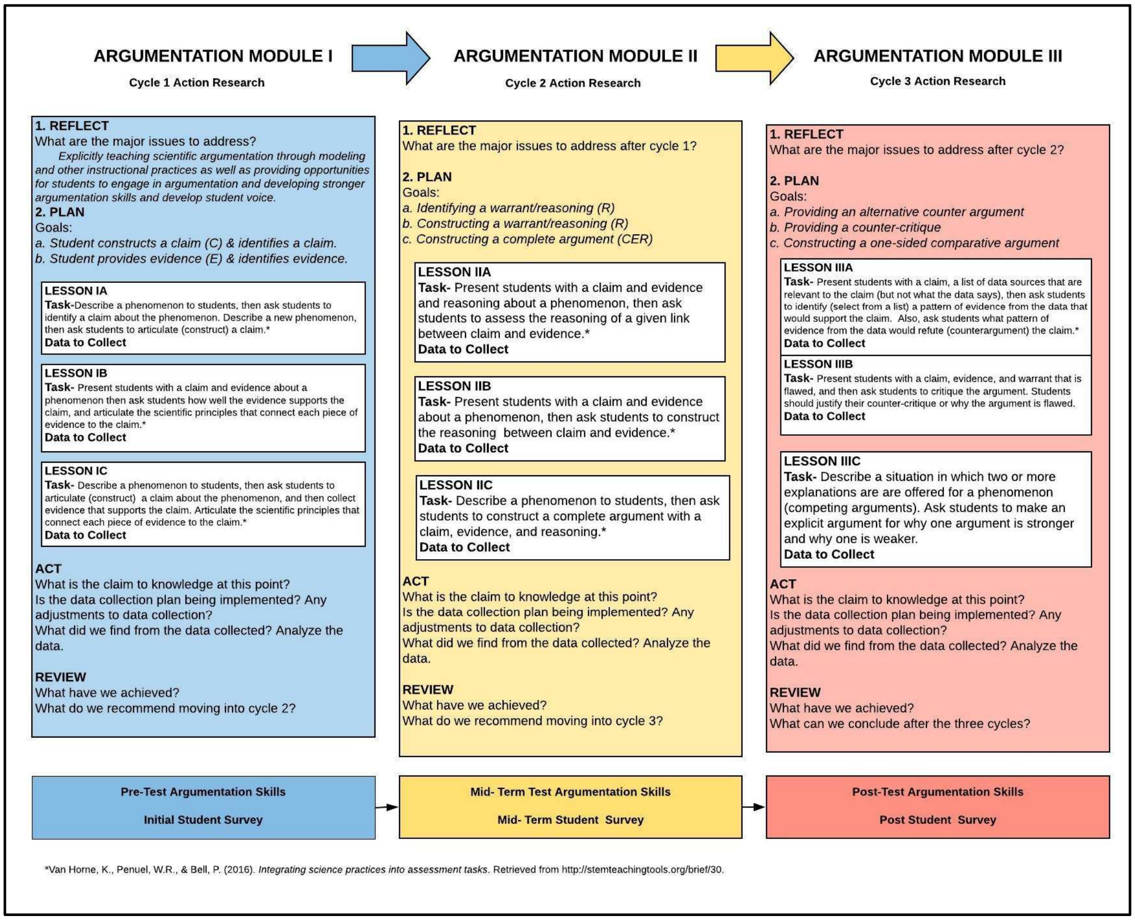


Figure 4. 2018-2019 Argumentation Action Research Plan

Chapter III is organized to explain the rationale of using action research and qualitative methods used to answer the research questions (RQ1, RQ2, and RQ3). Initially, the researcher brought forth data that provided evidence of systems of inequity. The PLC team set instructional goals to build argumentation skills in the ECP curriculum across one school year. In the end, the researcher intends on sharing the story of this localized issue so other school districts do not make the same mistakes we did years ago. However, our action research study does not attempt to generalize problems of tracking found in other school districts. Instead, the study suggests an alternative approach to detracking reforms. Issues with tracking and the achievement gap are found in many school districts. It is recommended that administrators look deeply into local school achievement and demographics data before making changes.

Other educators interested in action research or detracking course scope and sequences can use the products produced from our action research study. The action research plan, data analysis instruments, and rubrics found in the Appendix are examples of some of the products.

Rationale for Research Approach

Action Research

Action research is concerned with solving problems in schools by transforming practices and systems in context of the local setting. “Action research is a paradigm and not a method” (Pine, 2009, p. 29). It involves a conceptual, social, philosophical, and cultural framework. According to Stringer (2014) “action research is a systematic approach to investigation that enables people to find effective solutions to problems they confront in their everyday lives” (p. 1). Action research uses cycles of investigation to identify problems and solutions for a specific community or local setting. Herr (2015) states the goals of action research to be the generation of new knowledge, the achievement of action-oriented outcomes, the education of both researcher and participant, and sharing results that are relevant to the local setting, all through the employment of a sound and appropriate research methodology (p. 54). Action research is the best approach for this study because it will allow a team of investigators to learn and take action on our own practice. Actions on what to explore and what to change are accomplished collectively as a team. Action research was used in this study so practitioners can improve their own professional practice. Knowledge gained through this action research study may help students learn argumentation skills that also improve critical thinking and problem solving skills. These are skills needed to be successful in higher-level science courses.

The origin of action research came from the work of Kurt Lewin and the group-dynamic movement of the 1940s approach. “Lewin believed knowledge should be created from problem solving in real-life situations” (Herr & Anderson, 2005, p. 11). According to Herr and Anderson (as cited in Merriam and Tisdell, 2016) all action research approaches share four basic principles:

- Action research focuses on a problematic situation in practice.
- The design of the action research study is emergent through a spiral cycle of planning, acting, observing, and reflecting.
- Researchers engage participants as partners.
- The degree to which the researcher is an insider or outsider to community under study makes a difference and must be a consideration in any action research study (pp. 50-51).

Merriam and Tisdell (2016) add one more principle to the list: they state researchers conducting action research should collect and analyze multiple forms of data as cycles progress.

Action research is a collaborative approach between the researcher and practitioner. Collaboration between the researcher and teachers may produce knowledge that can be shared with other educators to create a social change for greater equity in schools. Action research is socially responsive and can assist in developing structures for institutionalization changes (Creswell, 2008; Herr & Anderson, 2005; McNiff & Whitehead, 2009; Pine, 2008). Educators involved in this study will reflect critically on their own practice and identify positive changes to enhance student performance. The discourse data collected from students were used to drive instructional changes. All member of the PLC are educators who work together to modify instructional practices and identify needed change.

Action research is an iterative process with cycles of reflect, plan, act, and review. Pine (2009) describes action research as a recursive process in which each cycle involves steps to reflect, plan, act, and observe for continual improvement (p. 73). The *2018-2019 Action Research Plan* found in Appendix outlines the stages of reflect, plan, act, and observe, and were used as a visual organizer. The plan includes three modules with three lessons in each. Each module equates to one action research cycle and provides guidance on what to include in each lesson. The basic steps within one cycle are labeled look, think, and act (Stringer, 2014, p. 8). First, researchers gather data and describe the specified issue or problem. Second, the data was analyzed and explored for interpretation and explanation. Third, a plan of action was implemented and then evaluated. Kemmis and McTaggart present (cited in Stringer, 2014, p. 9) a spiraling routine of cycles where look, think, and act were placed each cycle of plan, implement, and evaluate.

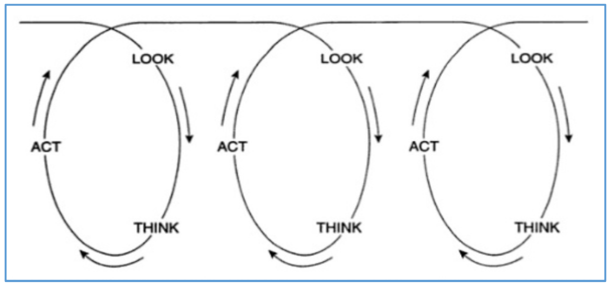


Figure 5. Stringer Action Research Interacting Spiral

Action research is much more than following a cyclic protocol. It involves societal values such as "enabling all people to participate (democratic), acknowledging people's equality of worth (equitable), providing freedom from oppressive, debilitating conditions (liberating), and enabling the expression of people's full human potential (enhancing)" (Stringer, 2014, pp. 14-15). A professional learning community (PLC) team is a model for how participants interact in a democratic fashion. The goal of the PLC team is to solve local issues and transform systems.

Practical action research. Kemmis (2009) describes action research as a "practice-changing practice" (p. 468). There are a number of different kinds of action research that differ in the patterns of dialogue, doings, and relationships. According to Creswell (2008), two broad categories of action research design exist, practical action research and participatory action Kemmis (2009) defines practical action research as "guided by an interest in educating or enlightening practitioners so they can act more wisely and prudently" (p.469). The purpose of practical action research is to research a specific local issue and improve the issue. Creswell (2008) states educators can test their own theories and explanations about learning and examine the effect of their practices on students. The major principles of practical action research include:

- Practitioner-researchers have decision-making authority to study an educational practice as part of their own ongoing professional development.
- Practitioner-researchers are committed to ongoing professional development and school improvement
- Practitioner-researchers want to reflect on their practices. Team members reflect individually or in school based teams.
- Practitioner-researchers use a systematic approach for reflecting on their practices, meaning that they use identifiable procedures to study their own problems rather than using a random, anything-goes design.
- Practitioner-researchers choose an area of focus, determine data-collection techniques, analyze and interpret data, and develop action plans (Creswell, 2008, p. 600).

The principles listed above are practical group norms PLC teams can use to solve local issues.

The research questions in this study fit within the practical action research paradigm. The questions are reflective of practical action research because they seek to find how student learn elements of argument as well as how the action research team modifies instructional practices. “The practitioner aims to act more wisely and prudently, so the outcomes and longer-term consequences of the practice will be for the best” (Kemmis, 2009, p. 470). The researcher is a practitioner who decides what to explore and what changes are to be made to improve practice. According to Kemmis (2009), the researcher is “treating the others involved not as objects but as subjects capable of speech and action, and as persons who will also live with the consequences of what is done” (p. 470). Members of the action research team have a voice in each research cycle. This is critical in providing feedback and insight to instructional changes. The research questions (RQ2 and RQ3) investigate how explicitly teaching elements of scientific argumentation can influence student understanding of argumentation structure, science content, and justification of claim. The argumentation lessons were developed to support the construction of science knowledge and to empower students for successful engagement in written and verbal scientific argument. Argumentation allows students to talk with other students and build knowledge together as a community. This type of discourse can be empowering for students and lead to success in mastery of argumentation. A collaborative approach to developing and implementing curriculum that promotes student-centered dialogue through argumentation may promote student voice and avoid inequitable practices.

Research Setting and Context

This study was conducted in a suburban public high school, NW High School, located near a large metropolitan city in the Midwest. Students come from five different feeder schools and other private and public schools not directly connected to the district. There could be up to eight or more different school districts from which these students come from. High school readiness skills differ for each student depending on which K-8 school the students come from. The learning experiences are not all the same nor equitable in terms of content learned or resources available.

NW High School has approximately 2,500 students in attendance with a four-year graduation rate of 96%. The student population has a 32% low socioeconomic status where 1% of the student population is homeless. NW High School is considered a racially diverse public school where there are 45% White, 4% Black, 16% Hispanic, 33% Asian, 0.2% American Indian, 0.1% Pacific Islander, and 1.7% two or More Races. For the past three years, a school wide goal has been to provide equitable opportunities to all students through student voice, brave communities, and curriculum. The NW High School Science Department goal is to develop one's own critical self-consciousness about differing cultural experiences and provide equitable opportunities to students so they have voice and take risks. All science teachers developed our goal after much critical self-reflection about our biases and data presented about our achievement gap. Tracking of students of color was identified as a local issue.

In 2018-2019, there were 28 students enrolled in Exploratory Chemistry and Physics. The demographic racial breakdown of students was 26% African American, 13% Hispanic, 19% Asian, and 39% White. For the past two years, the percentage of students of color in this lower level course exceeded the percentage of students of color in the total population. The data shown in the bar graph below *(Figure 6* and *Figure 7*) summarize the racial disparities that exist in the ECP course. In 2018-2019, the percentage of African American students in the entire high school is 5% and the percentage of African American students in the ECP course is 26%. During this same year, the Hispanic population (13%) is slightly lower in the ECP course than the total population (15%). However, the year before there was a higher percentage of Hispanic students (22%) than the total population (15%). For the past two years, the percentages of White and Asian students enrolled in ECP were lower than the total population of White and Asian students. We would expect that all science courses would have a racial distribution similar to the general population.

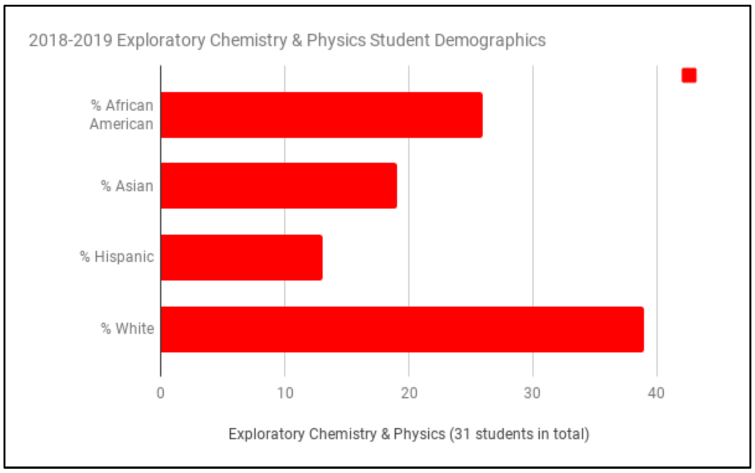


*Figure 6***.** Percent by Race of NW High School Students Enrolled in Exploratory Chemistry and Physics Science Course in 2018-2019.

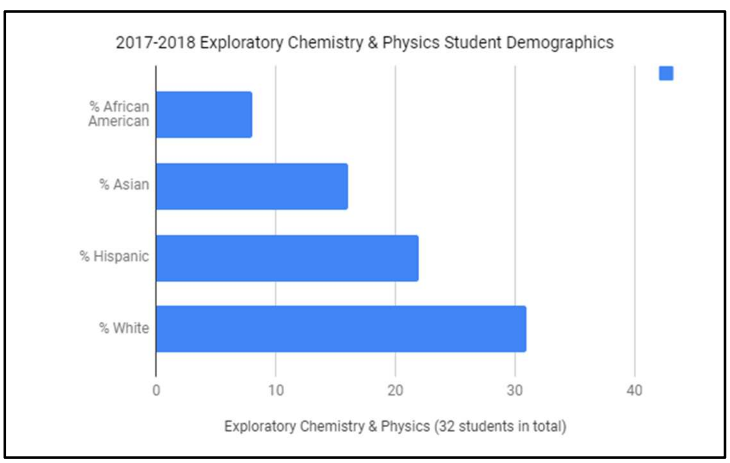


Figure 7. Percent by Race of NW High School Students Enrolled in Exploratory Chemistry and Physics Science Course in 2017-2018.

Student PSAT 8/9 test scores and 8th grade teacher recommendations were used to enroll students into the ECP course. The total score range of the standardized PSAT 8 test is 240-1440. The math section of the PSAT 8/9 test is 120-720 and the English section has the same score range of 120-720. The PSAT 8/9 is a standardized test created by the College Board to measure college readiness. According to the College Board (2017), 8th grade students who score 390 in Reading/Writing and 430 in Math are considered to be on the path toward college readiness. Based on these criteria and the scores of the incoming 8th grade class, the school district selected students for the ECP course if they scored 360 and below in Reading/Writing, and scored 330 and below in Math. *Table 3* below compares the PSAT 8/9 scores between the total populations of 9th grade students to the students enrolled in the ECP course. Students in the ECP course are well below the average 9th grade freshman student in reading and math skills.

Table 3

9th Grade Student Population & ECP PSAT 8/9 Test Scores

	NW 9th Grade Total Student Population	**NW High School ECP Student Data**
Total # Students	556	29
Avg. Score PSAT 8 Total	843.3	648
Avg. Score PSAT 8 Reading/Writing	430.1	344
Avg. Score PSAT 8 Math	413.2	303

Table 4 lists the average percent, total number of students, average PSAT 8/9 scores by racial demographics, gender, socioeconomic status, and IEP status. On average students

of color perform below students of White and Asian descent. Asian and Hispanic students had the highest average PSAT 8/9 score, White and Asian students had the highest average Reading/Writing scores, and Hispanic and Asian students had the highest average math score. The White population had the lowest average math score on the PSAT 8/9. *Table 5* can be used as a comparison between the total student population and the ECP student population.

Table 4

2017-2018 ECP Student Demographics & PSAT 8/9 Test Scores

	%	Total # Students	Avg. PSAT 8 Total	Avg. PSAT 8 Reading/Writin g	Avg. PSAT 8 Math
ECP Student Demographics					
Asian	18	5	650	348	302
White	36	10	649	351	298
African American	21	6	643	341	301
Hispanic	25	7	650	335	314
Gender					
Female	18	2	710	380	330
Male	82	9	657	302	356
Socio Economic Status					
Free	73	20	654	345	309
Pay	27	8	627	342	285
Special Education					
IEP	64	18	639	342	297
No IEP	36	10	653	345	308

Table 5

2017-2018 9th Grade Total Population Demographics & PSAT 8/9 Test Scores

2017-2018 NW High School	%	Total # Students	Avg. PSAT 8 Total	Avg. PSAT 8 Reading/Writing	Avg. PSAT 8 Math
Student Population Demographics					
Asian	35.86	199	870	444	426
White	44.86	249	844	431	412
African American	4.14	23	724	369	355
Hispanic	11.89	66	801	405	395
Native Hawaiian	0.36	2	695	375	320
Multiracial	2.88	16	850	422	428
Gender					
Female	47.48	264	842	435	406
Male	52.52	292	844	424	419
Socio Economic Status					
Free	30.22	168	789	402	386
Pay	69.78	388	866	441	424
Special Education					
IEP	9.71	54	652	335	317
No IEP	90.29	502	863	440	423

Research Sample and Data Source

Purposeful sampling, or nonprobability sampling, will be used in this practical action research study. Patton (2015) defines purposeful sampling as “selecting information-rich cases to study, cases that by their nature and substance will illuminate the inquiry questions being investigated" (p. 264). Merriam and Tisdell (2016) state purposeful sampling is based on the assumption that the investigator wants to discover, understand, and gain insight, and, therefore, must select from which the most can be learned" (p. 96). Students in the ECP course were selected to be in the sample because they are mostly students of color and are in the lowest level science course during their freshman year. Data will be collected from all 28 students enrolled in the ECP course. The data collected will not identify individual students in the study. All data collected in this study are a part of normal instructional practice and required of students to complete as part of the course. The institutional IRB panel to conduct this study granted a waiver of consent. A letter of agreement was signed by the science teachers to protect the identity of students. Science teachers agreed to redact any student names on documents before giving them to the researcher.

In this practical action research study, the PLC team (literacy coach and science teachers) collaborated with the researcher, who is also the Director of Science, to improve curriculum and implement three argumentation lessons. The literacy coach had a vested interest in the ECP students because they are the same students in her lower level English intervention course.

The Director of Science had a vested interest in preparing ECP students for higher-level science courses and improve science practice instruction. The researcher had a dual role in this study as an insider researcher and practitioner (Director of Science). The dual role has several advantages in this study: access to data, flexibility in schedule, less intrusive presence in the classroom, buy-in by teachers, willingness to support detracking efforts, and the existence of a trusting relationship. The Director of Science, inside researcher, worked closely with the PLC team to organize and maintain an action plan, coordinate meeting dates, prepare for PLC meetings, facilitate discussions, debrief about the meetings, create a system that organizes curriculum materials and data, coordinate PLC team member notes, and gather classroom data (observations of students, assessment results, field notes). The literacy coach and Director of Science are considered guests in the ECP classroom and the science teachers oversee the daily routines and procedures in the classroom. The science teachers give ECP students feedback and determine student grades. They have a vested interest in seeing students succeed as well as improving their own teaching craft.

For professional development, stakeholders such as the school principal, teachers within the school, curriculum directors, and superintendent may wish to investigate this action research protocol. The framework of action research is built from the teacher level and has a meaningful process. Parents and students may be interested in the finding of the study as well. The findings could educate community members about essential intervention systems, which would fuel support by school board members. The framework of this study could serve as a model for other educators to use when implementing argumentation lessons or action research studies.

Data Collection Methods

Procedures

A pilot action research study from the spring of 2018 collected data from a variety of sources, such as teacher interviews, observations, and student written documents. This pilot study provided insight into challenges students face when generating arguments. The action research team found student difficulty with writing justifications and accurately using science principles. The responses in the reasoning section on write documents failed to link evidence to claims. The action research team determined the next level of work would be to develop explicitly taught argumentation lessons and new tools that measure elements of argument.

This practical action research study utilized an action research plan that scaffolded elements of argumentation skills within nine lessons. The *2018-2019 Action Research Plan* (found in Appendix) organizes the study into three separate phases, or cycles, over a nine-month period. Each cycle includes a phases of action research: *reflecting, planning, acting, and reviewing*. First, in the *reflecting* phase the PLC team discussed major issues related to tracking. A discussion revolved around findings from an action research pilot study completed in the prior school year. Results from the pilot study revealed the need to model and explicitly teach elements of argument, measure accuracy of science content in reasoning, and build a community of learners. In the pilot study, the curriculum was taught as if students already knew how to speak and write an argument with claim, evidence, and reasoning (CER). The approach to teaching argumentation was more technical. Students approached scientific argumentation as a checklist rather than as a social construct of building knowledge as a community. By the end of the pilot study, the PLC team realized there was so much more to argumentation than writing claim, evidence, and reasoning. Argumentation is a social process that requires explicit teaching about components of CER. We started to think of argumentation as a social dialogic learning process and developed new lessons in the *planning* phase of the current study. The literacy coach and Director of Science used the results from the pilot study to define what explicit would mean in the argument lessons. A total of nine argumentation lessons were developed with a goal of explicitly teaching the skills scaffolded so each element of argument could build upon the next. The objective of each lesson is listed below:

- LESSON IA Task-Describe a phenomenon to students, then ask students to identify a claim about the phenomenon. Describe a new phenomenon, and then ask students to articulate (construct) a claim.
- LESSON IB Task- Present students with a claim and evidence about a phenomenon then ask students how well the evidence supports the claim, and articulate the scientific principles that connect each piece of evidence to the claim.
- LESSON IC Task- Describe a phenomenon to students, then ask students to articulate (construct) a claim about the phenomenon, and then collect evidence that supports the claim. Articulate the scientific principles that connect each piece of evidence to the claim.

- LESSON IIA Task- Present students with a claim and evidence and reasoning about a phenomenon, then ask students to assess the reasoning of a given link between claim and evidence.
- LESSON IIB Task- Present students with a claim and evidence about a phenomenon, then ask students to construct the reasoning between claim and evidence.
- LESSON IIC Task- Describe a phenomenon to students, then ask students to construct a complete argument with a claim, evidence, and reasoning.
- LESSON IIIA Task- Present students with a claim, a list of data sources that are relevant to the claim (but not what the data says), and then ask students to identify (select from a list) a pattern of evidence from the data that would support the claim. Also, ask students what pattern of evidence from the data would refute (counter argument) the claim.
- LESSON IIIB

  Task- Present students with a claim, evidence, and warrant that is flawed, and then ask students to critique the argument. Students should justify their counter-critique or why the argument is flawed.
- LESSON IIIC Task- Describe a situation in which two or more explanations are offered for a phenomenon (competing arguments). Ask students to make an explicit argument for why one argument is stronger and why one is weaker.

During the *acting* phase, the PLC team-taught argumentation lessons in the ECP classroom for approximately 42 minutes. After each lesson, the PLC team met to reflect on the lived experience and observations from the class. The researcher took reflection notes after each lesson taught and each meeting with the PLC team. Recommendations from the science teachers were considered in the development of the argumentation lessons. This occurred during the *review* phase of our action research plan.

Data Sources

Various forms of data were collected to measure how well ECP students understand and apply the elements of argument. According to Creswell (2014), a qualitative observation involves the researcher writing field notes on behaviors and activities at the research site, and qualitative documents are the artifacts, such as public or private documents, collected by the researcher (p. 190).

Both observations and documents were used as types of data collection. In addition, audio recordings were collected to see if students could speak to the elements of argument. Audio recordings will come from small student group discussions. In order to protect the individual student all data was reported in aggregate. Specific forms of data collected are listed in *Table 6*. The *Action Research Study Data Types/Sources* table aligns the research questions to the data sources, and provides a brief explanation of why those data sources were selected. Additional information about analysis instruments can be found in the *Action Research Study Data Analysis Framework & Instrumentation table* (found in the Appendix).

Table 6

Action Research Study Data Types/Sources

Research Questions	Data type/source	How data types/source increase credibility of study?
(RQ1): How does the process of action research influence our instruction of scientific argumentation in a high school science course?	1. Classroom Observations field notes of behaviors relating to student ability to state claims, collect evidence, justify claim with evidence, and counter critique. 2. Researcher reflection journal notes 3. Student written documents 4. Audio recording transcripts	1**. Triangulation**- Findings from the variety of data sources will confirm patterns of student progression of mastery of argumentation skills. 2. Transcripts from audio recordings and field notes will provide **rich thick descriptions** about group findings. 3. **Adequate engagement in data collection**- Over time student discourse can be analyzed for patterns and improvement. 4**. Critical self-reflection** in journal notes 5**. Audit trail** of methods, procedures 6**. Multiple sources** of student written documents will provide data to support whether groups of students are progressing in their ability to write a complete argument. 7. A **member check** will be conducted with the PLC team
(RQ2): How does student ability to **write** scientific argument develop over time?	1. Student Written Documents from lessons (IIA, IIB, & IIC) focused on argumentation during cycle II. 2. Student Written Documents Pre-Test of Argumentation skills & Post-Test of Argumentation skills 3. Researcher reflection journal notes 4. Student Survey: Pre-Student Questionnaire and Mid-Term Student questionnaire	
(RQ3): What role did **verbal** discourse play in students' developing understanding of elements of argument?	1. Transcript from audio recording of student groups during cycle II argument lessons (IIA, IIB, & IIC). 2. Classroom observations field notes of behaviors relating to student ability to state claims, collect evidence, justify claim with evidence, and counter critique. 3. Researcher reflection journal notes	

Student questionnaire. Students were given a questionnaire that asked students to define claim, evidence and reasoning. A questionnaire was given to students after each action research cycle. The researcher used Google Forms to create the questionnaire. The Pre-Student Questionnaire and Mid-Term Student Questionnaire were distributed to students and collected by the science teacher during science class. The Post- Student Questionnaire will be given after the last cycle or at the end of the school year.

Transcript from audio recordings. Student group discussions during argumentation lessons were recorded. An audio recorder was placed near student groups to record the argument. The purpose of the recording was to capture the dialogue between students since field notes were not able to capture specific student conversations simultaneously. Each audio recording was transcribed and analyzed by the researcher. The transcript was member checked by the PLC team. The audio recording transcripts provided data to answer research question RQ3. We investigated how verbal discourse contributed to student understanding of argument. The transcripts from the audio recordings were used to analyze students' ability to explain their claim, evidence, and reasoning. In the future, student discourse will be analyzed for patterns and progressions of science talk.

Student written documents. Student writing samples from cycle II lessons were collected and analyzed for level of mastery. Student written responses on the benchmark assessments werel also analyzed for mastery. Benchmark exams were given at the beginning of the school year in August, mid-year in November, and last in February. The benchmark assessments explicitly asked students to write scientific arguments using the claim, evidence, and reasoning framework. Student responses from these benchmark exams were used to identify the quality of elements of argument developed over time. Creswell (2014) cites many advantages to using written documents for data analysis. Written documents are already transcribed, convenient, and do not require interaction with participants (Creswell, 2014, p. 192). Student written documents allows the researcher to analyze student mastery of understanding argument by the class as a whole.

Construction of the language and format found on the *Evidence Based Argumentation Skills Rubric* (found in Appendix) were based upon criteria of quality argument from various scientific argumentation studies (Osborne et.al. 2016; Thompson, Braaten, Windschitl, 2014; Ambitious Science Teaching, 2018). The constructs listed in the claim, evidence, and reasoning section of the rubric determine the level of understanding. The rubric includes visual models of element of argument to assist student understanding. A claim answers the original question or problem. Students are expected to make accurate claims for mastery. Evidence is scientific data that supports the claim. Students are expected to collect appropriate and sufficient quantitative and qualitative data. Reasoning should be written to compare multiple forms of evidence, describe scientific principles, connect evidence to the claim, and use mathematical models when appropriate.

The elements of argument found on student written documents and benchmark exams were analyzed using of the conceptual frameworks of Toulmin and Zohar and Nemet. The majority of scientific argumentation research studies cite the use of the Toulmin Analytical Framework to measure constructs of argument. The student written samples will answer question RQ2. The following list of data sources will be used to measure how students develop understanding of argument:

Classroom observations field notes. A script was typed by the researcher during small group student discussions. The *Argumentation Classroom Observation Instrument -*

Fall 2018 includes a tab labeled *Script* that allowed the researcher to record student group interactions and dialogue. The researcher scripted student interactions during argumentation lessons. Field notes were taken on student ability to state claims, collect evidence, justify claim with evidence, and counter critique. In addition, the researcher recorded student interactions during argument conversations. The researcher used observations of student interaction to bring back to the PLC team. The team discussed the strengths and areas of improvements based on all the data sources, including these field notes. The field notes were used as a supplement to the audio recordings transcripts. The process of action research during this act phase influenced how we made changes to the next lesson. Field notes, transcripts from audio recordings, and researcher journal reflections notes were used to answer research questions RQ1 and RQ3.

The *Argumentation Classroom Observation Instrument - Fall 2018* (found in Appendix) was used to document field notes during student group interactions. The researcher scripted student group conversations. The instrument was also used to centralize information about mastery of elements of argument. The *Evidence Based Argumentation Skills Rubric* can be found on this instrument which defines three levels of mastery per each measured element of argument. The elements of argument include claim, evidence, reasoning, and counter critique. There are three levels of mastery on the rubric. Level 3 indicates mastery of the element, level 2 is a work in progress, and level 1 would indicate a lack of knowledge in elements of argument. A few research studies were used as models when creating levels of mastery on the rubric (Sampson & Clark, 2008; Toulmin, 2003; Zohar & Nemet, 2002).

Researcher reflection journal notes. Reflection is an important component of the action research approach. Conducting research as an insider has advantages of generating knowledge that can be shared with others in the Science Department (Herr & Anderson, 2005, p. 34). The reflexive and logical discussions about ideas and opinions can bring changes to instructional practices (Creswell, 2008, p. 604) Reflection is ongoing and asks what is learned and accomplished because of the actions. The researcher reflection journal notes are critical to the actions of the team for focus and improvement. The journal notes document the lived experiences and identify personal changes during the process. Kemmis (2009) summarizes:

> What is to be transformed in critical action research is not only *activities* and their immediate *outcomes* (as in technical action research) or the *persons* and (self-) *understandings* of practitioners and others involved in and affected by a practice (as is in the case of practical action research) but the *social formation* in which the practice occurs- the discourses (sayings) that orient and inform it, the things that are done (doings), and the patterns of social relationships between those involved and affected (relatings) (p.471).

The reflection journal documents the lived experience and reminds the researcher about the values that frame the transformation. Changes to the system of inequity in the Science Department is a complex process, which requires a collective social transformation by teachers and myself, the Director of Science. The reflection journal provided an audit trail of the details of curriculum development and decisions made during the cycles of action research. It also provided a rich thick description of the procedures, decisions, and self-reflection.

Data Analysis Methods

Data analysis in this action research study will include qualitative techniques that examine student mastery of argumentation skills and student perception of their role in the community of learners during argument. Argumentation theory provides a conceptual framework for this research study in a technical sense as well as a sociocultural perspective. Van Eemeren's (2012) version of argumentation theory, called pragma-dialectical theory, assigns four principles related to argument: externalizing a position or standpoint, expression of people's processes, function of managing resolution of disagreement, and efficient arguing on solving differences. These principles align with the sociocultural perspective because of the interactions that must take place between individuals in argument. The extent to which students are able to use elements of argumentation in student verbal and written discourse will be analyzed by the use of argumentation schemas from Toulmin, Zohar and Nemet. Both schema analyze the quality of each argument component of claim, evidence, and reasoning. Zohar and Nemet also include the ability to accurately use scientific principles in argumentation. Argumentation schema are useful when identifying components of argument such as claim, evidence, and reasoning in verbal and written discourse.

In this study, understanding elements of argument are of most interest. Scientific argumentation occurs through social interactions that impact student learning and can improve critical thinking skills. ECP students will need these skills to be successful in future higher-level science courses. Student responses and counter arguments can reveal how students learn elements of argument within a community. The results of these social actions between students can help the PLC determine changes to instructional practices. Carbo, Ahumada, Caballero, and Arguelles (2016) define discourse as a way of signaling the socially constructive and productive aspects of language use. Verbal discourse responses may be influenced by positioning, voice, and power among students. While developing lessons the team considered these discursive practices. For example, we may incorporate instructional roles so all students have opportunity to participate in discussion.

Analysis of the Process of Action Research (RQ1)

Action research is a journey of continual reflection and analysis of student data. Research question 1 (RQ1) investigates how the process of action research influences instruction of scientific argumentation in a high school science course. A narrative about the process and the changes made from continual analysis of data will be shared in Chapter IV. Research question 1 was answered through the analysis of reflection journal notes, and the results of written and verbal discourse data. First, the researcher's reflection notes were analyzed by use of open coding. Common themes were identified and then compared through axial coding. Last, selective coding was used to determine core themes and developed hypotheses. The core themes found from selective coding would assist with analyzing the data and determining the findings. The results from written documents and audio recording transcripts were discussed during PLC team meetings. The researcher took notes during the meeting and then wrote more detailed follow up notes. The analysis process of the reflection research notes was iterative as the action research phases progressed through each cycle.

Analyzing Argument in Student Written Response (RQ2)

Analysis of written discourse data used closed, axial, and selective coding. Argumentation theories were used to determine the pre-established coding scheme. The codes used for analysis of the written samples were claim, evidence, and reasoning. The *Evidence Based Argumentation Skills Rubric* (found in Appendix) was the instrument used to determine the mastery of elements of argument in written form. This rubric specified the definition of a claim, evidence, reasoning, and counter-critique and levels of mastery. A claim is defined as a statement that answers the original problem/question. Evidence is scientific data that supports the claim. Reasoning explains why the evidence supports the claim with accuracy of scientific principles. The quality of written claim, evidence, and reasoning were analyzed by use of *Evidence Based Argumentation Skills Rubric*. The progression of mastery in areas of claim, evidence, and reasoning were listed on this rubric.

Criteria for each of the three levels of mastery were used to create the *Evidence Based Argumentation Skills Rubric.* For example, a student must (1) compare multiple forms of evidence, (2) use accurate scientific principles, (3) connect evidence to claim, and (4) link to a mathematical model (if appropriate) for level 3 (high) mastery in the reasoning section. The three levels of mastery on the *Evidence Based Argumentation Skills Rubric* are high, medium, and low. Three points were given to each element of argument (claim, evidence, and reasoning) for a total of nine points. The sum of total points correlated to the level of high, medium, and low mastery. Written papers would have high mastery with a total of 9 points; medium mastery between seven and eight total points; and below seven total points low mastery.

The team determined three levels of mastery (high, medium, and low) would show progression of student growth. In addition, the team decided to use similar models of mastery found in scientific argumentation research studies. Over time, students should be able to score three points for a claim and three points for evidence. Based on student written samples from the pilot study, we found student ability to write a claim and evidence were much easier. If a student earned three points for a claim and three points for evidence, it did not show an understanding of how to write reasoning. We set the expectation for students to have medium mastery if they could earn between 7-8 points. Students would have to write reasoning, and earn 1-2 more points above what they earned for the claim and evidence. The team felt this was a reasonable expectation for students.

This research study is interested in identifying the level of mastery for each student written sample and then as the ECP group. In order to protect the identity of high school students, only group averages and general summary of mastery levels were reported. Individual statements and scores were intentionally left out of the findings section of this dissertation paper.

Understanding Argument in Verbal Discourse (RQ3)

The audio recording transcripts from the bottle rocket, circuits, and mousetrap argument lessons were analyzed to see what role verbal discourse played in students' developing understanding of elements of argument. Field notes and researcher reflection notes were also analyzed to determine student mastery of claim, evidence, and reasoning. Analysis of verbal discourse data used closed, axial, and selective coding. The codes used for analysis of the audio recording transcripts were claim, evidence, and reasoning. Argumentation theories were used to determine the pre-established coding scheme. These codes were selected because they were used to analyze elements of quality argument. Merriam and Tisdell (2016) describe coding as a scaffold where axial coding relates the themes to one another, and selective coding determines the core themes and developed hypotheses (p. 229). Once the audio recording transcripts were analyzed for claim, evidence, and reasoning these codes were compared for themes. By analyzing audio recording transcripts, the researcher looked for similar themes around how verbal discourse influences students' developed understanding of elements of argument. As the researcher continued to examine how the data unfolded, a constant comparison of data occurred over the three cycles of action research. For purposes of this dissertation study, only the second cycle was fully reported. IRB approval provided guidelines on when and how the data could be collected and reported. The following data sources were used to analyze audio recording transcripts:

1. Transcript from audio recordings of students in groups from cycle II lessons.
2. Classroom observations field notes of behaviors relating to student ability to state claims, collect evidence, justify claim with evidence, and counter critique.
3. Researcher reflection journal notes.

After each action research cycle, the researcher will gather evidence from the three data sources and analyze the constructs of argument (claim, evidence, reasoning, and accuracy of science). Using multiple sources of data over three cycles allows the researcher to cross check and compare data. Merriam and Tisdell (2016) state, "triangulation- whether you make use of more than one data collection method, multiple sources of data, multiple investigators, or multiple theories- is a powerful strategy for increasing the credibility or internal validity of your research" (p. 245). Coding each data source and looking for themes and patterns will validate the findings of the study.

One rule of thumb to use while analyzing data is to "review your information after it is coded to determine if there is a frequency of certain phenomena or powerful, unusual comments, events, or behaviors that particularly interest you" (Pine, 2009, p. 257). The *Argumentation Classroom Observation Instrument Fall 2018* (found in Appendix) is an instrumental tool used to record audio transcripts and field notes. The transcripts from these two data sources will be coded for patterns or themes relating to constructs of argument (claim, evidence, and reasoning).

Issues of Trustworthiness

Action research studies differ from traditional qualitative studies in that criteria for good action research cannot simply use terms such validity or trustworthiness. Neither term encapsulates the action-oriented outcomes. Action researchers are still interested in knowing if knowledge in valid or trustworthy, but are also interested in knowing outcomes beyond knowledge generation (Herr & Anderson, 2005, p. 49). The majority of researchers use the term validity with the understanding that both internal and external validity are included. According to Herr and Anderson (2005), action research studies focus on the local setting and can only justify using internal validity as a criterion for good research. A study is trustworthy when the findings of action research are credible to those who provided the data.

Creswell (2014) states “validity is one of the strengths of qualitative research and is based on determining whether findings are accurate from the standpoint of the researcher, the participant, or the readers of the account” (p. 201). This action research may not be generalizable to other school districts, but it certainly can provide findings that will transform the tracking practices in the high school. Internal validity is the “extent to which research findings are credible” (Merriam & Tisdell, 2016, p. 265) or the “trustworthiness of inferences drawn from data” (Herr & Anderson, 2005, p. 50). External validity is concerned with the extent to which findings can be generalized to other settings. However, this is not typically a concern for small case studies.

Herr and Anderson defined five validity criteria to legitimize the findings in an action research study. The five criteria are outcome, process, democratic, catalytic, and dialogic (Herr & Anderson, 2005, p. 54). They aligned action research goals to indicators of quality (validity):

- The generation of new knowledge- dialogic & process validity
- The achievement of action oriented outcomes- outcome validity
- The education of both research and participants- catalytic validity
- Results that are relevant to the local setting- democratic validity
- A sound and appropriate research methodology- process validity (p. 54).

The PLC team was encouraged to collaborate fully and to state opinions and beliefs about student performance and the interdisciplinary approach. The researcher will establish group norms and suggest each person hold each other accountable for input and following through on interventions and data collection. Members need to be reliable and prepared during meetings. A member check will be put in place to verify individual perspectives and to validate the importance of individual input. Democratic validity was essential so changes could be made to instructional practices that impact student learning.

Outcome validity will inform readers about the results of the study and how the solution leads to the next cycle of action research. Herr and Anderson (2015) describe outcome validity as being “synonymous with the ‘successful’ outcome of the research project” (p.55). There is ongoing reframing of problems, which leads to cycles of research. In this action research study, there are various forms of data collected: ECP benchmark exams, audio recording transcripts, field notes of classroom observations, student written documents, research reflection, and student questionnaires. The results from the ongoing collection of data drives the next cycle of action research. Thus, continuous conversations with the literacy coach and science teachers will be important to validate the findings from the data collected. The amount and variety of data is sufficient to triangulate data to increase validity of the results. Based on the results, improvements will be made to the curriculum or process of data collection.

Catalytic validity is a type of validity that will come from the changes seen amongst researchers in the study. The results could change how administrators approach problems using localized data, and avoid over generalizing initiatives such as detracking.

"All involved in the research study should deepen their understanding of the social reality under study and should be moved to some action to change it (or to reaffirm their support of it)" (Herr & Anderson, 2015, p. 56). The researcher will keep a reflection journal throughout the study to monitor changes in thought and progression of the study.

Credibility of this action research study was validated by the methods, procedures, discourse, and action taken to improve student learning. Validity in this study increased by member checks, triangulation of data, and thick description. Results of student performance data from written and verbal discourse was shared in the PLC team meetings. Teachers verified findings from this data and shared their own analysis of the results. This action research study may not be able to generalize a solution for all schools, but it may influence readers to think about how they could perform their own localized study to eliminate achievement gaps. Through thick description of this study, readers can determine if these results match their own localized environment. Threats of external validity will be a consideration. Generality is a major threat of external validity; the results of this study may not be applied to other similar situations. The action research methodology may increase the replication of research findings because of the nature of the procedure. Cycles of study allow for repeating research design. This study can continue to follow the student cohort years after this research study is over. However, the reliability may be problematic in other settings because of changes to human behavior.

The instruments (rubrics, questionnaire, assessments, etc.) used to measure student understanding of elements of argument can be trusted because of the reliability of conceptual frameworks used to create the instrument. Research scholars who study argumentation most frequently use the Toulmin framework. All argumentation research studies investigated in this study reference the Toulmin framework as the basis for analyzing argument. Stephen Toulmin is a competent philosopher and author of the most well-known cited book, *The Uses of Argument*. He is a well-known author who is developed practical arguments and constructs to organize argument. Sampson and Clark (2008) state, "Toulmin's perspective on argumentation has substantially influenced science education research" (p.450) and in other subject areas such as language arts and mathematics. Toulmin is cited in the *Next Generation Science Standards* as a framework to use to measure argumentation science practices. The recurring use of Toulmin's framework increase the reliability, or trustworthiness, of the instruments used in this study.

Limitations and Delimitations of the Study

The action research approach is a limitation. As generic as this argument sounds, there is a perception by researchers that there is a lack of rigor, criteria of quality, and legitimacy as a methodology (Herr & Anderson, 2005; Pine, 2009; Stringer, 2014). Academics tend to be more comfortable with action research as a means to generate knowledge on a local level, but are less comfortable when presented as public knowledge (Herr & Anderson, 2005). Positivist viewpoints may not see the value and rigor involved with action research studies. My own personal encounters with science educators reveal misunderstandings about qualitative methodology, and the lack of knowledge about the value of action research. Most science educators value quantitative methodology as a form of research. There are misconceptions about the rigor of action research and how the findings can transform science education. Practitioners are removed from research settings, and often do not realize the impact qualitative research has on science classrooms. Therefore, the researcher feels there is a need to legitimize action research as a valid means of generating knowledge. Action research is a messy and fluid process where the cycles of action may overlap and the initial plans may change. It concerns actual practices and is a social process, and therefore, a good match for educational settings.

A particular limitation to this study was the researcher's position of power as the Director of Science in the high school. Because of this position of power, interviews and other forms of collecting data from science teachers was avoided. It would be difficult to receive IRB approval for this study if individuals from the researcher's own department were included. It is understandable to exclude those who may be perceived as being coerced into the study, but it also limits the potential of the study. The science teachers would bring valuable expertise and experience to curriculum development and implementation. Multiple perspectives would improve democratic validity, the extent to which research is done in collaboration with all stakeholders (Herr & Anderson, 2005).

As an insider researcher and practitioner, the researcher was frequently reminded of the concept of positionality and bias in the study. The limitation was being in a position of power as the administrator. Having a position of power and privilege could also impact the working relationship with the teachers. In the social structure of the school, the researcher could not avoid nor negate this role. The researcher tried to communicate effectively, recognize the collaborative work of the teachers, and continuously reference the impact of our collected data on student learning. The teachers and researcher share a common belief of social transformation and emancipatory education. Our shared values and beliefs to help those marginalized by inequities in our education system fueled our work.

Yakushko, Badiee, Mallory, and Wang (2011) state, "one of the greatest challenges for each of us in a position of an insider/outsider is that we often fail to see the power and privileges we possess in relation to people in our home communities" (p. 281). It was important for the researcher to be sensitive to the literacy coach's feelings so she did not feel coerced into completing tasks. The literacy coach was selected in this study because of her many years of teaching experience, experience with literacy work, tenured position, and our established working relationship. Every effort was made to create an equal partnership in the study without overburdening the literacy coach with tasks that fall outside of the agreed upon expectations of the study.

The researcher role as an insider with a position of power comes with privileges that delimit the study. Privileges such as accessibility to students in the classroom, access to district databases with student information, time to meet with teachers, and observations in the classrooms were readily accessible to the researcher. The researcher could observe students in the classroom without having to seek formal approval by the school district. Access to classrooms and teachers delimits the study and is an insider advantage. Clearly, there are benefits to having the insider advantage, but the researcher should always be aware of the bias that comes with these privileges. Yakushko et al. (2011) stated "...authenticity of a research project is raised because perhaps one knows too much or is too close to the project and may be too similar to those being studied" (p. 280). Insider knowledge could limit ability to objectively analyze the data collected and identify next steps in the action research plan. The researcher has an internal conviction to see students succeed through academics by empowering their voices and moving into higher-level science courses in the future.

Summary

Chapter III reviewed the problem of tracking in the science program at NW High School and the need for designed curriculum to teach elements of argumentation. The researcher argues that students who learn elements of argument will develop critical thinking skills and the ability to advocate for their own learning by student voice. Research questions addressed this argument by use of qualitative methods. Details about the methodology of action research, data collection (procedures & instruments), data analysis, trustworthiness, and limitations (bias) were laid out in this chapter. Conceptual frameworks from both argumentation theory and sociocultural theory provide a sociocultural perspective. Engaging in argument involves both learning technical science practice skills and social skills. Constructs found in analytical frameworks from Toulmin and Zohar and Nemet provide the criteria to determine the mastery of elements of argument. Ambitious Science Teaching (2018), Windschitl, Thompson, Braaten (2014), Osborne, Henderson, MacPherson, Szu, Wild, Yao (2016) also influenced the development of analytical frameworks in this study. The limitations of this practical action research study focused on issues with researcher bias, generalizability, and types of validity (democratic).

CHAPTER IV

FINDINGS

Overview of the Study

Chapter IV begins by reviewing key aspects of the action research study and the recounts the events that occurred during the pilot study, cycle I, and cycle II of the study. We investigated how the process of action research influenced instructional practices relating to scientific argumentation, how student claim, evidence, and reasoning (CER) writing developed over time, and how verbal discourse played a role in student understanding of scientific argumentation.

This dissertation study analyzed data from research reflection notes, student written CER samples, audio recording transcripts, and field notes from cycle II. Findings were interpreted from data collected during cycle II. The IRB approved data collection from cycle II as long as the results were reported in aggregate and from normal classroom practices. The IRB also approved reporting findings from cycle III and I in aggregate form. In this chapter, the events from cycle I are reported so there is context to how past research influenced this study. Sharing the process of action research and findings in a narrative form may be of interest to educators. The findings found in this chapter tell a story about my own lived experiences and how our instructional practices changed from the process of action research.

The purpose of this action research study is to investigate how the process of action research influences our instruction of scientific argumentation and student mastery elements of argument. This dissertation study investigated the following research questions:

- Research Question 1 (RQ1): How does the process of action research influence our instruction of scientific argumentation in a high school science course?
- Research Question 2 (RQ2): How does a student ability to write scientific argument develop over time?
- Research Question 3 (RQ3): What role did verbal discourse play in students developing understanding of elements of argument?

The action research team generated new knowledge about designed curriculum and how to explicitly teach elements of scientific argumentation. Developing student critical thinking skills and social practices while engaged in argument was a part of the design. It was determined by the PLC team that mastering scientific argumentation skills associated would benefit ECP students in higher-level science courses. In addition, learning scientific argumentation would enhance the same skills in both English and math courses. English and math Common Core standards require students to write arguments as well.

Acquisition of critical thinking and social practices were determined to be important before entering into higher-level science courses. Numerous research studies confirm the importance of teaching argumentation skills. Erduran (2007) and his research team found that argumentation leads to improved problem solving skills and critical thinking skills when supported in the classrooms. According to Jimenez-Aleixandre (2007), the activity of engaging in argumentation deepens content acquisition. Engaging in argument from evidence is a science practice skill that purports higher level thinking processes through verbal and written discourse. These epistemic practices of argumentation involve knowledge production and learning through discourse.

Action research is a democratic process that is concerned with solving problems in schools by transforming practices and systems in context of the local setting. We found our problem of practice stemmed from detracking with the one-size fits all approach. Removing lower level science courses was a poor solution to lessening the achievement gap and eliminating tracking. Heterogeneous grouping students across all biology courses did not fix the issue of tracking. Years later, we found the elimination of the lowest course level exacerbated the issue of tracking. At NW High School, inequitable practices influenced course placement of students in science courses. Science course placement data highlighted the oppressive path in which students followed from one science course to the next. Year after year, our students, especially students of color, experienced little movement into higher-level science courses. A new intervention course called Exploratory Chemistry and Physics was created to detrack course placement and improve critical thinking and science practice skills. The PLC worked together to develop curriculum that would arm ECP students with argumentation skills. This PLC team was formed by the Director of Science with intentions of developing curriculum with high expectations; including topics focused on student interest and alignment to NGSS three-dimension performance expectations.

Conceptual Framework

Sociocultural Theory was used as a conceptual framework for this study. According to van Eemeren (2017), “to allow for well-founded treatments and improvements of argumentative practices, the practical component of the research programme has to be based on a theoretical model that does justice to all relevant aspects of sound argumentative discourse” (p. 325). Sociocultural theory was an appropriate theoretical model to use in this action research study. Curriculum development focused on how individuals learn from their social interactions within society and their culture. Explicitly teaching students elements of argument involves a social component where student interact in groups. Engaging in argument from evidence is more than the execution of writing CER. It also involves authentic disciplinary discourse using evidence to justify claims and counter argue.

Argumentation theories support the sociocultural perspectives because the basis of using Toulmin and Zohar and Nemet frameworks rely upon a social context. Argumentation theories involve science of civil debate, conversations, dialogue, and persuasion. This theory was appropriate to use in the study because of its technical components and social context. All students are expected to engage in one or more of these types of social interactions. Argumentation theory involves more than the individual epistemic building of knowledge. In addition, a social group together build understanding about science content. *Figure 8* is an organizational chart that maps out the conceptual and analytical frameworks used in this study.

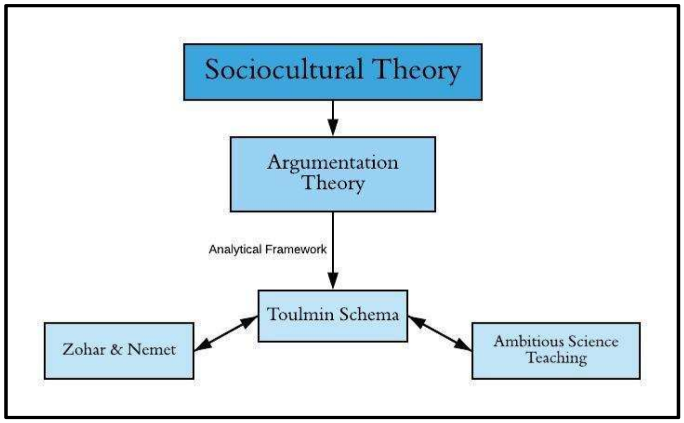


Figure 8. Organizational Chart of Conceptual Framework

The Sociocultural Theory and Argumentation Theory support the verbal and social activity of reasoning aimed at increasing the understanding of argument. In *Figure 8,* three analytical frameworks provide criteria for quality argument and the elements of argument. Toulmin, Zohar and Nemet, and Ambitious Science Teaching argument schema assist in the analysis of student data.

Action Research Pilot Study

In the 2017-2018 school year, the new freshman-level ECP science course welcomed the first cohort of students. The PLC team was excited to collaborate and produce curriculum that incorporated science practice skills with science content. This was the beginning of adopting a three dimensional approach promoted by Next Generation Science Standards (NGSS). The PLC team had to move away from the sole focus of science content and work toward weaving together both science practices and science content.

The PLC team met once a week and was tasked with learning the deeper meaning of argumentation, planning curricular lessons, and reflecting on student outcomes. A *PLAN Action Research Meeting Agenda Template* (found in Appendix) was used to keep the PLC team focused on the goals, outcomes, and reflection. Initially, we approached teaching argumentation as something that was done to students. Argumentation was thought of as an objective to accomplish rather than a framework of science practice. The PLC team had a sense of what argumentation meant, but really did not tie the process into building a social community of learners. The teachers added in the practice of argument into traditional ways of teaching science. Intertwining science practice and science content was not apparent to teachers. For example, the teachers developed a unit on flight where the content of physics was at the forefront of teaching. Argumentation tasks such as writing claim, evidence, and reasoning were treated as "add-on" tasks, rather than at the forefront and framework of lesson design. The PLC team realized there was so much more to the process of argumentation. This was the beginning of a shift in our PLC team mindset and practice. The process of action research surfaced the complex nature of argumentation. Argument was taught like most other physics topics, factual and by definition. Building a community of learners and productive academic dialogue were additional practices to consider when teaching argument. If students were going to write and speak about claim, evidence, and reasoning, then they had to learn how to do this together. Argumentation should function as a practice (routine structure that shape normative behavior) for the classroom community. The process of argumentation should provide students access to scientific ways of knowing, thinking, and acting. Our mind-set shifted from delivering elements of argument to using argument as knowledge building communities.

By the end of the pilot action research study, we determined three main areas of improvement. First, the instructional design of lessons should explicitly teach elements of argument. We found that students struggled to write quality justifications for their claims. We assumed students knew more about writing CER than they really did. Students did not have prior knowledge about argumentation coming into high school.

Second, communicating the expectations of quality elements of argument need to be reflected in the tools we use to measure mastery. At the end of the pilot study, the PLC team realized there was so much more to the practice of argumentation than just following completion of CER components from a rubric. Initially, the teachers used a simplistic rubric to measure student understanding of elements of argument. Through discussions in our team meeting we realized this rubric was too simplistic and really only acted as a checklist for whether students completed the CER elements. The CER rubric did not provide enough details and expectations of what to write. The rubrics measured whether a student completed the elements of argument instead of the quality of argument. Together we determined that the rubric needed revisions with higher expectations.

Third, we realized the need to treat argumentation as a form of discourse involving social interactions through discursive practices. The ability to argue goes beyond writing claim, evidence, and reasoning on paper. We realized much of what we asked students to do was on an individual level. Each student would complete tasks, such as collecting data from labs in groups. Thereafter, students wrote CER assignments as individuals. The PLC team decided we should investigate how verbal discourse could be utilized to understand elements of argument. Our lessons should consider how to organize classrooms so students can converse their understanding of argument.

Action Research Cycle 1

The PLC team noted the three areas of improvement from the pilot study and wrote a new action research plan for the following school year. During cycle 1, the PLC team focused on the explicit nature of teaching argument and collecting data from verbal and written discourse. I took an active role in organizing the team and gathering resources to supplement our understanding of argument. We read research studies that developed scientific argumentation lessons and used these as models for how to explicitly teach argument. The *Ambitious Science Teaching* model by Windschitl and Braaten, *IDEAS* by Osborne, the Nuffield Foundation, and the *Argumentation Toolkit* by The Learning Group were great resources to use when developing our lessons. These resources were influential in our own understanding of argumentation and connected our practical work to a sociocultural perspective. We learned that teachers whose lessons included the highest quality of argumentation also encouraged higher order processes in their teaching (Simon, Erduran and Osborne, 2006). The technical aspects of our work were discussed during our PLC team meeting along with a sociocultural perspective. As the leader of the team, I felt it was important to share the progress of our students as well. Below is an excerpt from my researcher reflection notes:

> *We started the meeting discussing the cohort from the 17-18 school year. I had shared my conversation with a student who was in the cohort. He struggled in ECP toward the end of the semester and failed the course. I ran into JH during*

> *homeroom this school year and asked what he remembered from ECP. He said he liked the hands on activities and felt the course was engaging. I asked if he remembered anything from last year that would help him in Biology this year, and he said he is using the CER (claim, evidence, reasoning) format again. This was great to hear considering this was a skill we wanted to build as they use this in all courses, especially English.*

Recognizing student faces behind the work was important. This story kicked off the year with a confirmation of how we affected our students.

Lessons were developed with tasks specific to teaching the components of CER. Each lesson was developed so argument would be taught sequentially from claim, evidence, to reasoning. Over time, each lesson added a new element of argument. A written action plan (see Appendix) helped the team focus on the objectives of each lesson. In cycle I, students were asked to identify and construct quality claims, as well as identify quality quantitative and qualitative evidence.

The first lesson taught in cycle 1 defined claim, evidence, reasoning, and counter argument. The first step of the lesson introduced the elements of argument and was explicit in teaching definitions and application. Each action research cycle had 2-3 lessons designed to provide explicit instruction about the elements of argument. *Figure 9* is a visual tool used in each lesson to reinforce the relationship between claim, evidence, and reasoning.

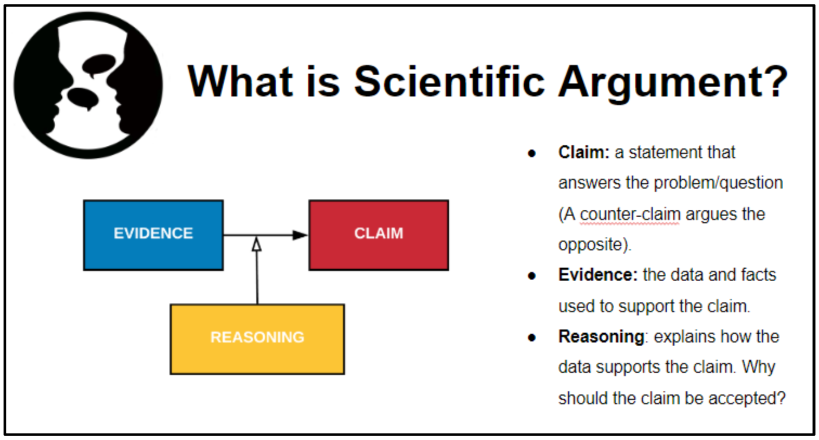


Figure 9. What is Scientific Argument?

The literacy coach and I taught the first lesson in cycle 1 (Lesson IA). The explicit nature of teaching argument started with the use of *Figure 9* as a model. We used triadic dialogue to start the lesson. We felt it was important to establish baseline knowledge about CER. In this first argumentation lesson, we followed the steps below:

1. Definition of argument
2. Scenario of cut finger and vase from *IDEAS* curriculum (Osborne et. al., 2006). Students were asked to select the best argument
3. Claim was defined
4. Students were asked to select the best claim as the answer to one essential question. There were six claims given based on one essential question. A card sort activity was used in this lesson.

Students were given an essential question, “Should we use animals for space exploration?” Prior to this lesson, students read about animals in space during a literacy lesson with textual information about animals in space flight. Thus, students had some prior knowledge about space exploration before lesson IA was taught. A card sort activity was created with different claims that answered the essential question. Two of the given claims did not answer the essential question. We asked students to sort the claim cards according to best claim. Students were assigned to small groups and asked to discuss their choices and why. During this lesson, we introduced students to the use of sentence starters. Students were reminded to use the sentence starters when speaking to one another. Sentence starters were selected as a group discussion strategy.

The second lesson (Lesson IB) was an extension of lesson IA where students reviewed the elements of argument using *Figure 9* as a model. The same essential question as lesson 1A was used in lesson IB- “Should we use animals for space exploration?” The intention of this lesson was to build on student understanding of claim and learn how to identify quality evidence. Students were presented with two claims and a list of evidence that supported either claim. The students were directed to determine which evidence best matched each claim through another card sort activity. Below are the directions given to students:

- Using the evidence cards, identify the best evidence statements that **SUPPORT** each claim. On your poster paper, draw the chart as shown above (a T-chart). Write each claim #1 and claim #2. Then glue the evidence cards that **SUPPORT** the claim to the poster. For each claim, one statement does not support the claim. Cross that statement out.
- Discuss with your group which evidence statement supports the claim. Use the following sentence starters:
    a. I think this piece of evidence supports this claim because…

b. I do not think this piece of evidence supports this claim because…
c. I think this statement needs to be thrown out because...
d. I agree because…
e. I disagree because…
f. Why do you think that?

- Be prepared to share your final results with one another. Once everyone is done identifying the evidence that supports each claim, you will gallery walk around the room to gather information from each group.

Overall, students were able to identify evidence that matched the two different claims. However, some groups included evidence that did not match either claim. We believe students who made this error did so because they thought they had to use all the evidence cards.

Lesson IA and IB were taught in an explicit manner. The PLC team agreed that the explicit teaching of argument during cycle I was an improvement over the lessons from the pilot study. However, we also felt our lessons in cycle II should spend less time introducing CER and use strategies that require students to move around the room. Transitioning from one activity to the next keeps students focused on learning.

Action Research Cycle II Data Collection

Action research is a continual cycle of reflecting, planning, acting, and reviewing. At the beginning of cycle II, the PLC team reflected on the questions and results from cycle I. The results from the first cycle of the action research study changed our approach to planning and teaching argumentation. We dug deeper into the meaning of argument and asked more questions about our own understanding of argument. During the second cycle of the action research study, our goal was to focus on lessons that required students to identify quality reasoning, construct reasoning from claim and evidence, and write a complete argument. Three lessons (lesson IIA, lesson IIB, and lesson IIC) were used to explicitly teach elements of argumentation. By this point in the study, the team felt students were capable of identifying quality claim and evidence. The next hurdle was to teach students how to write and verbally discuss their claim, evidence, and reasoning.

Data collected for this dissertation study came from student written documents, audio transcripts, field notes, benchmark assessments, questionnaires, and reflection notes from cycle II. At the start of cycle, II the Internal Review Board (IRB) granted approval for this study with a waiver to consent students and parents.

Research Question 1: How Does the Process of Action Research Influence Our Instruction of Scientific Argumentation in a High School Science Course?

The process of action research influenced the instruction of scientific argumentation in the ECP course. This influence is evident in three primary data sources: a written action research plan, PLC meeting agendas, and a researcher reflection journal. All are discussed in the sections below, along with key findings. Leadership transformation, curriculum development, collaboration, and professional learning were themes identified in the researcher reflection notes.

Leadership Transformation

A written action research plan was designed to unfold changes to instructional practices while the study was in the process of the cycling of reflecting, planning, acting, and reviewing. The findings from the data sources allowed changes to instructional design to emerge from one phase to the next. A constant comparison of data over cycles I and II was conducted during the PLC meetings. We collected and analyzed multiple forms of data in a systemic way as the research process unfolded. I developed a spreadsheet that organized the data collected by the teacher (see Figure 10). I used this spreadsheet to keep track of the data sources used for data analysis during the PLC team meetings.

Action Research Cycle II (Dec. 2018 - Feb. 2019)													
Research Questions	**Lesson IIA (Bottle Rockets Unit)** Learning target- Present students with a claim and evidence and reasoning about a phenomenon, then ask students to assess the reasoning of a given link between claim and evidence. Explicit Teaching of CER: "Why is the Amount of Fuel Important for the Bottle Rocket?"; Discussion of Claim Evidence Reasoning rubric.			**Lesson IIB (Circuits Unit)** Task- Present students with a claim and evidence about a phenomenon, then ask students to construct the reasoning between claim and evidence. Explicit Teaching of CER: Peer editing of reasoning given the collected qualitative and quantitative data and claim, reasoning revised based on student feedback from "Passive solar house CER Checklist" This became a new tool for assessing quality reasoning.			**Lesson IIC (Mouse Trap Unit)** Task- Describe a phenomenon to students, then ask students to construct a complete argument with a claim, evidence, and reasoning. Explicit Teaching of CER: Serafini Lesson Factors which impact speed of car						
							Factors Lesson						
	Data Sources			Data Sources			Data Sources			Data Sources			
	Student Written	**Student Audiorecordings**	**Field Notes**	**Student Written**	**Student Audiorecordings**	**Field Notes**	**Student Written**	**Student Audiorecordings**	**Field Notes**	**Reflection**	**Benchmark Assessment**	**Student Survey**	
	RUBRIC	RUBRIC	Field Notes Spreadsheet	RUBRIC	RUBRIC	Field Notes Spreadsheet	RUBRIC	RUBRIC	Field Notes Spreadsheet		Benchmark Exam Folder	Pre Questionnaire- Sept 2018	Mid-term Questionnaire- Dec 2018
(RQ3): What role did verbal discourse play in students' developing understanding of elements of argument?		Bottle Rocket Transcript Audio			Transcript Audio Metzler ECP Circuits Lesson Dec. 2018			Transcript Audio Mousetrap Factors Serafini Audio			PreTest Documents Serafini		https://doc
(RQ2): How does student ability to write scientific argument develop over time?	Metzler H, M & L Bottle Rocket Written Serafini H,M, & L Bottle Rocket Written Student Assess "Why is the Amount of Fuel Important for the Bottle Rocket?" Serafini Fuel Docs Serafini Fuel II Docs		Field Notes Lesson IIA- Card Sorting Bottle Rockets Unit	Metzler Circuits Student Written Serafini Solar House Student Written (original/revisions)		Field Notes 12.18 Lesson IIB (Circuits) Argumentation	Metzler Tortoise Race Serafini Mousetrap documents		Field Notes 1.24.19 Speed of Car Serafini	Reflection Document	PreTest Documents Metzler Mid Term Benchmark tests Metlzer Midterm Benchmark tests Serafini	Pre-Questionnaire Fall 2018 Student Responses	Mid-Term Questionnaire Dec 2018 Student Responses
(RQ1): How does the process of action research influence our instruction of scientific argumentation in a high school science course?											Post Test Benchmark Metzler Post Test Benchmark Serafini		

Figure 10. Data Collection- CER

In addition to the written research plan, PLC team meetings agendas and the researcher's reflection journal were integral to documenting the action research process and the influence of this process on our instruction and on us as educators. A reflection journal was used to record notes from the PLC team meetings. The notes were beneficial to the work of the team as well as this study. I reviewed the notes before our team meeting and carried the work of the team from one meeting to the next. As the leader of the team, I learned the importance of creating an agenda with specific goals. A template of the agenda can be found in the Appendix. Time was of the essence, so we needed an agenda to focus our conversation. The following list of questions were used to focus the group during each meeting:

- What is the goal of the meeting? Why?
- What are the objectives of the meeting? How will we accomplish this objective?
- What are the next steps in this cycle?
- Restate the purpose of this action research study. Review the action plan. Where are we in the work?

The agenda template stated the written goal to remind myself of the importance of our work, and to remind the team to do the same. Together the team con-constructed a goal to detrack the ECP course pathway by transforming our practices. We generated knowledge from the implementation of quality science curriculum with an interdisciplinary approach and equity perspective. Through this experience, I was learning how to prepare productive PLC team meetings. In addition, I believe I was transforming as a leader.

> *The literacy coach and I met today to determine the best steps to take with the next lesson. I wonder how to develop the practices of the team, so they will be more self-sufficient. Expanding this type of professional learning community into*

other courses will require me to spend less time with the ECP group. I need to create tools that can be used in a universal way. If teams are going to be productive and accountable for their work, then a system like an agenda with a purpose for the meeting should be helpful to use.

In my reflection notes, I am thinking more holistically about expanding action research into other teams of teachers. My involvement in these meetings serve a purpose of detracking, as well as a means to create a model for others to follow to do the same. My role was less about a supervisor checking on the work of the team. Instead, I became an instructional coach who organized the necessary resources to teach, ask questions to move the work, and gathered the opinions of the group. In many ways, I was also the cheerleader who kept the teachers motivated to continue the work. At the beginning of second semester, I shared the academic performance of students in the ECP course. In addition, I shared the exciting news of our pilot study cohort:

Today I shared my analysis of the 17-18 ECP student cohort. The exciting news was out of the total 29 students initially enrolled in the ECP course only 1 student will move into the 2019-2020 Science Topics course. This one student was moved into Special Education Physical Science at the end of the 2017-2018 first semester of ECP. All other students were recommended to move into Chemistry or Physics.

The results of the 2017-2018 ECP science course placements provided a positive outlook for our program and the needs of the students. The teachers need big picture accomplishments, so they can see the fruits of their labor. They lose sight of how their day-to-day interactions add up and impact student learning. Responses from teachers were positive and fueled further conversations of what we did in the past and how we have improved. The social interactions of our action research study changed my own practices in how I conducted meetings and assisted the team to continue the work. I found myself steering the team toward conversations of improvement:

> *Discussion of using CER rubric ensued about what was already in place for second semester. Moving toward CER with counter argument-discussed what does this really mean, the description would be above student level of understanding. Change wording within rubric to rebuttal, disproving, opposite view.*

Team members also used this forum to interact through dialogue that transformed instructional practices. Without this forum, the teachers would likely not have interacted with one another to dialogue deeply about the meaning of scientific argumentation nor would they have made changes to lessons to the extent it was done. One of the teachers commented that he would not have set up lessons with peer editing as a way to explicitly teach argumentation.

Evidence for changes to instructional practices can be found in the evolution of the explicitly taught scientific argumentation lessons and findings of discourse data. Certain assignments and products of lessons were developed to teach the expectations of quality CER and argumentation as a social practice. Our findings (reported on in the next sections) showed an increase in growth student ability to write evidence-bases scientific claims over time. However, as we further analyzed the student reasoning responses we found this to be the greatest area of struggle. Knowing this we developed assignments that provided systematic scaffolds of instruction to guide students to writing CER. The audio recording transcripts revealed students were able to provide more detail about CER in verbal discourse through group interactions. The student results from each lesson were presented in our PLC team meetings, which influenced our next steps in developing curriculum. Curriculum development, collaboration, and professional learning were themes identified in the researcher reflection notes. The student results from each lesson were presented in our PLC team meetings, which influenced our next steps in developing curriculum.

Curriculum Development

The action research study cycles focused on teaching elements of argument in stages as well as building a community of learners. The objectives during the first cycle asked student to identify and then write quality claim and evidence. The researcher reflection notes provide evidence of the PLC team discussing how to improve curriculum. Below is an excerpt from the reflection notes:

Today the Literacy coach and the two science teachers met to discuss the success and/or weakness of the first argumentation lesson taught.

1. *Working as a community of learners is hard to do with the ECP students. They begrudgingly move to work with others. This behavior seems to be more extreme than the students in higher levels are. The students not only resist working together, but also do not know how to work with one another. If we could come up with a script of what to say and how to discuss, we could model what productive dialogue or science talk looks like. The science teachers have found this to be a*

challenge. They work on this all year long. Students in higher-level science courses tend to already experience the group discussions. Although there is room for improvement.

2. *Engaging the ECP students will require movement into hands-on activities, or use of strategies that require them to move around the room, and transition from one activity to the next. Students respond to triadic dialogue for a short amount of time. In this first argumentation lesson we presented*
    a. *Definition of argument*
    b. *Scenario of cut finger and vase from IDEAS curriculum. Students were asked to select the best argument*
    c. *Claim was defined*
    d. *Students were asked to select the best claim from a card sort. There were six claims given based on a question.*
    e. *A discussion was facilitated to discuss which claim was selected and why. Most groups selected one of the same two. However, one group selected data instead of a claim. It was discussed as to why this would be evidence and not a claim.*
3. *For the next lesson, the Literacy Coach and I will develop a lesson about evidence and what quality evidence looks like. We will use data from the student bottle rocket activity to discuss the quality and best evidence to use. Format: Astrochimp Question for bottle rocket activity.*

The excerpt is one of many notes taken that shows the type of conversations taking place during the PLC team meeting. In this sample, there is specific evidence about the structure of the lesson as well as the social dynamics that occurred in the lesson. The analysis of the first lesson assisted future planning and changes to the development of the tasks. As stated, we needed to be more explicit teaching about quality evidence, transition frequently between tasks, and model group discussions. Future lessons changed to explicitly teach the elements of argument by use of a new rubric and break out the details of expectations through assignments in a checklist format. Scaffolding assignments were used to guide students rather than just hand students a CER rubric.

Comparison of reflection notes and classroom observations reveal the challenges of building a community of learners. The first step of the excerpt shows student rebellion toward working in groups. The process of action research allowed our PLC team to problem solve through these issues and build lessons that included instructional strategies that promote dialogue and student interaction. By the next lesson, we incorporated sentence starters and instructional roles to assist students in understanding how to deepen conversations around elements of argument. Sentence starters were periodically used by students most lessons. I thought using the sentence starters and instructional roles provided structure to the lesson.

Assessment Development

The CER rubric used to assess student written samples morphed from one (*Figure 11*) with few expectations and simplified language to one that was supported by science education research (*Figure 12*). A change to the initial rubric (*Figure 11*) was long overdue. When we reviewed the rubric more closely, we found that we could not come to a consensus on the meaning of certain words. For example, the use of the word "appropriate" or "sufficient" was too vague and meaningless to the student. Teachers would have to explicitly teach these descriptive words for each CER assignment. After months of using the CER rubric (see *Figure 11*) from the pilot study and cycle I, we took the time to dissect the terms used in the rubric. In my self-reflection, I was dumbfounded by this revelation. How could we have missed this obvious technique of teaching elements of argument? This simple act confirms why we need to spend time collaborating with one another about our instructional practices. As practitioners, we get lost in the day-to-day grind, and forget to stop and ask why we use certain documents or tools.

Claims-Evidence-Reasoning Rubric[1]

Component	Level		
	0	1	2
Claim	Does not make a claim, or makes an inaccurate claim.	Makes an accurate but incomplete claim.	Makes an accurate and complete claim.
Evidence	Does not provide evidence, or only provides inappropriate evidence (that does not support claim).	Provides appropriate but insufficient evidence to support claim. May include some inappropriate evidence.	Provides appropriate and sufficient evidence to support claim.
Reasoning	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 - but not sufficient - scientific principles	Provides reasoning that links evidence to claim. Includes appropriate and sufficient scientific principles.

Figure 11. CER Rubric from Pilot Study and Cycle I.

In lesson IIA, teachers explicitly taught the elements of CER by use of the new rubric (*Figure 12*) during class. The rubric was given to each student and used as a model to review the definitions of claim, evidence, and reasoning. The first column in the

Figure 12 lists each element of argument with the definitions for quick reference. The format changed to make the levels of mastery more clear.

Claim Evidence Reasoning (CER) Rubric								
Elements of Argumentation	Low Mastery		Medium Mastery		High Mastery		Scientific Knowledge	
1. CLAIM (C)	0 points		1 point		2 points			
A statement that answers the original problem/question	Does not make a claim, or makes an inaccurate claim	☐	Makes an accurate but incomplete claim	☐	Makes an accurate claim	☐		
2. EVIDENCE (E)	0 points		1 point		2 points			
Scientific data that supports the claim. Data needs to be appropriate and sufficient to support the claim.	Does not provice evidence or only provides inappropriate evidence (that does not support claim)	☐	Provides appropriate but insufficient evidence to support claim. May include some inappropriate evidence.	☐	Provides appropriate evidence related to question and sufficient amount of evidence to support claim	☐		
3. REASONING (R)	0 points		1 point		2 points		Inaccurate 0 point	Specific & Accurate 2 points
Explain why your evidence supports the claim. This must include scientific principles/knowledge that you have about the topic to show why the data counts as evidence.	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 -but not sufficient- scientific principles	☐	Provides reasoning that links evidence to claim. Includes appropriate and sufficient amount of **scientific terms and principles.**	☐	☐	☐
4. COUNTER-CRITIQUE (CC)	0 points		1 point		2 points			
Circumstances in which the general authority of the warrant would have to be set aside.	Response raises no new relevant concerns.	☐	Response raises some new relevant concerns.	☐	Response clearly raises new relevant concerns AND expresses them as counterarguments or rebuttals.	☐		

Figure 12. CER Rubric from Cycle II.

Over multiple PLC meetings, we found it necessary to discuss the reasoning section of the student CER rubric. We did not want the reasoning section to be cumbersome and too wordy. However, we also struggled with not including certain agreed upon criteria of quality reasoning. The reasoning criteria on the rubric should emphasize:

- Ability of student to compare multiple forms of evidence
- Student describes the relation of scientific principles and ideas within justification
- Student connects evidence to a claim that justifies a link between the data and theoretical components
- If applicable, the student should be able to justify the claim using mathematical models.

The ability to write or discuss reasoning with these criteria is a sign of mastery. The team agreed that students would need assistance with identifying scientific principles per assignment. Teachers would explicitly design lessons that state the scientific principles. The expectation would be for students to use accurate use of scientific terms in their reasoning.

Collaboration

The reflection notes revealed more than conversations about technical aspects of curriculum. In our PLC team, discussions there were deep discussions about the meaning of our work and questions about the work itself. The excerpt below comes from the reflection notes after cycle I. The group shares thoughts about strengths and weaknesses from argumentation lessons. At this time, we start the initial conversations about creating tasks with guiding questions per claim, evidence, and reasoning. The collaboration from the group steers changes to instructional practice.

New questions have come from the PLC team meeting:

1. *What are the details to consider when developing the argumentation lesson?*
2. *What does explicit teaching mean to us?*
3. *What should we see when students are in argument?*
4. *Will the sentence starters be useful to provide structure to the conversation? What is the framework for the conversation? Should we spell out the steps on what to say...like a theatrical script?*

   We have a rubric that provides a framework for writing. Should there be one for verbal discourse/argument?

The reflection notes also show productive discussions about data analysis. Collaboration is clearly represented in the following statement from the notes. There are collegial conversations taking place between team members, as well as a member check that validates the progress of student understanding.

> *Great conversation today about the data from written documents. We discussed the patterns and trends with data. A member check of what we see in the writing and the scores given was confirmed as to what they see within the classroom. The teachers indicated they have noticed improvement with student writing samples. My thought is by how much we see improvements and are there students who are stagnant in their learning.*

Overall, the reflection notes show how the process of action research is collaborative and influences our instructional practice. The notes also indicate that teachers feel the curricular and instructional changes are making a difference in student outcomes.

Professional Learning

The research reflection notes show professional learning about scientific argumentation occurred during the process of action research. We all learned more about claim, evidence, and reasoning. As our action research study cycled, we fine tuned and internalized the meaning of these elements. Initially, I thought I really understood the meaning each element. However, as we read more written samples and discussed the components of the rubric, we all realized how much we still had to learn. By the end of cycle II, we realized we ourselves had to continue learning more about the meaning of claim, evidence, and reasoning. It took the interaction with students in the classroom and the collaborative discussions with team members to get to the current point of understanding. The themes from written student responses guided our own misconceptions and discussion about how to improve student understanding.

Months of research has shown there is still a lot more to learn. Below is an excerpt from my research reflection notes that show professional learning taking place:

> *Reasoning discussion took longer to discuss. As a PLC team, we had to establish the difference between reasoning as argument versus reasoning as an explanation. We noticed a trend where students were writing explanations even though our rubric stated "provides reasoning that links evidence to claim, includes appropriate and sufficient amount of scientific terms and principles. Today we established the difference between explanation and argument. This was an eye opening conversation to the teachers. Prior to this meeting, we thought our rubric was self-explanatory. However, and again, we realized the students did not comprehend the difference, as they should. I created a spreadsheet with the CER written scores and included definitions of reasoning for argument and explanation.*

During this PLC team meeting, I recall the team having an epiphany moment. The analysis of the solar house written CER samples made us realize students were writing explanations and not reasoning for argument. I recalled one research study that explicitly stated reasoning for argument is not the same as explanation. My own lack of understanding influenced my decision to find research articles that state the difference. I shared my research of terms with the PLC team. The science teachers immediately started to discuss how they could improve the way they communicate how to write reasoning. We also brainstormed over how to adjust future assignments to teach reasoning in an explicit manner. The team felt we should change our rubric to include the word "convince" in our reasoning section.

Summary

The process of action research influenced the instructional practices of scientific argumentation in the ECP course. It also shows the benefits of practitioner research and how it influences student learning. Curriculum development improved with continuous data analysis and newly created tools that assessed student understanding of argument. Collaboration between the team members was a vital part of the action research process. Instructional practices changed as the team collaborated about best practices. The team learned from research studies and experience through the process of action research. By the end of cycle II, team members could explain their own understanding of claim, evidence, and reasoning. Transformation of the educators and leader were evident in the data sources collected.

Research Question 2: How Does Student Ability to Write Develop Over Time?

The Toulmin, Zohar and Nemet argumentation schema were used to measure the extent in which students could justify claims through verbal and written discourse. The main components of Toulmin's argument schema include claim, data, warrant, backing, and rebuttals. The simplistic nature of the Toulmin model makes it a user-friendly tool for high school students and teachers to understand. The Zohar and Nemet framework utilizes Toulmin's components, but also includes measuring scientific principles as part of their framework. The elements of argumentation schema were used as a basis for measuring quality written argument.

The Next Generation Science Standards first introduced us to argumentation as a science practice skill. Rubrics were gathered from online sources to measure the elements. Our PLC team found these online sources scant with detail. The *Claim Evidence Reasoning (CER) Rubric* (see *Figure 11*) was a tool used to measure mastery of CER. In this dissertation, study students were asked to write a CER, which is our term for students to write in a Claim-Evidence-Reasoning format. The PLC team created the rubric as a tool to measure student written CER with the main components of the Toulmin argument model. The *CER rubric* was used to analyze student mastery of claim, evidence, and reasoning by rating verbal and written discourse according to levels of mastery (high, medium, and low). Toulmin's analytical pattern (TAP) framework provided a structure that measures the elements of argument, but it is an incomplete framework for our needs. We found a need to include the accuracy of scientific knowledge. Thus, Zohar and Nemet's argument schema was added to the rubric to account for student mastery of science knowledge.

Students' abilities in written discourse were assessed during lesson IIA bottle rocket, lesson IIB circuit, and lesson IIC mousetrap. Benchmark assessments (pre-test, mid-term, and post-test), student questionnaires (pre-survey and mid-term survey), and researcher reflection notes were also used to analyze student mastery of claim, evidence, and reasoning. The overall findings from the written data sources show students able to write quality claim and evidence over time, but struggle with writing reasoning.

Lesson IIA Bottle Rocket Unit

Cycle II of the action research study began with lesson IIA. The objective of this lesson was to ask students to identify the quality (high, medium, and low) of student reasoning responses. The planning stage of the lesson asking students to identify the best reasoning statement that answered our essential question- “Why is the amount of fuel important for the bottle rocket?” Students worked in groups of three and analyzed three different reasoning statements. The PLC team thought it would be a good idea to use actual student samples to explicitly teach reasoning. We used the actual student samples to model how to analyze an argument and improve student performance. The team selected three student samples based on quality of reasoning responses. Three documents were created with a claim, evidence, and reasoning response. The claim and evidence were the same for each document, but the reasoning statements differed. We adjusted the reasoning statements so individual students could not be identified, and made the length of each statement the same. Unfortunately, students often identify quality by how long a response was written rather than by what was stated. Students worked in small groups to rank the CER samples as high, medium, and low quality. Criteria for ranking samples were found in our CER rubric.

The team still had questions about the criteria written within the rubric. In my researcher reflection notes I record the thoughts from the team:

> *Together we found there was a need for the rubric to change once again. This would be the fourth version of a rubric and one changed from the first cycle of this action research study. The rubric was modified to adjust the language to make it even more kid friendly and look more simplistic visually. We matched the definitions of claim, evidence, and reasoning to the Learning Group resources, but returned back to an original rubric used last semester. The descriptors used to measure high, medium, and low seem to best fit the kid language. We included science knowledge and principles, along with accuracy of those principles. Today the focus was on the meaning of the descriptors and the application of its use.*

During the lesson, expectations from the rubric were explicitly stated and explained by the team. The descriptors were printed directly on the student written samples so students could reference them during their discussion and while writing their rankings.

In lesson IIA, we started with the fundamentals of identifying quality reasoning, and by the end of cycle II students were assessed for their ability to write complete arguments. Students were asked to read written samples and identify selected papers with high, medium, and low mastery ranking.

Prior to this lesson, students designed and built bottle rockets in an inquiry-based investigation. At the end of the investigation, students were required to write a CER. The essential question for this lesson was “why is the amount of fuel important for the bottle rockets”? Science teachers selected student sample papers that were considered high, medium, and low mastery. The PLC read the papers together and found themes and patterns. *Table 7* below summarizes the finding found at each level of mastery.

After the PLC team selected high, medium, and low samples, students were asked to use the new rubric to rank the reasoning. Overall, the majority of student groups could determine the high, medium, and low papers. Nine groups participated in the Lesson IIA task of analyzing reasoning. Two groups struggled to identify the rankings.

Table 7

Common Student Written Responses r Bottle Rocket Lesson IIA

	High Level Paper (Level 3)	Medium Paper (Level 2)	Low Paper (Level 1)
Claim	Clearly, answers question. Most students' claim stated the amount of fuel is important for the bottle rocket because too much water weighs down the rocket and too little water prevents the rocket from moving up.	The claim answers the question with data, not with why the amount of fuel is so important. Students state the data such as 400 ml is the best amount of fuel to use.	Does not answer the question or a claim is missing. Student statement is vague. For example, a student would state the amount of water matters.
Evidence	Provides both qualitative and quantitative data. Gives specific measurements between volume of water and flight time in seconds, provides multiple trials. Describes what the rocket looked like during launch and references too much water so the rocket did not go up so high.	Provides time and volume of fuel for launch. Reports quantitative data, but not sufficient amount. Student mentions just one volume and it was the lowest time.	Missing quantitative and qualitative data. Students would state there are three rockets with little fuel.
Reasoning	Explains why the evidence supports the claim. "The amount of fuel is important for the bottle rocket because if you have too much, it weighs down your rocket and if you have too little the rocket won't go up so high.	Reports the data, makes a slight comparison, but misses theoretical component. Restates the evidence. In this case only volume and time.	Broad statements with no reference to evidence. Describes results as great or bad.
Pattern	Student responses reference science content (weight), and they explain how the evidence supports the claim.	Repeats evidence, missing scientific knowledge, fails to make comparisons, includes irrelevant information (weather, aerodynamics, etc.).	Does not include scientific principles.

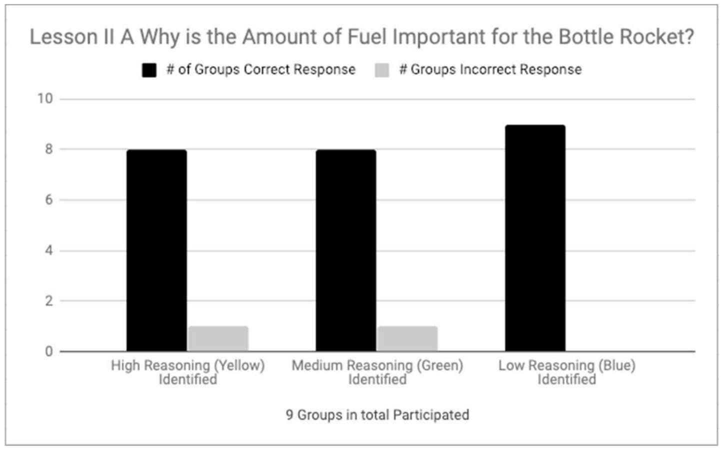


Figure 13. Results of Bottle Rocket Lesson IIA Identification of Reasoning.

It was difficult to determine exactly why the two groups of students were unable to identify the rankings. In the future, I would change our assignment to include space for students to write the reasons for why they selected the high, medium, and low rankings. The assignment sheet only asked students to rank the papers by circling the rubric. In this situation, verbal discourse data may play a role by shedding light on why the students identified high, medium, and low papers.

On the new rubric (*Figure 12*), level 3 mastery reasoning included language that tells student to link evidence to the claim and include appropriate and sufficient amount of scientific principles. The results of the bottle rocket discourse data made the team question how well we are communicating expectations about CER. After reviewing this data, the team decided to create new instruments that more effectively communicated expectations about quality argument. The next step was to scaffold the expectations of each element of argument. Our instructional practices in the next lesson IIB were modified by use of new tools (rubric and checklist). A new checklist with guiding questions spelled out the expectations found in a written CER. The use of the rubric alone was not enough to teach students how to write quality reasoning.

Lesson IIB Circuits

The second lesson in cycle II expected students to justify their claim with evidence given phenomenon about circuits. The focus during this lesson was to teach students how to write quality reasoning. The essential question asked during this lesson was, "what is the relationship that exists between the current through the battery and the current through the bulbs in a series circuit?" Prior to this lesson, students were asked to complete an inquiry activity that investigated the current change from a battery to light bulbs. Students collected data by use of a voltmeter. Students used data from their inquiry circuit lab to state a claim that answered the essential question. Each group added their claim to an online program called *Poll Everywhere.* The teacher projected the list of claims for the entire class to view. Each individual student voted on which claim was the best. The class discussed the best-written claim and the qualities that made it the best. The class talked about using language within the question to write a claim, and then they discussed how to answer the question. Students then had the opportunity to revise their claim. The claims projected onto the screen to discuss.

While working in groups, students started picking out evidence that matched their claim. The explicitly taught lesson continued with a discussion about appropriate answers to use when describing mathematical relationships between variables (increase/increase, increase/decrease, etc.). Students rewrote their claims to match the language of the question and the class talked about what makes quality evidence. They wrote out one piece of evidence to share with the class. Finally, the class discussed how the reasoning should include the connection between the claim and evidence. Through this exercise teachers explicitly taught how to write a quality complete argument. The teachers explicitly taught the terms “appropriate and sufficient” found on the rubric during this lesson. In addition, scientific terms important to the understanding of circuits were discussed as a class. Finally, students worked in groups to finish writing a CER that answered the essential question.

The difference between lesson IIA and IIB was the added use of a newly scaffold checklist. This checklist provided criteria for quality argument and created so students could ask questions about the criteria expected from the rubric. The checklist included a section of questions for claim, evidence, and reasoning. Each element of argument had specific scaffold questions (see Appendix). Teachers determined that the rubric was not enough to help students understand the expectations of what should be included in a written CER document. The questions on the guide addressed gaps students often had when writing a CER. For example, in the reasoning section of the CER written samples students often restated their evidence. They did not explain the connection of their evidence to the claim nor did they support their statements with scientific principles. Within the reasoning section of the checklist, we asked students the following questions:

- Does your evidence link with the claim? Is it relevant to the question?
- Are you repeating your evidence or explaining it?
- Are you explaining your choices and reasons for revisions?
- Do you include all scientific terms and ideas?

This checklist seemed to help students with their writing. Ten students CER written samples were collected and analyzed. Three student responses ranked as high mastery level; three ranked as medium, and four as low. The results from the written sample show more students in the high and medium level of mastery. A closer look at these samples reveal student understanding of claim and evidence, but many are still struggling to write the reasoning section. *Table 8* summarizes the common responses from the written samples. Each element of argument allotted three points. A student earned three points if the essential question answered with a complete and accurate claim. The evidence section was also worth three points. Students earned three points if they provided appropriate and sufficient evidence to support the claim. In addition, students were instructed to provide quantitative and qualitative evidence. Teachers expected at minimum two pieces of evidence. The reasoning section received three points if they connected the evidence to the claim, compared multiple forms of evidence, used powerful science ideas, and if applicable discussed a mathematical model. The total possible points a student could earn were 9 points. If a student earned three points for a claim, evidence, and reasoning he/she/they earned a high-level mastery ranking. Written documents that earned 7 to 8 points were give a medium mastery level. Low-level mastery papers earned less than 7 points in total. The PLC team established the breakdown of points that correlated with the level of mastery. We also used models from scientific argumentation research studies to determine the mastery levels found on the rubric. The *2018-2019 Student CER Rubric* (found in Appendix) assessed each element of argument and overall student level of mastery.

Table 8

Common Student Written Responses for Circuit Lesson IIB: Battery & Current

	High Level Paper- 3	Medium Level Paper- 2	Low Level Paper- 1
Claim	Answers question accurately and complete. A common response states the relationship that exists between the current through the battery and the current through the bulbs in a series circuit is that as the current in the battery increases, the current through the bulbs decreases.	Claim answers question completely and accurately	Does not answer the question. A student states a claim as a relationship that exists between a current in through a battery and a current through a bulb.
Evidence	Provided multiple data sources such as stating the amps to # of bulbs	2- 3 points Evidence is included with multiple trials; all have quantitative data	Difficulty with including evidence. Includes irrelevant information.
Reasoning	Included scientific knowledge and references back to the evidence/claim.	1-2 points. Explains either theoretical/science content or repeats evidence. Students stated that in a series circuit there is one path for the electrons to follow. Because of this the electrons from the battery also travels to the light bulb.	No connection between claim and evidence. Some discussed electron flow only.
Pattern	Student responses included science content, and explained evidence and why it supports their claim.	Repeats evidence, missing scientific knowledge, fails to make comparisons, includes irrelevant information (weather, aerodynamics, etc.).	Does not connect evidence to claim. Appears to have just included class notes.

Similar response patterns were found in the circuit CER written documents across the levels of mastery. The findings from these written document show that students are able to write a claim and provide evidence, but only partially respond to justifying their claim. The reasoning should persuade others that the claim is true by justifying their claim with evidence. The responses that received a lower level mastery ranking did not include justification for their claim. Most students who received one point for their reasoning only wrote about how electrons flow through a circuit. These students include scientific terms, but do not justify their claim with evidence. The patterns of response from the low-level papers reveal some assumptions about the instructional practices by the teacher. It appeared that the science teacher spent more time than a usual amount of time discussing electron flow in wires. During our PLC team, meeting the science teacher confirmed there was a lot of time spent on explaining electrical flow and current. Students were more likely to write about electricity and flow of electrons because of teacher directions. The PLC team spent additional meetings discussing how to help students use the rubric and the checklist. The following is an excerpt of my reflection notes regarding the ambiguity of terms on our rubric:

> *Last Thursday the literacy coach and I met with the science teachers to discuss the language of descriptors on the rubric. It was interesting to find that terms such as" appropriate" and "sufficient" were not well defined and ambiguous. We have our own definitions, but the terms would not be very clear to students. I had asked the teachers how they define appropriate. At first it was hard to express what this really meant. Other than stating that the word appropriate would have to mean how students can relate the evidence back to the claim and use accurate science principles. Sufficient was also an issue. We never really defined this before. Ultimately we agreed that sufficient would have to deal with a quantity of evidence. When asked how would the students know, the science teacher*

responded per each activity involving CER they as teachers would have to let the students know. The science teachers would have to follow up with criteria for what is appropriate, sufficient, and what the scientific terms were to be used in the reasoning.

Writing requires critical thinking and organizational skills. We speculated that students were not expected to write as frequently nor received feedback on how to improve. The PLC team spent more time asking questions than having answers. Based on these written reasoning responses, we assume students were following habits from the past.

Lesson IIB Circuits Solar House

Discourse data was collected from a second circuit assignment. The PLC team reflected on the results of the battery and light bulb circuit lesson, and felt there was a need to collect more data about student ability to reason. The teachers indicated they were seeing improved written CERs, but felt students needed more explicit instruction about writing a complete CER. During this lesson, the science teacher reviewed the CER rubric and introduced a new CER checklist. The checklist was a useful tool to guide student writing and verbal discourse. An excerpt from field notes taken during the circuit's lesson provides evidence of teacher communicating the use of a checklist:

The teacher announces to the class: in the evidence section, check your data that applies to your claim. He reads the guiding questions: Do you have quantitative and qualitative evidence? Do you include all appropriate possible data points? You will go through each question check by check.

While students were peer editing and discussing their solar house written samples, the teacher was reminding students to follow the guidelines found on the checklist. The results of the written CER samples are reported in *Table 9*. This table summarizes the common themes found on the high, medium, and low papers. The maximum score a student could earn was 9 points, and the minimum earned points was 0 points. Students with a low-level mastery score (below seven total points) struggled to write quality reasoning. Responses were vague and did not explain how evidence supports the claim. Evidence was completely missing from the reasoning. Students who scored low mastery did not refer to the Solar House Checklist guideline document. We know students did not refer to the guideline because they did not answer the following questions:

- Does your evidence link with the claim?
- Are you repeating your evidence or *explaining* it?
- Are you explaining your choices and reasons for revisions?
- Do you know what the proper scientific terms are for this assignment?
- Do you include all scientific terms and ideas?

The overall mean score on the CER student samples was 6.8 (rounds to 7). This mean score is a medium level of mastery. More students improved in their ability to write claim and reasoning. The mean score for claim was 2.7 and for evidence 2.6. The maximum score students could earn for their claim was 3 points, and for evidence three points. Both mean scores were close to the maximum possible score of three. Reasoning had a mean score of 1.5. This low score was an indicator for the team to develop lessons that focused on reasoning. One suggestion for improvement was to walk through the checklist with students while they reviewed their own writing.

Table 9

Data Analysis Student Written CER: Solar House

	ECP Student Scores (N = 13)
Maximum Score	9
Minimum Score	3
Overall Mean Score	6.8
Mean Score – Claim	2.7
Mean Score- Evidence	2.6
Mean Score- Reasoning	1.5

Table 10 lists the most common responses for high, medium, and low mastery written papers. The high-level responses earn the maximum three points because they were able to compare multiple forms of evidence, include scientific principles, and connect evidence to claim. However, most of what was written was more of an explanation rather than a persuasive argument. Explanation and possible solutions for why the house was not a success was written. The medium level reasoning only included

explanation of possible faults for their designed solar house. Low-level reasoning lacked any criteria from the rubric.

Table 10

Common Student Written CER Responses Circuit Lesson IIB: Solar House

	High Level Paper- 3	Medium Level Paper- 2	Low Level Paper- 1
Claim	Complete and answers question.	Complete and answers question.	Student statement does not answer the question. A student may respond with reasoning that states a light shined in the house but the openings made the experiment a little harder.
Evidence	Quantitative temperatures readings with multiple data points. Qualitative description of house	Quantitative temperatures readings with multiple data points. Qualitative description of house	Explains more about what happened. Identified one temperature reading.
Reasoning	Compares multiple forms of evidence, scientific principles, and connects evidence to claim. Many write more about possible solutions for why the house was not a success.	Students write explanations more than reasoning. Common student responses include how to improve the design of the house, but do not include connection of claim to evidence.	The reasoning does not include any criteria from rubric. The common response is vague and literally, states data supports claim. There is no evidence stated to connect to claim.

The PLC team learned a valuable lesson from the solar house discourse data. The checklist was a useful tool to use while guiding students through verbal and written discussion. An excerpt from my reflection journal documents the thoughts of the team:

> *The PLC team discussed the results of the solar house CER written statements today. The teachers felt the checklist was helpful and wished we had started the school year with the same format. The guiding questions are making for a more enriching conversation among students. However, the students are not writing all*

aspects of what is required from the rubric. The teacher is feeling like students are making a choice to not put forth the work to write reasoning.

Quality criteria for reasoning was stated in the rubric and checklist, but students were not writing to these expectations. Many of the written reasoning responses used explanation for why the solar house was unsuccessful. Many of our students wrote a reason as if they never built a solar house or they tried to justify why the temperature would not stay constant. The type of responses made our team investigate the difference between explanations and scientific argument. Student explanations were written as if the claim was already known to be true. However, reasoning in argument does not assume the claim is true. Students should write their reasoning to convince the reader that the claim is true based on the evidence collected. The team did not know the difference between explanation and reasoning and had to work together to establish our own understanding. In future lessons, our instructional practices would explicitly teach the difference between explanation and reasoning in argument.

Lesson IIC Mouse Trap Car

The Mouse Trap Car unit started during the second semester of the school year. The goal of lesson IIC was for students to construct a complete argument using claim, evidence, and reasoning. Students learned the basic scientific concepts about energy, force, friction, torque, and power by designing their own mousetrap car. Prior to designing and building mousetrap cars, students had to investigate the factors that impact the speed of a toy car. Lesson IIC was constructed to explicitly teach students the elements of argument by reviewing the rubric and providing another guiding checklist specific to the speed of the toy car. Similar to the solar house CER, the checklist provided questions to help students think through the quality of their written claim, evidence, and reasoning. The claim and evidence mean scores from the solar house lesson were respectively 2.7 and 2.6, so we were confident that the majority of students knew how to write a quality claim from collected evidence.

The essential question asked in lesson IIC was “How did the factor you selected to test impact the speed of the toy car?” In a prior lesson, students collected data from a lab that tested various factors that impact the speed of a toy car. They collected measurements in distance (meters) and time (seconds). The students were asked to look over the data collected, specifically write the factor tested, and what happened to the speed. Before moving on to discussing evidence, each student checked to make sure they answered the essential question and if the claim was an accurate statement. Next, students were asked to analyze their data and list evidence that were both qualitative and quantitative. Students were asked to check if the evidence related to the claim, and if the evidence was sufficient and appropriate. Lastly, the students were asked to write their reasoning using scientific terms and principles. A checklist of reasoning questions asked students to explain why there evidence supported their claim, and if there were, evidence cited in the response.

Table 11 summarizes the results of these written documents. The overall mean from student written samples was 5.21. This average decreased from the solar house activity in lesson IIB. The overall mean from lesson IIB was 6.8. The mean scores for claim (2.79), evidence (1.64), and reasoning (0.79) also decreased in lesson IIC.

Unfortunately, there were no high-level mastery ratings in this assignment. *Table 12* summarizes the common student responses from each level of mastery. The medium level mastery papers were able to state accurate claims and most had quantitative and qualitative evidence. The reasoning statements referenced evidence, but did not connect claim to evidence. Students had trouble writing scientific principles. The low-level papers did not answer the question nor include sufficient amount of evidence.

Table 11

Data Analysis Student Written CER: Factors and Speed of Car

	ECP Student Scores (N = 14)
Maximum Score	7
Minimum Score	2
Overall Mean Score	5.21
Mean Score – Claim	2.79
Mean Score- Evidence	1.64
Mean Score- Reasoning	0.79

Table 12

Common Student Written Responses Factors that Impact Speed of Car

	High Level Paper- 3	**Medium Level Paper- 2**	**Low Level Paper- 1**
Claim	This assignment did not have high-level mastery written responses	All groups are capable of answering the question and stating a claim.	The claim did not answer the question. One group only indicated the car without tires went right and wrong.
Evidence	This assignment did not have high-level mastery written responses	Of the four groups, one group presented multiple data points. However, this group did not include qualitative data as asked. The data included at least two quantitative pieces of evidence.	Response included only one data point and the graph did not support the data.
Reasoning	This assignment did not have high-level mastery written responses	References a graph that was bad, but does not explain the trends on the graph. Also, states "my evidence" proves the claim without connecting the actual evidence to the claim.	Reasoning does not include any quality criteria. Students state the reasoning supports claim in vague terms. They state the claim wants to know how fast the car went.

The stagnant results of written argument were disappointing to see in lesson IIC. The team recognized the challenges of writing reasoning statements, but also felt students were still making progress. An excerpt from classroom observation field notes show evidence of student misconception and their lack of understanding about speed:

> *Student is confusing the meaning of distance and time. Student #2 asks Student #12: did it go slower uphill? Student #1 is trying to figure out which car goes faster. They are confusing the concept of speed. The unit of measurements meter and second are conceptually reversed.*

Verbal discourse plays a role in correcting a misconception about speed. Through this conversation, the students are able to write correct scientific principles.

ECP Benchmark Exams

A pre-test benchmark exam, mid-term benchmark exam, and post-test benchmark exam were given to ECP students during the school year. The pre-test was given in August 2018, the mid-term benchmark exam in November 2018, and the post-test benchmark exam in February 2019. The results of the benchmark exams helped validate our findings from the lessons by triangulation of our data sources. The findings from the lessons were compared to the benchmark exam results.

Students had to use their data analysis skills to determine their claim, cite evidence, and justify their claim with evidence through reasoning. Benchmark exam written documents were evaluated using the same rubric from the lessons. Three levels of mastery were used to categorize the responses. The results allowed the PLC team to determine the level of CER mastery over time. *Table 13* below shows the results of the exam.

Table 13

CER Benchmark Exams Mean Scores Over Time

	Pre-Test (N= 23)	Mid-Term (N= 25)	Post-Test (N= 22)
Overall- Mean Score	4.78	5.52	5.27
Claim- Mean Score	2.22	2.48	2.32
Evidence- Mean Score	1.57	1.88	1.86
Reasoning- Mean Score	1	1.16	1.09

The findings from the pre-test to mid-term benchmark exams show overall growth over time. The mean score from the pre-test was 4.78 and on the mid-term exam 5.52. However, the results from the mid-term benchmark exam to the post-test benchmark exam are constant with no growth. The overall mean score on the mid-term is 5.52 and on the post-test, the overall mean score is 5.27. The reasoning sections of the exams still have the lowest mean score. The mean scores from lesson IIB and IIC are similar to the benchmark exams. This confirms that writing reasoning is more of a challenge for students than writing claims and evidence.

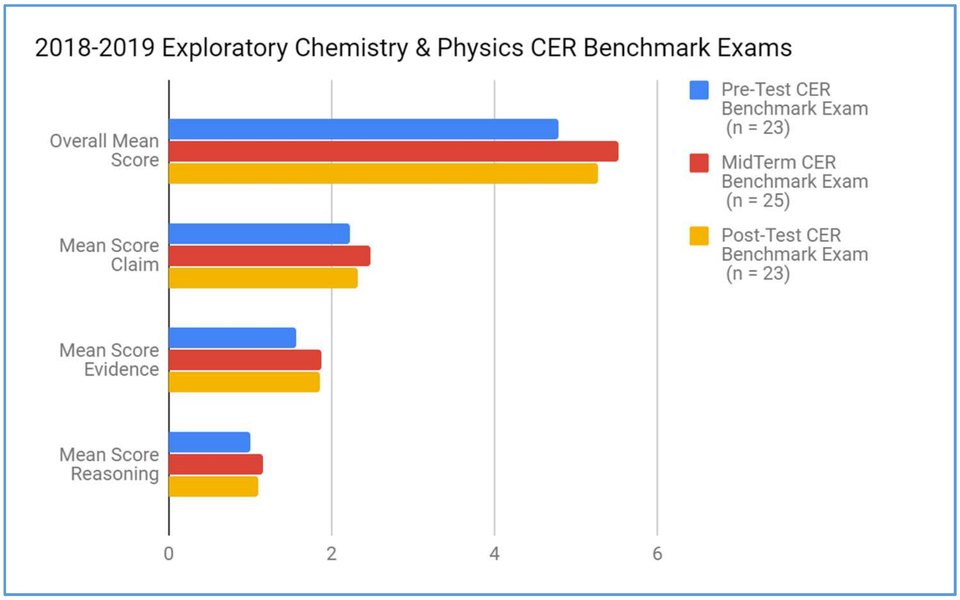


Figure 14. ECP Benchmark Exam Results

Figure 14 shows the results of the benchmark exam mean scores for claim, evidence, and reasoning. The top bar (blue) represents the pre-test exam, the middle bar (red) represents the mid-term exam, and the bottom bar (yellow) represents the post-test exam. On average, the mid-term exam had the best overall mean score in all areas, but the post-test was close. We hoped to see more growth in the post-test, but also understand the stagnant growth. By the end of the second semester, we will assess whether the students made any progress with writing reasoning.

During our PLC team meetings, we discussed the results of these benchmark exam scores. The reflection notes indicate progress with student understanding of how to write a claim. Below is an excerpt about claims from our PLC team meeting:

Students at the beginning of the ECP course did not understand how to write a claim. We assume these students would have some exposure to CER when they enter the course. They do not. The students were able to learn the concept of

> *writing a claim. We did notice an increase in scores. In addition, the rubric to measure level of mastery was straightforward. Students understand the concept of making an accurate and complete claim.*

Our conversations moved into a discussion about evidence. Overall, we felt students had the prior knowledge about evidence and how to collect data. However, students still needed help telling the difference between qualitative and quantitative data. I noted the following in my research reflection journal:

> *Evidence was also seen as improving where students can write both quantitative and qualitative data as the course progressed. Students had to learn the difference between these two terms. They are better at writing the evidence. We all agreed that students only need to write the numbers with units or statements of descriptions. Many of them are writing the evidence as their reasoning. When the students write their reason they see this as a repetitive process and will often write little for the reasoning.*

The PLC team took longer to discuss reasoning. By the time, we gave the post-test benchmark exam I noticed students were writing explanations rather than reasoning for argument. The team had to decipher the meaning of these two terms and how to teach students to avoid explanations.

> *As a PLC team, we had to establish the difference between reasoning as argument versus reasoning as an explanation. We noticed a trend where students were writing explanations even though our rubric stated "provides reasoning that links evidence to claim, includes appropriate and sufficient amount of scientific terms*

and principles". Today we established the difference between explanation and argument. This was an eye opening conversation to the teachers. Prior to this meeting, we thought our rubric was self-explanatory. However, and again, we realized the students did not comprehend the difference, as they should. I created a spreadsheet with the CER written scores and included definitions of reasoning for argument and explanation.

The spreadsheet was a useful conversation starter about the results of the exams. Teachers analyzed and member checked the results. We analyzed the trends in scores and agreed upon why the students were earning the points. Much of what we saw had to do with very few points earned in the reasoning section.

ECP Student Survey

Student questionnaires were given to students at the beginning of each school year semester (August 2018 and January 2019). The purpose of giving this questionnaire was to evaluate whether students could define claim, evidence, and reasoning. If students could recall definitions of CER, then they should have less trouble with applying their knowledge. We asked three simple questions about argumentation: what is a claim, what is evidence, and describe how students should justify a claim with evidence. Many students recall hearing the term claim from their middle school English and science class. We would expect students to state a claim is a statement that answers a problem or question. Based on the pre-survey results most students do not know the meaning of a claim. A common student response is that a claim is an opinion or a central sentence of your ideas and about how you feel about the topic. At the beginning of the second semester, students changed their definition of a claim as an opinion toward answering a question. For example, many students responded with “restating the question and answering it". Others describe the claim as a statement or sentence.

Evidence is scientific data that supports the claim. Data needs to be appropriate and sufficient to support the claim. At the beginning of the year, the majority of students know that evidence supports the claim. Only a few students had difficulty defining evidence. For example, one student stated, "evidence is something you’re proving". The results from the mid-term survey show students defining evidence as the element of argument that supports the claim. For example, "evidence is information that supports your claim". In this mid-term survey, we find more students including the term "data". We did not see this in the initial survey results. For example, a student would define evidence as "… data of any sort to support your claim".

The last question we asked of students was to describe how to justify a claim with evidence, or what is reasoning. This question was proposed to determine students' baseline understanding of the term reasoning. Reasoning explains why your evidence supports the claim. Quality reasoning compares multiple forms of evidence, explains why something happens with scientific principles or content, includes a mathematical model (if appropriate), and links the observable data to unobservable/theoretical components. Students would not be expected to know all the conditions of quality, but should move toward improving their reasoning skills. In the beginning of the year, students are not able to define reasoning. An example of a student response would be “students should use evidence to support a claim because they should prove what they believe". This statement is close to understanding how to support a claim. This student understands she/he should persuade or prove his/her claim. A few students bring in the idea of using outside resources such as information from websites. However, as expected the majority of students have difficulty describing how to use the evidence to support the claim. By the end of the first semester students understood that reasoning is written to justify your claim with evidence. For example, some students state they should use evidence to support a claim by using data, pictures, or a graph. Other students understand how reasoning should include scientific principles. A student wrote, "explaining your data with scientific words". This student understands the need to include scientific principles in his/her understanding.

Research Question 3: What Role Did Verbal Discourse Play in Students' Developing Understanding of Elements of Argument?

The pilot study brought out challenges students had with writing claim, evidence, and reasoning. The PLC team wondered if students could verbalize the elements of argument better than in writing. This third research question addresses the role verbal discourse has on student understanding of argument. The audio recording transcripts from the bottle rocket, circuits, and mousetrap argument lessons were analyzed to see what role verbal discourse played in students' developing understanding of elements of argument. Field notes and researcher reflection notes also analyzed student mastery of claim, evidence, and reasoning.

Lesson IIA Bottle Rocket Unit

In lesson IIA, we introduced students to audio recording their small group conversations. The PLC team wondered if students could verbally explain their understanding of argument, and improve their writing through epistemic practices. The social interaction among students in the small group changed. Below is an excerpt from my research reflection notes describing student behavior:

> *The goal of the lesson today was to determine quality reasoning. The students were given an unmarked CER paper marked high, medium, and low. Student's audio recorded their group discussions and found the process of recording to be different and interesting. Students' use of the device made them curious and in some ways formal in their use of the device. Some used it like a reporter holding the device up to the student.*

When students were asked to use the audio recorder there was a heightened sense of accountability and control by students. They were more careful about the words they used and for the majority they were more engaged and on task. On another day, I noted:

> *Most student voices were heard. Audio recording the student groups is new and a novelty. Some spoke in a natural type conversation while others still did not understand the point of the recording. They spoke directly into the device. The recording did keep students accountable for learning*.

The small group audio recordings provided more than information about student ability to verbalize their understanding of claim, evidence, and reasoning. The audio recordings also provide information about the culture and climate of learners within the room. The students were not receptive to interacting with one another at the beginning of the year. At the beginning of the second semester, students were much more willing to have discussions and even held other accountable. During one classroom observation, students told the teacher how excited they were to finally hear one student share his argument about the toy car. The students in the small group made a comment on the audio recording as this being a momentous occasion. These social interactions play a role in how students construct knowledge about argument. Student communication and collaboration is key to understanding argument. They need one another to engage in dialogue and learn different perspectives of argument.

Table 14

Common Student Responses Lesson IIA Bottle Rocket Verbal Discourse

	High Mastery (Level 3)	Medium Mastery (Level 2)	Low Mastery (Level 1)
Student Common Responses for High, Medium, & Low Reasoning	• It has a lot of evidence. • Shows how much volume was used and explains why the amount of fuel influences the time • Gives a lot of detail • Has qualitative and quantitative data- cites the rubric • It was descriptive	• States some evidence and connects to the claim • Uses graph and explains what the graph shows • Explains well but does not have scientific terms.	• Does not explain the details. • Discusses only about what happens • Did not show any numbers • Does not include appropriate evidence • Explains only the danger not the volume nor time

The audio recording transcripts reveal common themes among understanding demonstrated by the student groups. *Table 14* lists the most common responses by students. Comments on the high-level paper pertain to the amount of detail and the use of data types. We did not hear students commenting on the use of scientific principles. However, one group did comment on the lack of scientific principles when analyzing the medium level paper. The majority of groups were able to identify the low-level paper and what was missing from the reasoning statements. The focus was on the missing evidence as well as the lack of connection to the claim. We did not find students conversing about scientific principles. The expectation by the team was for students to analyze the reasoning statements as well as bring forth an understanding about why fuel was important for the bottle rocket flight. Students should have discussed the factors that influenced flight, such as pressure building up with more water, gravity, or even engineering and design.

Lesson IIB Circuits

The findings from Lesson IIB audio recordings reveal most students discussing proportional relationships between the current from the battery to the light bulbs. The teacher in this lesson worked with small groups of students and provided frequent guidance on how to have a conversation about their data. Students were asked by the teacher to explain what was happening to the current across the wire from battery to bulbs. The science teacher was modeling how to have a conversation between students. This lesson marked the beginning of how students should conduct themselves while engaged in argument. Once the teacher walked away from the group, the students struggled to accurately identify proportional relationships and their qualitative and quantitative evidence. One group spent time establishing the definition of a claim and evidence. Other groups spent time asking each other what they meant by their statements.

Lesson IIB Circuits Solar House

After students wrote their first version of their solar house CER, they were asked to use a checklist to make revisions. Students were placed into groups to peer edit their written CER samples. Group conversations were recorded with an audio recorder. In addition, I observed the class and recorded field notes. The audio recordings were more effective in capturing student conversations than my field notes. I would recommend capturing student conversations through the audio recordings rather than field notes. At the very least, record field notes along with the use of audio recordings. Student conversations occur simultaneously throughout the classroom; so capturing student voice is very difficult to do with field notes.

The audio recording transcripts from the solar house project revealed students having more in-depth discussions about claim, evidence, and reasoning. Observations from field notes reveal students asking questions about what evidence should be included on their worksheets, and asking what is the difference between qualitative and quantitative data. The groups used the checklist as guide in their discussion. The transcript revealed that students used the checklist to discuss each component of argument. We also found students had a deeper discussion about reasoning in verbal discourse compared to what they wrote individually in the first draft. The students pointed out the reasoning section should include evidence, and some mentioned the evidence should link to the claim. Unfortunately, the use of scientific principles in reasoning never came up in any groups. The teacher had to point out the need to include scientific principles in the reasoning section. In one group conversation, the teacher asked students if they read any samples with scientific principles included. Those students said science terms were missing, and that they did not know what should be included. They were unsure of what to write.

Lesson IIC Mousetrap Car

The findings from the toy car audio recording transcripts show different results from the written documents collected from this lesson. Students overall explained their argument in more detail verbally than they did in writing. Students were able to state a claim about their factors (uphill, without tires, smooth surface, etc.) and the impact of this factor on the speed of their toy car. During their conversations, they constructed knowledge about scientific terms. For example, one group explained how the toy car would move slower going uphill because force would be needed to move up the steep hill. Another group added the scientific concept of friction into their conversation. These points were brought up in more detail during student dialogue versus written responses. The field notes…

Student asks the teacher a question about their toy car set up using friction. The student inquires about the set-up and asks them what they think. The student explains that at first the car was slow. The teacher tells the small group to look over the data collected. The student explains the factor they selected was friction. A second student references the graph. Together the group describes how the data shows the toy car slowing down.

In this excerpt, students are able to connect their data to the concept of friction. Through verbal discourse, they are able to include scientific principles as part of their reasoning.

The PLC team discussed the results of the written and verbal discourse data. The science teacher believed the results of this activity had more to do with student lack of interest in the topic about speed of cars. The teacher felt the students had an “off” day when they used audio recorders, and did not write as well as they could. In addition, teachers added they felt the beginning of the second semester was always a challenge for students because students often forget what was expected or taught. Teachers end up reviewing topics taught from first semester.

CHAPTER V

DISCUSSION

Removing lower level academic courses is not a quick fix to tracking issues nor will it lessen the achievement gap. Tracking is a complex systemic issue influenced by a myriad of factors. Oakes (1985) defines tracking as a sorting of students where they are separated in a public manner by intelligence and accomplishments, labeled by learning type (high ability, low achieving, slow, average), defined by others, and has a different schooling experience. The unsorting of students into heterogeneous ability groupings does not detrack students for success. This dissertation study began with a review of NW High School science course enrollment data and the failure rate of students after the lowest level freshman science course was eliminated. The removal of the lowest level freshman science course tracked students into lower level future science courses and tripled the number of failures. Detracking efforts at NW High School magnified issues of tracking. Thus, we proposed creating an intervention course, called Exploratory Chemistry and Physics (ECP), which holds students to high expectations and gives them similar learning experiences to higher-level courses, but with more support that is academic. Explicitly teaching scientific argumentation was an intervention skill taught in this course to improve high school readiness skills and improve school performance. A team was formed to develop curriculum and implement instructional practices that would teach argumentation skills, so students could move successfully into higher-level science courses. Our study set out to investigate an alternative approach to detracking. Action research was selected as the methodological approach because the process can lead to the generation of living theories of practice. Analyzing discourse data could improve instructional practices and student academic outcomes. This qualitative methods study asked three research questions:

- Research Question 1 (RQ1): How does the process of action research influence our instruction of scientific argumentation in a high school science course
- Research Question 2 (RQ2): How does student ability to write scientific argument develop over time?
- Research Question 3 (RQ3): What role did verbal discourse play in students' developing understanding of elements of argument?

This chapter begins with an overview of the major findings presented in Chapter IV and the concluding thoughts about the results. Findings from this action research study are situated within sociocultural theory and argumentation theories. Implications of these findings are discussed along with recommendations for administrators and classroom teachers who are seeking detracking reform efforts. Final thoughts about future research and limitations of the study are shared at the end of the chapter.

Overview

Oppressive practices of tracking have a negative impact on students by slowing their academic growth, and minimize opportunities for success in higher-level courses. Hispanic and African American students are most at risk of falling into tracking pathways. Concerns of tracking influenced administrators to remove lower level science courses five years ago. This issue remains within the Science Department and is of great concern to me. Following the decision to detrack courses, three years of data showed inequitable patterns within science course enrollment and increased failure rates. The failure rates were most concerning to me because students who fail Biology are not eligible to graduate high school. The increase in failure rates fueled my mission to find alternative detracking methods to eliminating lower level science courses. I believed there should be a focus on building high school readiness skills (scientific argumentation) and improving instructional practices so students would move to higher-level science courses.

My values and beliefs for social justice and a growing awareness of my own critical consciousness fueled my actions to transform the science program. Paulo Freire's values and beliefs behind his concept of banking education inspired my work in this study. I also believe in empowering students to embrace their own learning and eliminating oppressive instructional practices. Freire's book Pedagogy of the Oppressed inspired critical researchers in the United States (Herr & Anderson, 2005, p. 15) to develop critical knowledge for social transformation. Paulo Freire's emphasis on dialogue and concern for the oppressed inspired me to create an action research group.

Our action research team was founded from a critical perspective, but the process was practical in nature. The ECP intervention course was designed to accelerate the skill development of those students who started in the lowest level science course. Rather than eliminate lower level courses, we worked to detrack science students by improving educational outcomes through high-quality teaching. The University of Washington Center for Educational Leadership (2019) stated high-quality teaching is the most important school-based factor in improving educational outcomes for students (p. 3). School leadership is a close second to high-quality teaching.

Research Question 1

Research question 1 asks how does the process of action research influence our instruction of scientific argumentation in a high school science course? This action research study provided a forum where our PLC team collaborated with one another to improve our ECP curriculum and explicitly teach science argumentation skills. All members of the team had a strong belief in helping academically at-risk students, as well as lessen the achievement gap within the Science Department. Our long-term goal was to detrack the course placement path and help students successfully transition into higher-level science courses. These values and beliefs were at the core of our instructional work. The process of action research challenged our own understanding of scientific argumentation and how to improve instructional practices. The action research cycles and repetitive stages of reflecting, planning, acting, and reviewing kept us focused on improving curriculum and the means for professional learning. During cycle II, we researched various studies that defined argumentation and provided a foundation for practical implementation of argumentation lessons. Toulmin, Zohar, Nemet, Osborne, Erduran, Thompson, Braaten, and Windschitl are some of the research studies that strengthened our understanding of argumentation. The instruments and tools we created during the action research process provided evidence of our work and changes made to our instructional practices.

Findings from the pilot action research study highlighted areas for curricular improvement. First, we designed our lessons so definitions, application, and practices of scientific argumentation were made clear. Our latest version of the CER rubric evolved from rubrics that had less specific language about expectations and criteria. The CER rubric became a tool to use with students as well as to deepen our own understanding of CER. We communicated quality criteria for writing and discussing CER. In addition, we learned that argumentation required building a community of learners who need social interactions to construct their own knowledge about CER. We did not realize how important it was for students to discuss CER in groups. Students completed science investigations in groups and were asked to write CER arguments as individuals. We did not plan for group discourse or peer editing at the time.

Analysis of the researcher reflection notes from cycle I and II reveal four major themes: collaboration, professional learning, curriculum development, and transformation in leadership. The collaboration that took place during weekly PLC team meetings was essential to conducting action research. The time was needed to reflect on lessons taught, analyze data, and plan for curricular changes. This democratic forum brought insight to our planning and an awareness to what was happening in the classroom. The data I collected was reported to the PLC team and member checked for validity. The results of the findings prompted the team to problem solve for improved instructional practices and curriculum. Outcomes from student written responses and verbal discourse sparked multiple questions about how to improve lessons. As the leader of the team, I was committed to continuously sharing data and my own analysis of data patterns and themes. These patterns were validated or refuted by the team. I believe the work of the team was fueled by these results since it gave us a purpose and direction on how to move forward with our work. Traditionally, teachers will progress monitor student learning by looking over grades. Our team never used grades to progress monitor growth; instead we focused on the criteria of quality argument.

The term explicit is defined as “state clearly in detail and leave no room for confusion or doubt” (Merriam-Webster, 2019). The ECP curriculum was modified and changed to be explicit about the meaning of claim, evidence, and reasoning. As a team, we worked on changing the language on the CER rubric so it would explicitly state the criteria and expectations of quality. The rubric evolved from the pilot study to what we use today. We challenged one another to dissect out the meaning of each word used on the rubric. These conversations led us to questioning our own understanding of claim, evidence, and reasoning. Findings from student written responses questioned whether we were teaching students to write explanations or reasoning in argument. This conversation was a revelation for all of us. An explanation was accepted as reasoning in argument. In the end, we all understood that reasoning in argument should be persuasive when justifying a claim with evidence.

A checklist of questions was created to guide students through the CER framework. These questions were especially useful during small group discussions. Students were hesitant to have productive academic dialogues about CER with other students. We learned that students did not have a foundation for elements of CER and suspect they did not engage in small group discussions while in middle school. Argumentation lessons incorporated tasks that required students to peer edit CER work. Teachers emphasized the importance of small group discussion to improve written CER work. A sociocultural perspective became a core value while developing lessons. We structured lessons so tasks would allow students to construct meaning through experiences with one another. For example, we set up small groups so students could peer edit each other's work. This was beneficial to students since they had the opportunity to revise their original written work. One of the teachers commented that he would have not thought to include peer editing on his own. Our PLC team discussion inspired him to try peer editing.

Dedication and commitment by the teachers kept our study moving forward. I believe my dual role as a leader and researcher influenced the work by keeping the team focused and updated on the action research plan. Reporting the findings from discourse data motivated the team to make improvements and change practices.

Research Question 2

Through the cycles of action research, the PLC team continuously analyzed written CER documents and used these findings to modify lessons. The second research question asks, How does student ability to write scientific argument develop over time? Written discourse data was collected from all three lessons (IIA, IIB, and IIC) taught during cycle II and was analyzed using argumentation theories. Zohar and Nemet (2002) argued that argumentation instruction should include the following factors: knowledge about the structure, nomenclature of arguments about the characteristics of a good argument, the enhancement of argumentation skill via writing, the teaching metacognitive knowledge about argumentation, and using authentic problems that have some relevance to students' lives (p. 39). Writing is known to be an epistemic tool where students explain their own learning. The act of writing provides a means to construct knowledge and promotes a way of thinking at a higher level. The use of the Toulmin argument model (Toulmin, 2003) provided a structure for our rubrics and for students to follow when writing. Students in the ECP course often expressed displeasure when asked to write a CER. Many students referenced how they were required to write a CER in their English courses and wondered why they were also asked to write a CER in science class. We found that ECP students are aware of the CER framework, but are often unmotivated to write. Student responses during the audio recordings confirm their dislike by stating they do not want to write and would rather talk.

The challenge in writing a CER involves drawing upon factual or conceptual science content knowledge, procedural knowledge, and epistemic knowledge. Students are asked to construct a justification between a claim and supporting evidence. Sandoval and Millwood (2005) believe that the manner in which "students incorporate and refer to data in their writing reflects their implicit epistemological commitments about the nature and role of data in the generation and evaluation of scientific knowledge" (Erduran et al., 2007, p. 52). There is a higher cognitive demand put upon students when they write an argument. Other forms of writing, such as exposition or narrative, are easier for students. Writing a scientific argument is persuasive which contains justification and reasoning.

The goal in writing CER is one of persuasion, and not just an explanation of understanding. "Scientific argument is a complex form of reasoning requiring domain-specific knowledge to construct and critique claims and their relation to any supporting evident to persuade other members of the community of their validity" (Osborne et. al., 2016, p. 823). During this study, it was a challenge for students to write reasoning because of the multiple criteria required to justify their claims with evidence.

The findings from the action research study show the majority of students able to recognize high, medium, and low mastery reasoning statements written by another student. In this situation, the complete argument was given to students. The findings from the lesson IIA bottle rocket written samples show lack of understanding about sufficient and appropriate evidence as well as how to write reasoning. Lesson IIA bottle rocket lesson asked students to identify the high, medium, and low reasoning statements. The reasoning statements were selected from student written responses and modified to hide the identity of the students. In the reasoning section, students repeat evidence or fail to link evidence to the claim. In addition, they also did not include scientific principles. The findings from lesson IIB circuits unit show growth in areas of writing claim and evidence. In the circuits unit students are able to identify the difference between qualitative and quantitative data. More students include two or more data points for evidence. Lesson IIB circuits written reasoning shows more students connecting evidence to their claim, but they still do not include scientific principles, a key component of reasoning. The responses for reasoning are more like explanations than argument. Reasoning should be an argument or persuasion, connecting the evidence to scientific principles, not an explanation of solutions. The argument or persuasion should convince others that the claim is true based on the evidence given. Lesson IIC findings were similar to lesson IIB written responses. Unfortunately, we found less effort by students to write details in their lesson IIC CER.

The lesson that had the highest overall mean score (6.8 out of 9) for a complete argument was the lesson IIB solar house activity. The lesson was designed so students could peer edit their first draft and revise after given feedback. Peer editing was implemented as an instructional strategy to improve writing in lesson IIB, but was not done in lesson IIC. Instead, students worked in groups with a guided checklist. They did not spend time revising their initial written work. Peer editing was beneficial to students since they were able to make corrections and analyze their own writing. Our team decided that future explicitly taught lessons should include peer editing. The team believed this was another layer of feedback and means to improve students' CER writing.

The results of the ECP benchmark exam provided another data source to answer research question 2. The findings of these benchmark exams show similar trends to those found on lesson IIA, IIB, and IIC written samples. Students are showing growth in areas of writing claims and evidence, but struggle with reasoning. The overall mean score increases from the pre-test (M= 4.78) to the mid-term (M = 5.52), but then remain essentially the same from the mid-term (M =5.52) to the post-test (M = 5.27). Students still need practice and guidance on how to write reasoning in argument. The results of the student survey confirm a need to help students think through and write reasoning. Students were challenged to explain how to justify a claim with evidence in their reasoning.

Writing leads to students constructing a better understanding of the main ideas of science (Cetin & Eymur, 2017). In our study, examining student writing assisted our team in finding common areas of improvement and changes to our instruction. General themes and patterns from written samples revealed whether students had a better understanding of science concepts and argumentation as a skill. Analyzing this data pushed our thinking on how to teach argument and adjust the tasks during the lessons.

Research Question 3

Research question 3 asks, What role did verbal discourse play in students' developing understanding of elements of argument? Hoek (2005) stated "…research shows that (verbal) peer interaction can be effective for improving conceptual understanding provided that interaction includes the use of domain-specific concepts, various ways of reasoning, elaboration, and co-construction of knowledge" (p. 21). Learning by peer interaction is a lot easier said than done. We found that students are challenged to stay on task and engage in productive academic dialogue. The team had more to teach than just the elements of argument. Research question 3 asks, What role did verbal discourse play in students' developing understanding of elements of argument?

Based on the results of the written CER and the group audio recording transcripts, I would argue that verbal discourse in small group settings show students able to verbalize their use of CER better than in writing. It is interesting that students also felt more excited about and perhaps confident in talking than writing. Group audio recording transcripts show students engaging in conversation about claim, evidence, and reasoning as well as what can be improved. Students are able to verbally critique the writing of others, even more so than their own writing. However, they were challenged by how to add specific details to add to their own written CER. The verbal comments made during peer editing show evidence of student ability to recognize what is missing from a written CER. Early findings from lesson IIA verbal discourse data show students' ability to identify criteria for claim, evidence, and reasoning. Analysis of the audio recording transcript identified key terms from the CER rubric. For example, students compare multiple forms of evidence and cite the lack of detail with scientific terms. The idea of what is sufficient and appropriate was discussed as well. Students could also explain how the high-level mastery papers contained scientific terms. In lesson IIB, students pointed out the reasoning section should include evidence, and some mentioned that the evidence should link to the claim. Unfortunately, the use of scientific principles in reasoning never came up in any group. In lesson IIC, inklings of scientific terms started to appear in the toy car conversations, but many groups left the terms out. Force and friction are examples of scientific terms used in reasoning. Analysis of transcripts indicated that the guided checklist used during the toy car discussion was a useful tool to help organize student thoughts and conversations. I was surprised by the level of guidance the students needed to have while in conversation. The PLC team incorporated other discussion techniques so students would stay engaged and on task. Examples of techniques used in this action research study included think pair share, sentence starters, assigned roles, guided checklists, and group responsibilities.

Findings Interpreted through Sociocultural Theory

The triangulation of the data from the audio recording transcripts, field notes, and reflection notes were helpful in determining the role verbal discourse play in students' understanding of elements of argument. Findings from these varied data sources suggest that argumentation functioned as a social process within a classroom community. Sociocultural Theory situates the importance of social interactions in students' knowledge construction. The sociocultural perspective points to the social interaction in learning and thinking processes. Argumentation in writing or speech is connected within a social context. According to Vygotsky (1978), speech facilitates problem-solving capabilities, plays a role in the autonomy of individuals and empowers future action, and directly affects behavior. Engaging in argument through speech allowed ECP students to express their understanding of science investigations (bottle rocket, circuits, and mousetrap cars) to scientific principles and thought. The interactions between students, and students with teacher, allow for questions and a growing understanding of claim, evidence, and reasoning.

In this study, many groups attempted reasoning, but most spent time talking about claim and evidence. I would argue that the students are challenged by the higher order thinking skills involved with reasoning. Discussions of reasoning would require students to know how to have a dialogue and bring scientific knowledge into the conversation. At the beginning of this study, students expressed displeasure in working together. By the time, we taught lesson IIC students were much more comfortable working in groups. Setting expectations and using instructional strategies such as sentence starters were helpful as a way for students to ease into conversations. Scientific terms were mentioned more frequently in student discourse over time. These strategies were used to build a community of learners.

According to Vygotsky (1978), using language can encourage collaborative learning. The checklist with guiding questions used in the lessons acted as a script for students to follow within the group setting. Students would follow the steps of claim, evidence, and reasoning and ask the guiding questions to think through the process of argument. Their use of language first identified the problem of the investigation and addressed the given essential question. Next, students formulated a plan of action to address the essential question. Lastly, by use of speech with one another, students took action in scaffolded stages to answer guiding questions.

Disciplinary knowledge is constructed, framed, portrayed, communicated, and assessed through language, and thus understanding the epistemological base of science and inquiry requires attention to the uses of language (Kelly, 2007). Language used in verbal discourse plays a role in helping students organize their thoughts and in communicating ideas. Vygotsky (1978) believed that "the most significant moment in the course of intellectual development…occurs when speech and practical activity; two previously completely independent lines of development converge" (p. 24). ECP students engaged in inquiry based investigations followed by discussion about their claim, evidence, and reasoning. First, students constructed knowledge on a social level and later on the individual level. When students wrote their claim, evidence, and reasoning assignments, they had to internalize understandings as individuals.

Practical Recommendations and Suggestions for Administrators

The findings from this study focused on the process of action research and its influence on instructional practices, as well as, student understanding of scientific argumentation through written and verbal discourse. Scientific argumentation builds knowledge about the nature of science, develops citizenship, and develops higher order thinking (Erduran, 2007). The logic behind this study was to develop higher order thinking skills so students would be successful in higher-level science courses. We developed curriculum that would arm students with critical thinking and science practice skills needed for higher-level science courses. Our PLC team set out to eliminate barriers and provide support so students could succeed in the ECP course and later higher-level science courses.

This study provides an example of how to move students into higher-level science courses with success. Our message to administrators is to avoid the elimination of lower level courses. Instead, focus on long-term goals for instructional improvements that impact student learning in the lower level courses. Eliminating the lowest level course is not a solution to detracking and does not eliminate the achievement gap.

First, detracking reforms should be specific to each school and supported by local data. Collect data from course enrollments across the years and continue to analyze the school course placement data yearly. Local trends in data can provide a powerful message to teachers, and summon action to eliminate inequitable practices. The problems of inequitable practices and systems of tracking are critical to communicate to teachers. Teachers may have misconceptions about tracking. Initially, teachers did not see the problem with students in lower level courses. Teachers reacted once I shared data trends with Hispanic students remaining in the lower level courses throughout the years.

Second, engage teachers in the exploration of pressing common problems of student learning. Teachers need to take ownership of the critical work and develop a shared understanding of a problem we are trying to solve. This may require an action plan for gathering more data. During our PLC team meetings, I frequently reminded teachers about our long-term goal to detrack ECP students. I believe this motivated the group to continue our curricular work.

Third, I would recommend administrators find out how teachers collaborate and support them around the problems of students learning. Professional learning communities, instructional and content coaching, and teacher-led learning are examples of collaboration. Assess the ways in which teachers are supported when they are attempting new practices. Professional learning communities need support with continuous improvement, especially with scaling up and expanding effective teacher learning efforts. In this study a professional learning community was established to solve issues around tracking. The PLC team identified a problem to address by analyzing data. Thereafter an action research framework was used to share ideas on how to improve instructional practice and develop curriculum. Teachers also used this time to express frustrations and roadblocks in reaching students. As a leader working with the PLC team, I immersed myself in the work firsthand and was able to speak to the specifics of the issues. I would recommend school districts consider the necessary investments needed to develop a culture conducive to coherent, authentic and ongoing teacher collaboration and professional learning.

Practical Recommendations and Suggestions for Teachers

Watanabe, Nunes, Mebane, Scalise, and Claesgens (2007) found heterogeneous chemistry classrooms were most successful when teachers believed students could develop their own learning, focused on inquiry-based pedagogy with real world context, focused on science study skills, and had a strong sense of community in the classroom. Research studies, such as the Watanabe study, were used as models for our own study. Science education research studies provided examples of how to explicitly teach scientific argumentation as well as structure our own values and beliefs around the work. The sociocultural perspective was at the core of our argumentation curriculum. Students were asked to learn the elements of argument and engage in social interactions to learn science concepts on a deeper level. I would recommend teachers learn from academic scholars and research studies that are similar to their own curricular work. Ask not only what should be done, but also why it is important. Teachers who are interested in conducting action research should look beyond the curricular resources and dig deeper toward conceptual frameworks.

Used as a methodology, action research is beneficial to professional learning communities. The process of action research is democratic in nature and allows all teachers to have a voice. The stages of action research in each cycle is an effective structure since it scaffolds the steps of action. Reflecting, planning, action, and reviewing keep teachers focused on continual improvement. I would recommend teachers to create an action plan to stay organized. More importantly, teachers should be committed to the work and dedicate time to accomplish each stage of the cycle. Initially, teachers start off strong, but may burn out over time. Action research requires three cycles and continuous data analysis and improvement. Cycles of research are added to a timeline, but the teachers have to follow-up and commit to the plan. In this study, we decided to meet during a designated forty-two-minute period once a week. Meeting once a week became routine for all of us. The team reviewed items on the agenda from each meeting and set a goal to accomplish before the next meeting. To be productive meetings should be meaningful, collaborative, and report on findings.

One major challenge of action research is the time teachers need to fully engage in the process. A major challenge is using existing time effectively for teacher learning. There is a wealth of information to learn from, but only a limited amount of time to filter through it. When thinking about how to use existing time effectively for teacher learning, I would recommend developing a system to target specific strategies for each meeting. Plans for a meeting should be similar to teacher classroom lesson plans. Professional learning and accomplishments will only occur during these meetings if there is a purpose and an end goal. Set a vision for what transformed teaching and learning ultimately looks like and what students may be able to do. I would suggest team members take turns leading each meeting, and provide an agenda. Establish behavior norms for each meeting as well.

Lastly, I would recommend teachers conduct a student-needs assessment from performance data. The findings from the needs assessment should guide teacher professional learning efforts. The process of action research includes reviewing data or other outcomes. The review process allows teachers to member check student results for accuracy of data. There should be a sufficient amount of data to analyze and interpret. Triangulation of data would be best practice, but may not be feasible given the circumstance of the research. Working with data and discussing the findings could also motivate the team to make improvements or celebrate accomplishments.

Limitations of the Study

One potential limitation to this study was the attrition of participants. Attrition occurs when participants leave during a study. During this study, there was a loss of some students from the ECP course. The student participant pool was not consistent across the full study, which may have influenced the average mean scores and the reporting of trends. Three students were removed from the ECP course by the end of the first semester and placed into a special education life science course. Unfortunately, the three students struggled to keep up with simple classroom instructions and could not process the concepts well enough to write or verbalize their understanding of elements of argument. Written claim, evidence, and reasoning documents from these students were included in data analysis before they exited the course. In addition to losing students from the ECP course, there were students who were chronically absent and on attendance probation. Chronic absences made it difficult to collect assignments from ECP students. The loss of students from the course and the chronically absent students decreased the number of written assignments and lessened the number of participants in small group work.

Short-term maturation effects may also limit the findings of the study. Collecting data occurred within an approximate three to four-month window of time. Student behaviors may contribute to the results of the study. For example, one teacher expressed that students were bored with working with their toy car investigation. Controlling participant-led factors such as boredom was difficult for the teacher. Developing a unit with a relevant student topic may be a solution to the issue of boredom. Understanding science concepts such as velocity could be accomplished by other means such as music and sound waves. Motivating students to produce quality written products was a challenge. The findings of lesson IIC mousetrap car show stagnant results in student writing of reasoning. These results may have been due to the participant led-factors.

Audio recordings of ECP students took place during cycle II of the action research study. It would be beneficial to the findings of the study to record students in cycle I of the study as well as cycle II. The audio recordings were used to assess the role verbal discourse played in student understanding of argument. The progression of student understanding from the beginning of the year into second semester would provide a stronger conclusion. Students need longer periods of time and training on how to discuss claim, evidence, and reasoning. The conversations between students improved over time, but were limited in the area of reasoning. Another major limitation, due to IRB concerns, was the inability to report individual student data. I was unable to show the individual student written and verbal data, nor include quotes or work samples. This limited the level of detail of my findings. The results of the study may be more robust knowing the individual student growth in writing claim, evidence, and reasoning.

Suggestions for Future Research

Action Research Cycle III- Future

This research does not end with the findings from cycle II. A third action research cycle is underway and ends with the school year. The goal of cycle III lessons is to teach students how to provide alternative counter arguments, construct a one-sided comparative argument, and analyze competing theories. Lessons would involve a situation in which two or more explanations are offered for a phenomenon (competing arguments). Students would be asked to make an explicit argument for why one argument is stronger and why one is weaker.

Argumentation does not end with reasoning, but also includes a critical component of counter critique or rebuttal. Deeper thinking is involved in counter argument because students need to use scientific knowledge and problem solving skills to explain why a claim is flawed. Counter critique requires students to apply what is known about a phenomenon and support or refute a claim. In cycle III, the PLC team plans to teach ECP students how to think deeply about argument and the skills needed for rebuttal. The PLC team believes students should know how to counter critique others to build critical thinking skills, and use rebuttal to express their thoughts among peers. If students are able to challenge one another's thinking, then they may be more confident and productive while working in small group settings. We believe developing this skill will assist students in higher-level science courses. Students need to take ownership over their own learning and see the value of working with others in small groups. In order to improve these skills, we will need to add lessons that teach productive academic dialogue and social emotional skills.

During one of our PLC team meetings, I introduced the concept of counter claim. This was a new concept for some teachers, and one of the teachers commented on how she liked it when she was given something to learn. The definition from MacPherson, Szu, Wild, and Yao (2016), was used to define counter critique:

…is somewhat more demanding requiring the cognitive operations of analysis to identify the salient elements of an argument, that is, claim, warrant, data, followed by an evaluation of the truth status of these elements or their validity while drawing on factual or conceptual knowledge, and then creating or synthesizing a counter-argument which is relevant to the argument that has been advanced (p. 823). The team predicted it would be very difficult for students to counter critique another student's reasoning because of students' struggles to write reasoning. As we move forward there will be more explicit lessons created using competing theories. The team thought counter critique would be a challenge, but may help build reasoning skills.

Science Talk

The audio recording transcripts and field notes revealed areas for additional research in science talk. According to Lemke (1990), learning science means learning to talk science (p. 1). Observing students' social interactions while in discussion about claim, evidence, and reasoning intrigued me. There was so much more than the technical understanding of elements of argument. In future research, I would like to use discourse analysis to investigate the social patterns of dialogue. A discourse study would address the limitation of using student quotes from written or verbal discourse data. A sociocultural perspective includes the social activity to construct knowledge about scientific argumentation. Investigating the patterns of science talk would enhance our findings about technical use of argument.

A variety of researchers describes discourse as language in use to construct knowledge. In addition, there are behaviors along with language use that can influence student learning. “Foucault (1969) considers discourse to be a combination of enunciations describing objects, themes, and practices with regularity (an order, correlations, and effects of activated positions, transformations) in terms of a historically determined social system” (Carbo, Ahumada, Caballero, & Arguelles, 2016, p. 364). According to Kelly (2007), “discourse is typically defined as language in use, or a stretch of language larger than a sentence or clause” (p. 1). He also connects social context, such as social knowledge, practice, power and identity, to the use of language. Of all descriptions of discourse, Gee (2010) provides the most applicable and insightful. Gee (2010) refers to Discourse with a capital “D” and a definition where Discourse is language-in-use about ‘saying, doing, and being’ (p. 34). Characteristic ways of acting-interacting-feeling-emoting-valuing-gesturing-posturing-dressing-thinking-believing-knowing-speaking-listening rather than just the use of language exist in Discourse (Gee, 2010). These scholars deepen our thinking about verbal discourse by providing the social context involved with learning. There is more to student learning than just the use of technical terms such as claim, evidence, and reasoning. As stated by these academic scholars, the social context of student behavior along with language use influence learning.

Discourse in small group settings is important to investigate in future research studies since these interactions provide experiences that allow students to construct meaning. This is the main tenet of Vygotsky's sociocultural theory, which asserts that learning is a social and cultural process.

Conclusion

The purpose of this dissertation was to investigate how the process of action research influenced our instruction of scientific argumentation and the mastery of elements of argument.

The goal of the study was to develop critical thinking skills by mastery of argumentation skills, so students would be prepared to successfully move into higher-level science courses. As argued earlier, to accomplish this goal, school districts should consider alternative means of detracking and use specific local level solutions. Eliminating lower level courses without supports and intervention is not a solution to detracking and does not eliminate the achievement gap. Instead, I would recommend researchers investigate detracking reform efforts and add to the existing claims of tracking research. The following list provides suggested topics to research:

- Alternative approaches to detracking reform efforts that eliminate lower level courses.
- Interventions that provide supports to students for high school readiness skills.
- The impact of quality curriculum that maintains high expectations in intervention courses and maximizes student academic growth.

- Design curriculum that explicitly teaches elements of scientific argumentation that can be used as an intervention to create learning conditions that improve student critical thinking skills, student dialogic skills, and empower student voice.

The intent of this action research study was to break the system of inequities and point out the flaws of generalized detracking reform efforts. The findings in this study show the power of teacher collaboration within an action research approach, and improvement of argumentation skills in both verbal and written discourse over time. Improvement occurred because of the scholarly work and dedication of a PLC team who believes all students deserve more. This study improved our own understanding of the process of action research, elements of argument, and the dynamic relationships of professional learning communities. The process of action research produced tools that are practical and used by any interested educator. The claim, evidence, and reasoning rubric developed as part of this action research project is a user-friendly tool that measures the level of mastery, or quality of argument. Our claim, evidence, and reasoning checklist with guiding questions were another tool that transformed how we approach teaching argument. The checklist ensured that our teaching was more explicit. This dissertation contributes these new tools, as well as what we learned about developing and using these tools. In addition, it may be useful to practitioners to have a detailed report of our action research study when considering methods on how to improve their own instruction. Recommendations for teacher practice, suggestions for administrators, and suggestions for future research studies add to the body of knowledge needed to improve our instructional practices.

CHAPTER VI

PERSONAL REFLECTION

My purpose in writing this personal reflection is to document the history of events and share my story. In my district, administrator turnover has increased over the years. Thus, I am one of the few administrators and educators who hold historical capital within the district. Most know the famous quote: “Those who cannot remember the past are condemmed to repeat it.” This reflection will document the past so history will not be repeated.

History of Detracking Reform

As an administrator, who is also a researcher, I became concerned about the inequitable systems and practices in our science program at Niles West High School. The generalized cultural context surrounding issues related to the achievement gap inspired me to look more closely at our local student achievement data as well as investigate how are own actions as educators perpetuate systems of inequity. I started by investigating student failure rates in our science courses and student enrollment in science courses across five years. Course enrollment data showed a disproportionate percentage of Hispanic and African American students in lower-level science courses and an increase in student failures. Clearly, there was achievement gap between different racial groups and inequitable practices found in the Science Department. In 2014-2015, a detracking reform to eliminate the lower-level science course was implemented by our district administration. College readiness was the focus and removal of basic level courses was the plan of action. Unfortunately, this detracking plan unintentionally made tracking worse for students. Removing the lowest level science course increased the student failure rate in our regular level Biology course. Failed students had to repeat the Biology course the following school year. Thereafter, if a student passed Biology the second time they were placed in the lowest level science course called Science Topics. Failure in Biology magnified the tracking pathway for students. The percentage of failures was four times higher than what was reported in the past. I should also mention there were a handful of students who failed Biology two times. Eventually the school gave these students an online course, ALS, to fulfill their life science graduation requirement.

Inequities in various school systems allowed students to move through elementary and middle school unprepared for high school. Many of our ECP students move from one school to another before reaching high school or 8th grade. After further investigation I found many of our ECP students were in three different schools before 8th grade. Preparation for high school would require some catching up in academic areas such as reading and math. Science teachers in my department initiated a solution to this issue. They proposed introducing a new intervention science course called Exploratory Chemistry and Physics (ECP) that would prepare students for high school expectations and curriculum. The ECP course was created to teach students the necessary high school readiness skills needed to succeed in future science courses. The new ECP science course would provide an integrated curriculum from Next Generation Science Standards, Common Core Math, and Common Core English Language and Arts. Both content and practice were emphasized in the ECP curriculum. I proposed focusing on evidence based argumentation in dialogue and writing because this is a common practice found in areas of math, English, and science. We decided to focus on argumentation skills because it was one of the best science practices defined by Next Generation Science standards, Common Core Math standards, and Common Core English Language Arts (ELA) standards. The NGSS framework identifies proficiency in science with the use of combination of three dimensions of science learning: Science Engineering Practices (SEP), Disciplinary Core Ideas (DCI), and Crosscutting Concepts (CCC). All three dimensions of learning were used in the development of ECP curriculum. Best practices in science curriculum should include connections student lives, be culturally relevant, use cross cutting concepts and design, and communicate phenomenon through evidence based argumentation and artifacts.

A team of science, math, and English teachers were brought together to help our academically at risk students. A professional learning community (PLC) was organized to dialogue about the activities needed to develop argumentation skills and to share learning experiences. A collaborative team designed instruction to support student repetitiously developing and contesting the grounds for knowing through argumentation practice. The Toulmin structural approach (CER) was used as a framework in instruction. We met during our PLC meetings to design activities and tasks that would teach evidence based argumentation skills. I decided to participate in this work because I felt strongly about helping students succeed and move into higher-level science courses. It would be my responsibility to carry the accomplishments and challenges of the ECP student cohort. I have organized data systems with student standardized test scores in reading (STAR), course grades, and course placements. After observing and progress monitoring the 2017-2018 ECP cohort of students, I am elated by our recent findings. All students from the first cohort have been placed into higher-level science courses for their junior year. They were not placed into Science Topics, the lowest level junior year course.

Politically the deck was stacked up against this intervention course. Initially, district administration did not approve the proposal for the ECP course. However, the school board felt differently and approved the course anyway. With the board approval, we moved forward with constructing the curriculum for the course. The PLC team worked hard to ensure our students received a quality science curriculum and that would prepare them for higher-level science courses. Essentially, students would learn argumentation skills as I would personally parallel the process of improvement.

A practical action research study was implemented to develop explicitly taught curriculum that would improve evidence based argumentation skills. A circle of critical friends was established within the PLC team. We identified a problem, formulated questions, collected data, analyzed data, and discussed the outcomes of the study.

Reflection and Critique

Experiential learning is a powerful agent of change and transformational in thought. The practical nature of action research developed my skills in technical and adaptive ways. This research study changed my mindset and actions as a leader. I would identify myself as a critical theorist with a strong practitioner lens. Initially, learning was more technical, but now I would describe myself as having a deeper adaptive thought process. Equity has a different meaning to me now than when I started my journey as an administrator five years ago. I believe adaptive thinking involves an expression of my own identity and culture within my work. Changes are addressed through my own belief systems and those I work with. Together we learn through deeper conversations involving our cultural perspectives. I started to sense a shift in mindset about equity and in our own critical self-consciousness. Conversations moved from “what” was taught to the “why” we are teaching. Our teaching practice evolved from direct teaching to student-centered dialogue with voice. We wanted to get to know students and their own identity.

All research has the goal of advancing knowledge and generating theory. I believe I have accomplished this goal through the process of action research in this study. My intent was to improve particular issues within inequitable systems. Improvement was possible because of my position of power and because of the professional learning community I created. Working collaboratively with the PLC team improved my own understanding of scientific argumentation through a sociocultural perspective. These shared practices constructed my own understanding of leadership, and effective collaboration with teachers. I built a team of dedicated and passionate teachers who inspired me to work for the betterment of our students, especially our students of color.

Five years ago, I became the Director of Science, and a new student in the Doctorate of Curriculum and Instruction program. These synchronized events advanced my knowledge about social justice in an educational setting. The praxis of living out the theoretical principles in my leadership role made me more confident in my administrator role. I felt it was important to share what I learned with others. I found myself sharing my values and living out these values with a team of educators who felt the same way. However, I found a delicate balance between my role as a practitioner and researcher. I was fearful that using research jargon would impress a self-serving intention and overpower the discussions. During our meetings, I was transparent about my Loyola University research goals and made it clear that my schooling enhances my understanding as well as what I bring to the team. At times, I caught myself toning down research language because I did not want to lose trust with the team. Otherwise, I thought my role as a team member would be lost. In preparation for meetings, I carefully planned how to offer my own expertise while being subservient to the needs of the team.

Breaking down the system of tracking was important to all of us. For years, I observed students flounder in the freshman level Biology courses. It was difficult for me to observe students disengaged in learning. I could see teachers doing their best to help these students. Balancing the expectations of the course and providing a differentiated curriculum became a difficult task for teachers. When students were reading at a third grade level it was difficult to provide, resources that would help them master the course objectives. This was a time of moral and ethical turmoil for me. I questioned the researchers who adamantly opposed tracking and tried to find meaning in their work. Jeannie Oakes (1985) is a researcher who is well known for her research on tracking. She described the inequitable conditions students would endure in lower level courses, such as receiving unqualified teachers and watered down curriculum. In our situation, we were moving toward providing a watered down curriculum in the on level courses. If a student passed the course with a D, it was more likely due to special grading and allowing students to learn less than expected. I was disappointed with this hidden practice, and started to see the impact of this practice on student learning. Student promotion (with barely a D grade) had to stop. As an administrator with some voice, I felt we had to make changes to the system. A position of power helped in this situation. I decided to improve my own understanding of tracking, take action in my own learning, and while doing so influence the learning of others.

The power relationships described by Foucault and Paulo Freire's banking education messages shaped my own values and mission to eliminate oppressive practices. Recognizing my dual role as an administrator and my position of power was important when working with others. My own biases were expressed to the group, as well as avoidance of top down directives. My leadership practices are closely tied with a participatory approach and a shared vision of collaboration. Power relationships can be oppressive and damaging to the democratic process.

Foucault provides a thorough analysis of the effects of power and knowledge in various social settings. According to Foucault, "Individuals could now be placed ("streamed") into a relatively permanent place in their society based upon their past ability of willingness to conform to the disciplinary norms, rather than on their present growth and insight or their future goals and potential ability and initiative" (Jardine, 2005, p. 64). The work by Foucault transformed my thinking as a leader. Prior to my schooling and study, I never considered how positions of power could influence the thinking of others. For example, school administrators were using their positions of power to eliminate lower level courses. Changes were made without the input from teachers. Subtle strategies were also used to control public discourse about these curricular decisions. There were no opportunities to discuss the implications of these actions. As a new leader, I did not want to use my position of power to intimidate or prevent teachers from voicing their concerns. Instead, I wanted to use my position of power to create systems of communication. This system would allow me to share what I learned as well as learn from stakeholders.

In my doctoral courses, I always appreciated the list of research articles and books we were asked to read and reflect upon. I learned how to be a critical thinker in my own learning. During this action research study, I found myself searching for knowledge in research studies and textual resources. The process of research allowed me to discover the field of epistemic science and argumentation. I learned how argumentation should be approached as an epistemic practice and used to build a community of learners or knowledge building communities. This action research study developed curriculum that promoted a community of student learners. As this was taking place, I was also building a community of learners with the teachers.

Future Goals

I learned that action research is messy, really messy. The challenge of action research for me is letting go of my own control and authority. In collaborating with the group, I prepared agendas and instruments that facilitated discussions. However, I found the best discussions were organic in nature, and mostly in line with my own thoughts. I learned to prepare essential questions, but not take over the PLC meeting. I was pleased with the results of our work, and the continuous reflective discussions that allowed us to move forward and improve. Collecting data can also be overwhelming and messy. I learned there we needed to balance of the amount of data collected. Identifying which data gave the “biggest bang for the buck” was a challenge. I think the results from student written samples and classroom observations were most informative to the PLC team. The results improved explicitly taught lessons.

Personal goals of mine include using the skills I learned in my doctoral courses and research. I can see how my dual role as a practitioner and novice skill set as a researcher can be beneficial to various learning communities- high school, universities, and professional organizations. Teaching has always been an informal research laboratory for me. Early on in my teaching career, I thought of myself as a scientist who was delivering science knowledge to my students. However, with a better understanding of the craft of teaching, I started to see myself as a researcher who experimented with instruction to help students learn. I am so glad I took this formal journey into the research community. For me, researcher and practitioner are one in the same. I believe I have enhanced my skill set to work with teachers as they improve their own craft.

As my Loyola University Chicago research ends this semester, I recognize the value of networking with other researchers and plan to participate in spaces that will continue to challenge my thinking and share my research experiences. My first step will be to publish my dissertation findings. I plan to join the Association for Science Teacher Education and present my findings at one of the conferences. In addition, I would like to publish my findings in the ASTE Journal of Science Teacher Education (JSTE). Last year, I attended the Action Research Symposium with ILEARN (Illinois Leaders and

Educators Action Research Network). If there is another symposium, I would like to present my findings at the conference as well. I hope to find additional networks that will support my desire to learn and perhaps work with teacher preparation programs in the future.

APPENDIX A

NW HIGH SCHOOL SCIENCE COURSE ENROLLMENT 2017-2018

NW High School Science Course Enrollment 2017-2018

	2017-2018	% African American	% Asian	% Hispanic	% White
Total Population of Students	**2512**	**4.8**	**33.2**	**14.9**	**44.3**
Total Science Dept. Enrollment	**2417**				
% Enrolled in Science	**96.20%**				

		2017-2018	% African American	% Asian	% Hispanic	% White
	# Students Enrolled	% # Student enrolled/Total Population	% African American	% Asian	% Hispanic	% White
Biology 12-22	373	14.85%	7	32	12	46
Biology 11-21	170	6.77%	2	44	9	43
Science Topics	133	5.29%	6	24	26	42
Chemistry 10-20	136	5.41%	8	21	30	38
Chemistry 12-22	294	11.70%	2	34	11	49
Chemistry 11-21	179	7.13%	1	37	13	39
Physics 10-20	90	3.58%	8	28	22	41
Physics 12-22	296	11.78%	3	34	17	43
AP Physics 1	134	5.33%	0.76	48	6	45
Science Research Topics	8	0.32%	11	22	22	44
Anatomy & Physiology III	55	2.19%	5	25	22	44
Anatomy & Physiology IV	117	4.66%	4	51	10	33
Health Careers	139	5.53%	6	43	18	32
AP Biology	40	1.59%	3	68	3	28
AP Environmental	87	3.46%	5	33	16	46
AP Chemistry	45	1.79%	4	47	0	47
AP Physics C	29	1.15%	0	48	0	48
STEM Inquiry & Research (SIRs)	36	1.43%	0	56	6	39
Astronomy	24	0.96%	0	13	8	79
Exploratory Chemistry & Physics	32	---	8	16	22	31

APPENDIX B

NW HIIGH SCHOOL SCIENCE COURSE ENROLLMENT 2016-2017

NW High School Science Course Enrollment 2016-2017

	2016-2017	% African American	% Asian	% Hispanic	% White
Total Population of Students	2623	4.3	32.9	15.6	45.2
Total Science Dept. Enrollment	2419				
% Enrolled in Science	92.20%				

		2016/2017	% African American	% Asian	% Hispanic	% White
	# Students Enrolled	% # Student enrolled/Total Population	% African American	% Asian	% Hispanic	% White
Biology 12-22	449	17.12%	4	28	18	46
Biology 11-21	166	6.33%	1	37	13	39
Science Topics	87	3.32%	7	18	30	44
Chemistry 10-20	140	5.34%	5	27	21	44
Chemistry 12-22	284	10.83%	3	33	21	40
Chemistry 11-21	172	6.56%	2	47	4	46
Physics 10-20	112	4.27%	7	21	30	42
Physics 12-22	305	11.63%	6	38	13	43
AP Physics 1	106	4.04%	3	49	4	45
Science Research Topics	13	0.50%	15	8	15	62
Anatomy & Physiology III	76	2.90%	3	33	17	46
Anatomy & Physiology IV	98	3.74%	0	43	8	48
Health Careers	138	5.26%	5	45	19	31
AP Biology	35	1.33%	0	54	6	40
AP Environmental	95	3.62%	3	35	12	51
AP Chemistry	59	2.25%	0	59	3	36
AP Physics C	18	0.69%	0	39	6	56
STEM Inquiry & Research (SIRs)	50	1.91%	0	72	4	24
Astronomy	16	0.61%	0	19	6	75
Exploratory Chemistry & Physics	---	---	---	---	---	---

APPENDIX C

NW HIIGH SCHOOL SCIENCE COURSE ENROLLMENT 2015-2016

NW High School Science Course Enrollment 2015-2016

	2015-2016	% African American	% Asian	% Hispanic	% White
Total Population of Students	2627	5.6	32.0	14.9	46.6
Total Science Dept. Enrollment	2336				
% Enrolled in Science	88.90%				

		2015/2016	% African American	% Asian	% Hispanic	% White
	# Students Enrolled	% # Student enrolled/Total Population	% African American	% Asian	% Hispanic	% White
Biology 12-22	446	16.98%	5	31	20	41
Biology 11-21	143	5.44%	1	43	6	50
Science Topics	70	2.66%	17	20	26	35
Chemistry 10-20	171	6.51%	9	21	29	40
Chemistry 12-22	305	11.61%	5	36	13	45
Chemistry 11-21	147	5.60%	3	49	9	39
Physics 10-20	129	4.91%	7	24	18	51
Physics 12-22	286	10.89%	3	27	17	53
AP Physics 1	139	5.29%	0.7	50	7	43
Science Research Topics	23	0.88%	18	5	23	45
Anatomy & Physiology III	59	2.25%	3	24	21	52
Anatomy & Physiology IV	100	3.81%	2	43	5	50
Health Careers	45	1.71%	4	60	4	32
AP Biology	37	1.41%	0	74	0	26
AP Environmental	93	3.54%	1	36	9	54
AP Chemistry	49	1.87%	2	44	2	52
AP Physics C	24	0.91%	0	46	4	50
STEM Inquiry & Research (SIRs)	39	1.48%	0	64	3	33
Astronomy	31	1.18%	0	13	23	65
Exploratory Chemistry & Physics	---	---	---	---	--	---

APPENDIX D

AGENDA: EXPLORATORY CHEMISTRY AND PHYSICS PLC TEAM MEETING

AGENDA: Exploratory Chemistry and Physics PLC Team Meeting

Attendees:
Date:

GOAL: Detrack ECP student course placement by transforming our practices to generate knowledge from the implementation of quality science curriculum with an interdisciplinary approach and equity pedagogy.
Objectives:
Focus Questions
• What is the goal of the meeting? Why? • What are the objectives of the meeting? How will we accomplish this objective? • What are the next steps in this cycle? • Restate the purpose of this action research study. Review the action plan. Where are we in the work?
Reflection:

ECP Team Tasks for Next Meeting
Science:
Literacy Coach:
Questions to Address Next Meeting:

"For detracking to truly serve those whom it was intended to benefit, schools may need to put more resources into measures that support these students. This may include insuring that detracked classes are smaller and therefore able to provide more personalized support for students. ***It also is helpful to add classes and programs designed to accelerate the skills development of students who were previously tracked low****. Finally, and perhaps most importantly, teachers who will be required to teach detracked classes must be provided substantial support and training on how to teach such classes. They also may need the opportunity to meet regularly as a group, to observe each other teaching, and to share and analyze student work so that they can support each other in meeting the academic goals of this reform" by Beth Rubin & Pedro Noguera (2004)*

APPENDIX E

2018-2019 ACTION RESEARCH PLAN

2018-2019 ACTION RESEARCH PLAN

ARGUMENTATION MODULE I

Cycle 1 Action Research

1. REFLECT
What are the major issues to address?
Explicitly teaching scientific argumentation through modeling and other instructional practices as well as providing opportunities for students to engage in argumentation and developing stronger argumentation skills and develop student voice.

2. PLAN
Goals:
a. Student constructs a claim (C) & identifies a claim.
b. Student provides evidence (E) & identifies evidence.

LESSON IA
Task-Describe a phenomenon to students, then ask students to identify a claim about the phenomenon. Describe a new phenomenon, then ask students to articulate (construct) a claim.*
Data to Collect

LESSON IB
Task- Present students with a claim and evidence about a phenomenon then ask students how well the evidence supports the claim, and articulate the scientific principles that connect each piece of evidence to the claim.*
Data to Collect

LESSON IC
Task- Describe a phenomenon to students, then ask students to articulate (construct) a claim about the phenomenon, and then collect evidence that supports the claim. Articulate the scientific principles that connect each piece of evidence to the claim.*
Data to Collect

ACT
What is the claim to knowledge at this point?
Is the data collection plan being implemented? Any adjustments to data collection?
What did we find from the data collected? Analyze the data.

REVIEW
What have we achieved?
What do we recommend moving into cycle 2?

ARGUMENTATION MODULE II

Cycle 2 Action Research

1. REFLECT
What are the major issues to address after cycle 1?

2. PLAN
Goals:
a. Identifying a warrant/reasoning (R)
b. Constructing a warrant/reasoning (R)
c. Constructing a complete argument (CER)

LESSON IIA
Task- Present students with a claim and evidence and reasoning about a phenomenon, then ask students to assess the reasoning of a given link between claim and evidence.*
Data to Collect

LESSON IIB
Task- Present students with a claim and evidence about a phenomenon, then ask students to construct the reasoning between claim and evidence.*
Data to Collect

LESSON IIC
Task- Describe a phenomenon to students, then ask students to construct a complete argument with a claim, evidence, and reasoning.*
Data to Collect

ACT
What is the claim to knowledge at this point?
Is the data collection plan being implemented? Any adjustments to data collection?
What did we find from the data collected? Analyze the data.

REVIEW
What have we achieved?
What do we recommend moving into cycle 3?

ARGUMENTATION MODULE III

Cycle 3 Action Research

1. REFLECT
What are the major issues to address after cycle 2?

2. PLAN
Goals:
a. Providing an alternative counter argument
b. Providing a counter-critique
c. Constructing a one-sided comparative argument

LESSON IIIA
Task- Present students with a claim, a list of data sources that are relevant to the claim (but not what the data says), then ask students to identify (select from a list) a pattern of evidence from the data that would support the claim. Also, ask students what pattern of evidence from the data would refute (counterargument) the claim.*
Data to Collect

LESSON IIIB
Task- Present students with a claim, evidence, and warrant that is flawed, and then ask students to critique the argument. Students should justify their counter-critique or why the argument is flawed.
Data to Collect

LESSON IIIC
Task- Describe a situation in which two or more explanations are are offered for a phenomenon (competing arguments). Ask students to make an explicit argument for why one argument is stronger and why one is weaker.
Data to Collect

ACT
What is the claim to knowledge at this point?
Is the data collection plan being implemented? Any adjustments to data collection?
What did we find from the data collected? Analyze the data.

REVIEW
What have we achieved?
What can we conclude after the three cycles?

Pre-Test Argumentation Skills
Initial Student Survey
→
Mid- Term Test Argumentation Skills
Mid- Term Student Survey
→
Post-Test Argumentation Skills
Post Student Survey

*Van Horne, K., Penuel, W.R., & Bell, P. (2016). *Integrating science practices into assessment tasks*. Retrieved from http://stemteachingtools.org/brief/30.

APPENDIX F

ACTION RESEARCH STUDY DATA TYPES/SOURCES

Action Research Study Data Types/Sources

<table>
<tr><th>Research Questions</th><th>Data type/source</th><th>How data types/source increase credibility of study?</th></tr>
<tr><td>(RQ1): How does the process of action research influence our instruction of scientific argumentation in a high school science course?</td><td>1. Classroom Observations field notes of behaviors relating to student ability to state claims, collect evidence, justify claim with evidence, and counter critique.
2. Researcher reflection journal notes
3. Student written documents
4. Audio recording transcripts</td><td rowspan="3">1. Triangulation- Findings from the variety of data sources will confirm patterns of student progression of mastery of argumentation skills.
2. Transcripts from audio recordings and field notes will provide rich thick descriptions about group findings.
3. Adequate engagement in data collection- Over time student discourse can be analyzed for patterns and improvement.
4. Critical self-reflection in journal notes
5. Audit trail of methods, procedures
6. Multiple sources of student written documents will provide data to support whether groups of students are progressing in their ability to write a complete argument.
7. A member check will be conducted with the PLC team</td></tr>
<tr><td>(RQ2): How does student ability to write scientific argument develop over time?</td><td>1. Student Written Documents from lessons (IIA, IIB, & IIC) focused on argumentation during cycle II.
2. Student Written Documents Pre-Test of Argumentation skills & Post-Test of Argumentation skills
3. Researcher reflection journal notes
4. Student Survey: Pre-Student Questionnaire and Mid-Term Student questionnaire</td></tr>
<tr><td>(RQ3): What role did verbal discourse play in students' developing understanding of elements of argument?</td><td>1. Transcript from audio recording of student groups during cycle II argument lessons (IIA, IIB, & IIC).
2. Classroom observations field notes of behaviors relating to student ability to state claims, collect evidence, justify claim with evidence, and counter critique.
3. Researcher reflection journal notes</td></tr>
</table>

APPENDIX G

ACTION RESEARCH STUDY DATA ANALYSIS FRAMEWORK & INSTRUMENTATION

Action Research Study Data Analysis Framework & Instrumentation

Research Question	Data Collection	Data Analysis Criteria of Measure	Instrument
(RQ1): How does the process of action research influence our instruction of scientific argumentation in a high school science course?	1. Classroom Observations field notes of behaviors relating to student ability to state claims, collect evidence, justify claim with evidence, and counter critique. 2. Researcher reflection journal notes 3. Student written documents 4. Audio recording transcripts	Qualitative Methods. Constant comparison of data over the three cycles of action research will be conducted. The focus will be on how data unfolds during the three cycles of action research. Open coding will identify categories of how action research influenced instruction. Axial coding will be utilized to compare the identified themes. Selective categories will	Argumentation Classroom Observation Instrument- Fall 2018 2018-2019 Student CER RUBRIC 2019 Data Collection-CER
(RQ2): How does student ability to **write** scientific argument develop over time?	1. Student Written Documents from lessons (IIA, IIB, & IIC) focused on argumentation during cycle II. 2. Student Written Documents Pre-Test of Argumentation skills & Post-Test of Argumentation skills 3. Researcher reflection journal notes 4. Student Survey: Pre-Student Questionnaire and Mid-Term Student questionnaire	Data was analyzed using closed, selective coding. Toulmin and Zohar/Nemet Framework. The presence and quality if claim, evidence, reasoning, & counter critique. The accuracy of scientific content. (Toulmin, 1958; Zohar & Nemet, 2002)	2018-2019 Student CER RUBRIC CER Level 1-3 Mastery Rubric- Fall 2018 Descriptive statistics will be used to determine how students perform collectively over the progression of argumentation lessons The test results will be analyzed by comparing the percentage of points earned on the pre-test to the percentage of points earned on the post-test.

(RQ3): What role did **verbal** discourse play in students' developing understanding of elements of argument?	1. Transcript from audio recording of student groups during cycle II argument lessons (IIA, IIB, & IIC). 2. Classroom observations field notes of behaviors relating to student ability to state claims, collect evidence, justify claim with evidence, and counter critique. 3. Researcher reflection journal notes	Toulmin and Zohar/Nemet Framework. The presence and quality if claim, evidence, reasoning, & counter critique. The accuracy of scientific content. (Toulmin, 1958; Zohar & Nemet, 2002)	2018-2019 Student CER RUBRIC CER Level 1-3 Mastery Rubric- Fall 2018 Descriptive statistics will be used to determine how students perform collectively over the progression of argumentation lessons The test results will be analyzed by comparing the percentage of points earned on the pre-test to the percentage of points earned on the post-test.

APPENDIX H

LESSON IIB CIRCUIT STUDENT GUIDE

Lesson IIB Circuit Student Guide

Question: ***What is the relationship that exists between the current through the battery and the current through the bulbs in a series circuit?***

What is the question asking us to do?
Write a claim that answers the question. Use the language of the question in your claim.

Claim:

Using your lab, find three pieces of evidence that support your claim. Write 1-2 sentences describing each piece of evidence.

Evidence #1:
Evidence #2:
Evidence #3:

Discuss and compare your evidence pieces with those of the other members of your group. Include additional evidence below.

Additional Evidence:

What scientific terms play a role in this question? See your notes for help.

Terms:
- Current
- Series circuit
- Circuit

Created by JM

APPENDIX I

PASSIVE SOLAR HOUSE CER CHECKLIST

Passive Solar House CER Checklist

CLAIM: Check that one applies to your claim.	**Definitely YES**	**Not sure (Ask a teacher)**	**Definitely NO**
Do you have a claim?			
Does your claim include all necessary parts?			
Is your claim accurate? Does it answer the question?			
EVIDENCE: Check which one applies to your claim.	**Definitely YES**	**Not sure (Ask a teacher)**	**Definitely NO**
Do you have both **quantitative** and **qualitative** evidence?			
Does your evidence support your claim?			
Does your evidence have some evidence?			
Do you include all appropriate evidence possible?			
REASONING: Check which one applies to your claim.	**Definitely YES**	**Not sure (Ask a teacher)**	**Definitely NO**
Does your evidence link with the claim? (Or is it irrelevant (Think Mrs. Kim and safety)			
Are you repeating your evidence or *explaining* it?			
Are you explaining your choices and reasons for revisions?			
Do you know what the proper scientific terms are for this assignment?			
Do you include all scientific terms and ideas?			

Now what do you have to do to revise?

Created by MH and AS

APPENDIX J

RUBRIC MASTERY LEVELS

Rubric Mastery Levels

Evidence Based Argumentation Skills Rubric

Evidence- Based Argumentation Skills Rubric

Elements of Argumentation			Representation (Osborne, et. al.)	Level 1	Level 2	Level 3 Quality Argument: structure, content, & justification
Claim *A statement that answers the original problem/question* *Student constructs a claim (C) & identifies a claim.*				Does not make a claim, or inaccurate claim	Makes an accurate but incomplete or vague claim	Makes an accurate and complete claim
Evidence *Scientific data that supports the claim. Data needs to be appropriate and sufficient to support the claim* *Student provides evidence (E) & identifies evidence.*				Does not provide evidence, or only provides inappropriate evidence (evidence that does not support claim).	Provides appropriate but insufficient evidence to support claim. May include some inappropriate evidence.	Provides appropriate and sufficient evidence to support claim
Reasoning *Explain why your evidence supports the claim. This must include scientific principles/knowledge that you have about the topic to show why the data counts as evidence.* *Identifying a warrant/reasoning (W)* *Constructing a warrant/reasoning (W)* *Constructing a complete argument (CEW)*	**Degree to which student makes comparisons among evidence**			Student only includes one form of evidence. For example, discussion of data in a simple experiment, or discussion of an amino acid sequence from a textbook	Student reports multiple forms of evidence. For example, reports data from a complex controlled experiment, or reports human, chimp, and gorilla amino acid sequence from a textbook example.	Student compares multiple forms of evidence (data from one investigation or mulitple investigations) in a sophisticated way.
	Degree of depth in student explanation	**Explanation with theoretical components**		Student describes what happened Student summarizes, restates a pattern, trend in data without making a connection to any unobservable/theoretical components.	Student describes how or partial why something happened. Student addresses unobservable/theoretical component tangentially	Student explains why something happened. Student can trace a full causal story for why a phenomenon occurred. Student uses powerful science ideas that have unobservable/theoretical components (like kinetic molecular theory) that explains observable events
		Explanation with mathematical components		Student describe what happened Student describes, summarizes, or restates a pattern or trend of data	Student describes how something happened Student links observations to mathematical concepts in isolation For example, correlates the number of strings supporting a load in a pulley system with the effort to lift the load.	Student explains why a mathematical model accounts for a phenomenon. Student links observations to statistical or mathematical model Student explains the links between observations and statistical or other mathematical expressions
	Degree to which evidence and explanation are integrated in written products			Students reports of data are sandwiched in between descriptions of what happened.	Students begins to describe how their data are about a larger idea Connections between evidence and explanations are implied but not fully described	Students writes about how observable/measurable components are cases of unobservable/theoretical ideas Students can identify how the specific component from the investigation(s) relates to the general case from theory or a complex mathematical relationship Student explanation contains a claim that justifies the link between observable data and unobservable/theoretical components
Counter-Critique *Circumstances in which the general authority of the warrant would have to be set aside* *Providing an alternative counter argument* *Providing a counter-critique* *Constructing a one-sided comparative argument*				Counter argument missing, or weak new claim with no backing in critique.	Student offers a counter argument as a way of rebuttal to another student's claim	Student offers a counter argument as a way of rebuttal to another student's claim. Provides a critique of why the claim is flawed and justifies why.

Osborne, J.F., Henderson, J.B., MacPherson, A., Szu, E. Wild, A., & Yao, S. (2016). The development and validation of a learning progression for argumentation science. *Journal of Research in Science Teaching*. 53(6), 821-846.
Thompson, J., Braaten, M., Windschitl, M. (2014). Collaborative inquiry into students' evidence-based explanations: How groups of science teachers can improve teaching and learning. Retrieved from:http://tedd.org/wp-content/uploads/2014/03/APEX-Collaborative-Inquiry.pdf
Ambitious Science Teaching. (2018). Pressing for evidence-based explanations. Retrieved from https://ambitiousscienceteaching.org/tools.

APPENDIX K

2018-2019 STUDENT CER RUBRIC

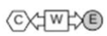
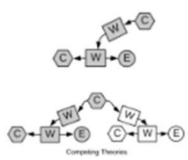
2018-2019 Student CER RUBRIC

Claim Evidence Reasoning (CER) Rubric								
Elements of Argumentation	**Low Mastery**		**Medium Mastery**		**High Mastery**		**Scientific Knowledge**	
1. CLAIM (C)	**0 points**		**1 point**		**2 points**			
A statement that answers the original problem/question	Does not make a claim, or makes an inaccurate claim	☐	Makes an accurate but incomplete claim	☐	Makes an accurate claim	☐		
2. EVIDENCE (E)	**0 points**		**1 point**		**2 points**			
Scientific data that supports the claim. Data needs to be appropriate and sufficient to support the claim.	Does not provice evidence or only provides inappropriate evidence (that does not support claim)	☐	Provides appropriate but insufficient evidence to support claim. May include some inappropriate evidence.	☐	Provides appropriate evidence related to question and sufficient amount of evidence to support claim	☐		
3. REASONING (R)	**0 points**		**1 point**		**2 points**		**Inaccurate 0 point**	**Specific & Accurate 2 points**
Explain why your evidence supports the claim. This must include scientific principles/knowledge that you have about the topic to show why the data counts as evidence.	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 -but not sufficient- scientific principles	☐	Provides reasoning that links evidence to claim. Includes appropriate and sufficient amount of **scientific terms and principles.**	☐	☐	☐
4. COUNTER-CRITIQUE (CC)	**0 points**		**1 point**		**2 points**			
Circumstances in which the general authority of the warrant would have to be set aside.	Response raises no new relevant concerns.	☐	Response raises some new relevant concerns.	☐	Response clearly raises new relevant concerns AND expresses them as counterarguments or rebuttals.	☐		

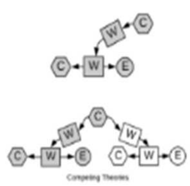
APPENDIX L

2018-2019 STUDENT CER RUBRIC

2018-2019 Student CER Rubric

2018-2019 Student CER Rubric					
ELEMENTS OF ARGUMENT	**Level 1**	**Level 2**	**Level 3**	**Science Knowledge** Inaccurate	**Science Knowledge** Specific & Accurate Science
1. CLAIM (C) A statement that answers the problem/question 	Answer given, but not structured as a claim or inaccurately identifies the claim being made.	Partially identifies the claim being made.	Accurately identifies the claim being made.	☐	☐
2. EVIDENCE (E) Scientific data that supports the claim. Data needs to support the claim. 	Uses evidence that fails to support claim	Uses some evidence to support claim	Accurately identifies most of the evidence used to supports the claim.	☐	☐
3. REASONING Explain why your evidence supports the claim. This must include scientific knowledge that you have about the topic to show why the data counts as evidence. 	Answer does not make a conclusion to accept, reject or withhold a decision about the claim **nor** provides an explanation for reasoning.	Makes a conclusion to accept, reject, or withhold a decision about the claim **OR** provides an explanation about his or her reasoning.	Makes a conclusion to accept, reject, or withhold a decision about the claim **AND** provides an explanation about his or her reasoning. Response may link to math and/or powerful science ideas.	☐	☐
4. COUNTER Argues the opposite of the claim. 	Response raises no new relevant concerns.	Response raises some new relevant concerns.	Response clearly raises new relevant concerns AND expresses them as counterarguments	☐	☐
Total Points for CER Components					

2018-2019 Student CER Rubric

2018-2019 Student CER Writing Rubric								
	Elements of Argumentation						**Scientific Knowledge**	
	Needs Improvement		**Good Progress**		**Excellent Meets Standards**		**Inaccurate**	**Specific & Accurate Science**
1. CLAIM (C)		1 point		2 points		3 points	0 point	1 point
A statement that answers the original problem/question 	Response given but not structured as a claim, or inaccurately identifies the claim being made.	☐	Partially identifies the claim being made	☐	Accurately identifies the claim being made.	☐	☐	☐
2. EVIDENCE (E)		1 point		2 points		3 points	0 point	1 point
Scientific data that supports the claim. Data needs to be appropriate and sufficient to support the claim. 	Identifies evidence that fails to support claim	☐	Accurately cites some evidence to support claim	☐	Accurately identifies most of the evidence used to supports the claim.	☐	☐	☐
3. REASONING		1 point		2 points		3 points	0 point	1 point
Explain why your evidence supports the claim. This must include scientific principles/knowledge that you have about the topic to show why the data counts as evidence. 	Response does not make a conclusion to accept, reject or withhold a decision about the claim nor provides an explanation for reasoning.	☐	Makes a conclusion to accept, reject, or withhold a decision about the claim OR provides an explanation about his or her reasoning.	☐	Makes a conclusion to accept, reject, or withhold a decision about the claim AND provides an explanation about his or her reasoning. Response may link to math and/or powerful science ideas.	☐	☐	☐
4. REBUTTAL		1 point		2 points		3 points	0 point	1 point
Circumstances in which the general authority of the warrant would have to be set aside. 	Response raises no new relevant concerns.	☐	Response raises some new relevant concerns.	☐	Response clearly raises new relevant concerns AND expresses them as counterarguments or rebuttals.	☐	☐	☐
Total Points for CER Components								
Total Points for Essay								

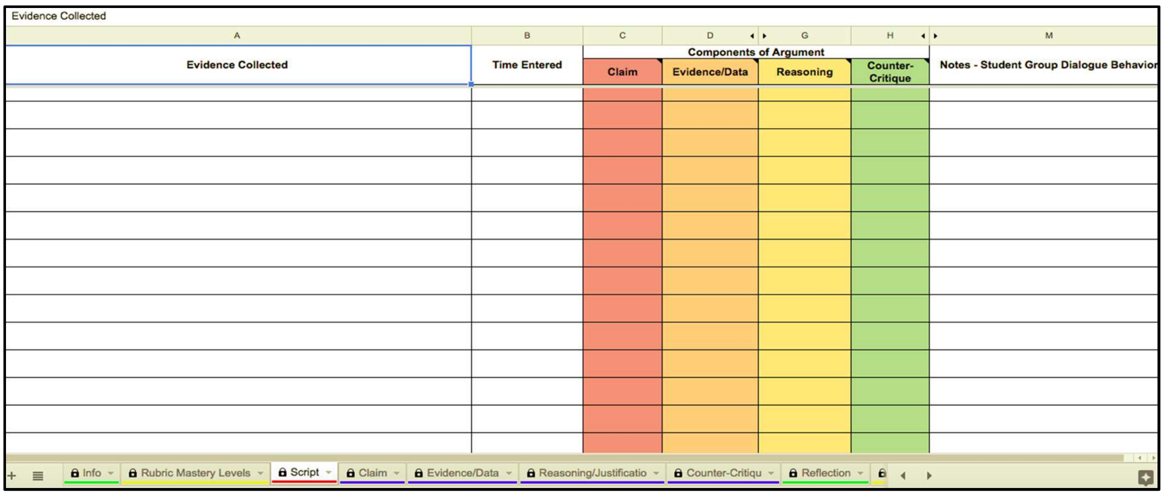
APPENDIX M

CLASSROOM OBSERVATION FORM

CLASSROOM OBSERVATION FORM

GOOGLE SHEETS

Link to the spreadsheet with tabs (Instructions, Rubric Mastery Levels, Script, Claim, Evidence/Data, Reasoning/Justification, Counter-Critique, Reflection, and Summary of Mastery Level).



APPENDIX N

SAMPLE TEACHER CONSENT FORM

TEACHER CONSENT FORM

CONSENT TO PARTICIPATE IN RESEARCH

Project Title: Explicit Teaching of Scientific Argumentation Skills and the Empowerment of Freshmen High School Science Student Voice Through Action Research

Researcher: Ami LeFevre

Faculty Sponsor: Dr. Lara Smetana from Loyola University Chicago.

Introduction:

You are being asked to take part in a research study being conducted by Ami LeFevre for her dissertation work under the supervision of Dr. Lara Smetana in the Department of Curriculum and Instruction at Loyola University of Chicago.

You were recruited as a participant for this action research study because of your ongoing collaboration as Literacy Coach with the Science Department, and as one who is interested in elements of argumentation. Your expertise and training as an English teacher brings a different perspective and unique skill set to this study. As a literacy coach, you can provide teaching strategies and the development of curriculum regarding evidence based argumentation skills.

Please read this form carefully and ask any questions you may have before deciding whether to participate in the study.

Purpose:

The purpose of this action research study is to investigate how the process of action research influences our instruction of scientific argumentation and student mastery elements of argument.

The mastery of learning progressions associated with argumentation may influence student academic achievement and enhance a skill set that influences their future placement in higher-level science courses. A long-term goal would be to successfully detrack our academically at-risk science students into higher-level science courses. After freshman year, students in our lowest level science course, Exploratory Chemistry and Physics, would move into higher track Biology, Chemistry, and Physics science courses.

The designed curriculum will include best science practices defined by Next Generation Science standards (NGSS). The NGSS framework identifies proficiency in science with the use of combination of three dimensions of science learning: Science Engineering Practices (SEP), Disciplinary Core Ideas (DCI), and Crosscutting Concepts (CCC). Best practices in science courses should allow students to make connections to their own lives, be culturally relevant, use cross cutting concepts and design, and communicate phenomenon through evidence based argumentation and artifacts. The NGSS framework defines argumentation as the process by which explanations and solutions are reached. The NGSS standard for argumentation states: “Engaging in argument from evidence in

9–12 builds on K– 8 experiences and progresses to using appropriate and sufficient evidence and scientific reasoning to defend and critique claims and explanations about the natural and designed world(s). Arguments may also come from current scientific or historical episodes in science". Lessons developed in this action research study will use this standard as a framework for learning the component skills of argumentation.

Procedures:
Action research in this study is viewed as an emancipatory practice aimed at helping oppressed groups of students. As a participant you will follow the cycles of action research: *reflect* on current practices and identify an area for improvement, *plan* an intervention (designed curriculum) through which improvement might occur, *act* on one improvement plan while collecting particular data points, and *review* the intervention at play while also analyzing data to measure the effectiveness of the plan. This action research study will follow three full cycles of reflect, plan, act, and review. After one full action research cycle, we will begin a new cycle based on our first cycle review.

The action research study will take place from August 2018 to April 2019. If you agree to be in the action research study, you will be asked to:

1. Assist in developing nine argumentation lessons (3 per unit) that explicitly teach elements of claim, evidence, reasoning, and counter-critique. Each lesson will be designed in a collaborative manner between you and the researcher. The objective of each lesson is listed below:
   - LESSON IA Task-Describe a phenomenon to students, and then ask students to identify a claim about the phenomenon. Describe a new phenomenon, and then ask students to articulate (construct) a claim.
   - LESSON IB Task- Present students with a claim and evidence about a phenomenon then ask students how well the evidence supports the claim, and articulate the scientific principles that connect each piece of evidence to the claim.
   - LESSON IC Task- Describe a phenomenon to students, then ask students to articulate (construct) a claim about the phenomenon, and then collect evidence that supports the claim. Articulate the scientific principles that connect each piece of evidence to the claim.
   - LESSON IIA Task- Present students with a claim and evidence and reasoning about a phenomenon, then ask students to assess the reasoning of a given link between claim and evidence.
   - LESSON IIB Task- Present students with a claim and evidence about a phenomenon, then ask students to construct the reasoning between claim and evidence.
   - LESSON IIIC Task- Describe a phenomenon to students, then ask students to construct a complete argument with a claim, evidence, and reasoning.
   - LESSON IIIA Task- Present students with a claim, a list of data sources that are relevant to the claim (but not what the data says), and then ask students to identify (select from a list) a pattern of evidence from the data that would support

the claim. Also, ask students what pattern of evidence from the data would refute (counterargument) the claim.

- LESSON IIIB

Task- Present students with a claim, evidence, and warrant that is flawed, and then ask students to critique the argument. Students should justify their counter-critique or why the argument is flawed.

- LESSON IIIC Task- Describe a situation in which two or more explanations are offered for a phenomenon (competing arguments). Ask students to make an explicit argument for why one argument is stronger and why one is weaker.

2. Contribute to the collection of resources and add them to a designated Google Drive folder.
3. Present the nine lessons to students during science class, as you would normally do as a literacy coach.
4. Provide the researcher with student documents that you and the researcher deem pertinent to the study.

Risks/Benefits:
There are no foreseeable risks associated with participating in this study beyond what a teacher would experience in everyday life. Participants could possibly benefit from the new collaborative experience, impact student learning, reflect on professional practices in new ways, and improve instructional practices; all of these skills can be useful in the classroom, with teaching course teams, and with PLC teacher teams. Many authors report action research as an effective type of professional development.

Confidentiality:
In the reporting of data collected for this study, no records will be created or retained that could link you to personally identifiable descriptions, paraphrases, or quotations. Your actions or things you say may be presented without specific reference to you, reference only by pseudonym, or combined anonymously with the actions and words of other participants.

During data analysis, participants' names will be removed from the transcriptions and replaced with pseudonyms only known to the researcher. All materials collected including transcriptions will be stored on a secured, password-protected hard drive of the researcher's computer or in locked file drawers; only the researcher will know the password and possess the key to locked data.

All data will be kept for three years, after which time electronic data will be purged and paper data will be shredded.

Voluntary Participation:
Participation in this study is voluntary. If you do not want to be in this study, you do not have to participate. Even if you decide to participate, you are free not to answer any

question or to withdraw from participation at any time without penalty. Participation in this study, or declining to participate in the study, will not alter current or future relationships between you and the researcher. You will receive no compensation for participating in the study.

Contacts and Questions:
If you have questions regarding this study, you may contact Ami LeFevre at (847) 626-2670 or amilef@d219.org, or the faculty sponsor, Dr. Lara Smetana at lsmetana@luc.edu. If you have questions about your rights as a research participant, you may contact the Loyola University Office of Research Services at (773) 508-2689.

Statement of Consent:
Your signature below indicates that you have read the information provided above, have had an opportunity to ask questions, and agree to participate in this research study. You will be given a copy of this form to keep for your records.

___________________________ ___________________________
Participant's Signature ***Date***

___________________________ ___________________________
Researcher's Signature

APPENDIX O

SAMPLE STUDENT ASSENT FORM

STUDENT ASSENT FORM

STUDENT PARTICIPATION ASSENT FORM

Project Title: Explicit Teaching of Scientific Argumentation Skills and the Empowerment of Freshmen High School Science Student Voice Through Action Research
Researcher: Ami LeFevre
Faculty Sponsor: Dr. Lara Smetana from Loyola University Chicago.

Dear Student,

Today I am asking for your valuable input and participation in a research study involving high school students and their role in the learning process about science practices. The purpose of the study is to gain a better understanding of how we can create activities and assignments that help you develop critical thinking and argumentation skills. I hope to learn more about developing curriculum that will increase opportunities for you to express your opinions and voice about how you learn best.

As part of this study, you are being asked to give me permission to use your student work as part of my data in this study. Your participation in this study is voluntary, which means you do not have to share class work with me if you do not want to. Nothing will happen to you or your grades if you decide not to participate.

Please read the following statement and sign if you agree to participate.

I understand if I do not wish to participate in this research study then no penalty will come to me. If I decide at a later point in time to not participate then I will not be penalized for this decision.

Signature: ________________________________

Name (Please Print): ________________________

Date: ______________________

There are two copies of this letter. After signing them, keep one copy for your records and return the other one. Thank you in advance for your cooperation and support.

If you have questions regarding this study, you may contact Ami LeFevre at (847) 626-2670 or amilef@d219.org, or the faculty sponsor, Dr. Lara Smetana at lsmetana@luc.edu. If you have questions about your rights as a research participant, you may contact the Loyola University Office of Research Services at (773) 508-2689

APPENDIX P

SAMPLE PARENT LETTER AND CONSENT FORM

PARENT LETTER AND CONSENT FORM

Parent Consent Form

Project Title: Explicit Teaching of Scientific Argumentation Skills and the Empowerment of Freshmen High School Science Student Voice Through Action Research
Researcher: Ami LeFevre
Faculty Sponsor: Dr. Lara Smetana from Loyola University Chicago.

Introduction:
Your child is being asked to take part in a research study conducted by Ami LeFevre, Niles West High School Director of Science, for a dissertation under the supervision of Dr. Lara Smetana in the Department of Curriculum and Instruction at Loyola University of Chicago.

Your child is being asked to participate because of the science course he/she is enrolled in. The reading teacher who works with students in this science course has agreed to work with me as a collaborator in the research process. The reading teacher provides literacy support in all our science courses including the science course your child is enrolled in. Your decision to not allow your child to participate will not affect your child's grade in any way.

Please read this form carefully and ask any questions you may have before deciding whether to allow your child to participate in the study.

Purpose:
The purpose of this action research study is to investigate how the process of action research influences our instruction of scientific argumentation and student mastery elements of argument. The mastery of learning progressions associated with argumentation may affect student academic achievement and enhance a skill set that influences their ability to think critically and succeed in future science courses. The designed curriculum will include best science practices defined by Next Generation Science standards (NGSS).

Procedures:
During the 2018-2019 school year, the reading teacher and I will develop lessons that explicitly teach the elements of argumentation skills. Students will learn science content by use of argument skills that require them to construct claims, evidence, reasoning, and counter argument. During these lessons, students will engage in-group conversations and write about their experiences. Thus, participants will be asked to share their written work,

share their opinions and voice on three questionnaires, audio recorded during group conversations, and complete a pre-test/post-test about argumentation skills.

Risks/Benefits:
There are no foreseeable risks involved in participating in this research beyond what your child would experience during his regular school activities. I anticipate there will be certain benefits for your child to participate. A potential benefit would be to improve the ability to work with other students and to critically analyze scientific content in a deeper and more meaningful way. This study will also potentially benefit your child and others as we learn how to create curriculum that supports best science practices.

Confidentiality:
All information gathered will be kept confidential. The following precautions will be taken to protect individual student information:

1. Electronic data will be stored on a password- protected computer, digital files will be password-protected, and paper copies of data will be kept in a locked drawer in the researcher's office.
2. Your child's name will not be used on any data sources. Names will be replaced with a pseudonym. The document that links the pseudonyms to the participants' names will be kept on a password-protected computer and will be a password-protected file. The researcher will be unable to extract anonymous data from the database should the participant wish it withdrawn.
3. Confidentiality will be maintained to the degree permitted by the technology used.
4. All data will be kept for three years, after which time electronic data will be deleted and paper data will be shredded.

Voluntary Participation:
Participation in this study is voluntary. If you do not want your child to be in this study, he/she does not have to participate. Even if you decide to allow your child to participate, he/she is free not to answer any question or to withdraw from participation at any time without penalty.

Contacts and Questions:
If you have questions regarding this study, you may contact Ami LeFevre at (847) 626-2670 or amilef@d219.org, or the faculty sponsor, Dr. Lara Smetana at lsmetana@luc.edu. If you have questions about your rights as a research participant, you may contact the Loyola University Office of Research Services at (773) 508-2689.

Statement of Consent:

Your signature below indicates that you have read and understood the information provided above, have had an opportunity to ask questions, and agree to allow your child to participate in this research study. You will be given a copy of this form to keep for your records.

__________________________________ ____________________
Parent's/Guardian's Signature Date

__________________________________ ____________________
Researcher's Signature Date

APPENDIX Q

STUDENT QUESTIONNAIRE WITH SCRIPT

STUDENT QUESTIONNAIRE WITH SCRIPT

Student Survey Script

Students will be sent the following Google Form student questionnaire and will be completed during science class:
https://docs.google.com/forms/d/e/1FAIpQLSf9n790eJeBFnBILIrjnX8Ij_tNTwdaYZ77xJjk2vOn95lu7w/viewform

---

Science ECP Student Questionnaire (Fall 2018)
Please read each question carefully and share your thoughts. There are no right or wrong answers to each question. We are interested in your learning experiences.

1. First and Last Name
2. Please list the name of ALL schools you attended from Kindergarten to 8th grade. If you list more than one school then please indicate the grade level (1st grade, 2nd grade, etc.)
3. Please describe ONE classroom experience where you felt you had a voice in the process and learned a lot.
4. While in my 8th grade science class I shared my own ideas and spoke to other students in a small group...
Never, 1,2,3,4, 5 Everyday
5. Think back to your 8th grade science course, how many times did you present to the whole class?
6. I feel I have a voice when I participate in group discussions and science activities.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

7. Working with other students on class projects is something I enjoy

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

8. I enjoy discussing my ideas about science topics with other students.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

9. I enjoy hearing what other students think while in class.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

10. Students can learn more by sharing ideas with each other.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

11. I would prefer teachers ignore me during class.

- Yes
- No
- Maybe

12. When I do not understand something I try to figure it out by myself. *

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

13. I participate in group discussions.

- Always
- Often
- Sometimes
- Rarely
- Never

14. The classroom activities in my 8th grade science class allowed me to express my thoughts and ideas with other students.

- Strongly disagree
- Disagree
- Neutral
- Agree
- Strongly agree

15. I feel comfortable asking questions in class.

- No, I never ask questions
- 1
- 2
- 3
- 4
- 5
- Yes, I ask students and the teacher questions all the time.

16. What does it mean to "state a claim"?

17. What is "evidence"?

18. Describe how a student should use evidence to support a claim.

APPENDIX R

STRUCTURED TEACHER INTERVIEW PROTOCOL

STRUCTURED TEACHER INTERVIEW PROTOCOL

Date: _________________

2018-2019 Semi-Structured Teacher Interview Questions

1. What aspects of the designed curriculum worked well with students? Specifically, what were the strengths of the lesson? What could be improved about the lesson?

2. How do you perceive student understanding of the components of argumentation (claim, evidence, reasoning, & counter-critique)?

3. How do you think students perceived their own identity during group discussions?

4. How do you think students perceived the power dynamics occurring during group discussions?

5. Do you have any other thoughts or comments about the designed curriculum? Student interactions with other students?

NOTES from Interview:

REFERENCE LIST

Ambitious Science Teaching (2017). Tools for ambitious science teaching. Retrieved from: https://ambitiousscienceteaching.org/get-started.

Anfara, V. A., & Mertz, N. T. (Eds.). (2006). *Theoretical frameworks in qualitative frameworks*. Thousand Oaks, CA: Sage Publications.

Argys, C. (1983). Action science and intervention. *The Journal of Applied Behavioral Science*, *19*(2), 115-140.

Argys, L.M., Rees, D.I., & Brewer, D.J. (1996). Detracking America's schools: Equity at zero cost? *Journal of Policy Analysis and Management*, *15*(4) 623-645.

Bavis, P. (2017). Detracked- and going strong. *Kappan*, *98*(4), 37-42.

Bernhardt, V. L. (2013). *Data analysis for continuous school improvement*. Larchmont: NY. Eye on Education, Inc.

Bevan, B. (2011). Scientific argumentation approaches and orientations. Retrieved from http://rr2p.org/article/120.

Bianchini, J.A. & Cavazos, L.M. (2007). Learning from students, inquiry into practice, and participation in professional communities: Beginning teachers' uneven progress toward equitable science teaching. *Journal of Research in Science Teaching*, *44*(4), 586-612.

Bianchini, J.A., Dwyer, H.A., Brenner, M.E., and Wearly, A.J. (2015). Facilitating science and mathematics teachers' talk about equity: What are the strengths and limitations of four strategies for professional learning? *Science Education*, *99*, 577-610.

Boaler, J. (2006). How a detracked mathematics approach promoted respect, responsibility, and high achievement. *Theory into Practice*, *45*(1), 40-46. doi: 10.1207/s15430421tip45016.

Bookwalter, G. (2019, February 15). Long-term Evanston Township H.S. performance scores largely trending up, officials say. *Chicago Tribune*. Retrieved from https://www.chicagotribune.com/suburbs/evanston/news/ct-evr-eths-202-long-term-trends-tl-0214-story.html.

Braaten, M., Windschitl, M., & Braaten, M. (2013). Developing a theory of ambitious early-career teacher practice. *American Educational Research Journal*, *50*(3), 574-615.

Braaten, M., & Sheth, M. (2016). Tensions teaching science for equity: Lessons learned from the case of Ms. Dawson. *Science Education*, *101*(1), 134-164.

Brown, N.J.S., Furtak, E.M., Timms, M., Nagashima, S.O., Wilson, M. (2010). The evidence-based reasoning framework: Assessing scientific reasoning. *Educational Assessment*, *15*(3) 123-141. doi:10.1080/10627197.2010.5305.

Bulgren, J.A., Ellis, J.D., & Marquis, J.G. (2014). The use and effectiveness of an argumentation and evaluation intervention in science class. *Journal of Science Education and Technology*, *23*(2), 82-97.

Bureau of Labor and Statistics. (2014). STEM 101 intro to tomorrow's jobs. Retrieved from https://www.bls.gov/careeroutlook/2014/spring/art01.pdf.

Burris, C.C. (2010). Detracking for success. *Principal Leadership*, *10*(5), 30-34.

Burris, C. C. (2014). *On the same track: how schools can join the twenty-first-century struggle against resegregation*. Boston: MA. Beacon Press.

Burris, C. C., & Garrity, D. T. (2008). *Detracking for excellence and equity*. Alexandria, VA: Association for Supervision and Curriculum Development.

Bybee, R. (2002). *Learning science and the science of learning science educators' essay collection*. Arlington, VA: NSTA Press.

Bybee, R. (2010). *A new challenge for science education leaders: Developing 21st century workforce skills. In Science education leadership: Best practices for a new century, ed. J*. Rhoton, Arlington, VA: NSTA Press, 33-49.

Bybee, R. (2011). Scientific engineering practices in K-12 classrooms: Understanding a framework for K-12 science education. *Science & Children*, *49*(4), 10-16.

Calhoun, E.F. (2002). Action research for school. *Educational Leadership*, *59*(6) 18-24.

Cannella, G. (2010). *Critical theory research*. In C. Kridel (Ed.), Encyclopedia of curriculum studies. (pp. 158-162). Thousand Oaks, CA: SAGE Publications, Inc. doi:http://dx.doi.org/10.4135/9781412958806.n94.

Capobianco, B.M. & Feldman, A. (2006). Promoting quality for teacher action research: Lessons from science teachers' action research. *Educational Action Research*, *14*(4), 497-512.

Carbo, P.A., Ahumada, M.A.V., Caballero, A.D., & Arguelles, G.A.L. (2016). How do I do discourse analysis? Teaching discourse analysis to novice researchers through a study of intimate partner gender violence among migrant women. *Qualitative Social Work, 15*(3), 363-379.

Cavagnetto, A.R. (2010). Argument to foster scientific literacy: A review of argument interventions in K-12 science contexts. *Review of Educational Research*, *80*(3), 336–371.

Charmaz, K. (2006). *Constructing grounded theory: A practical guide to through qualitative analysis*. Thousand Oaks, CA: Sage Publications.

Cheuk, T. (2015). *Commonalities among the practices in science, mathematics, and English language arts* [pdf document]. Retrieved from: http://nstahosted.org/pdfs/ngss/PracticesVennDiagram.pdf.

Clarke, L.W. (2006). Power through voicing others: Girls' positioning of boys in literature circle discussions. *Journal of Literacy Research, 38*(1), 53-79.

Cohen, E.G., & Lotan, R. A. (1995). Producing equal-status interaction in the heterogeneous classroom. *American Educational Research Journal*, *32*(1), 99-120.

Cohen, E.G., & Lotan, R. A. (2014). *Designing groupwork: Strategies for the heterogeneous classroom*. New York, NY: Teachers College Press.

Cole, M., John-Steiner, V., Scribner, S., & Souberman, E. (1978). *Mind in society: The development of higher psychological processes*. Cambridge, MA: Harvard University Press.

Coleman, E. (2014). *Science youth action research: Promoting critical science literacy through relevance and agency* (Doctoral dissertation). Retrieved from Loyola University eCommons. (https://ecommons.luc.edu/luc_diss/892).

Coleman, E. & Leider, M. (2013). Personal and professional growth realized: A self-study of curriculum design and implementation in a secondary science classroom. *Studying Teacher Education*, *10*(1), 53-69.

College Board. (2014). Achieving Equity. Retrieved from http://professionals.collegeboard.com/k-12/assessment/ap/equity.

College Board. (2017). PSAT 8/9 Understanding Scores. Retrieved from https://collegereadiness.collegeboard.org/pdf/psat-8-9-understanding-scores-spring-2017.pdf.

Conley, D. (2003). Understanding university success. Retrieved from https://www.aau.edu/WorkArea/DownloadAsset.aspx?id=15280.

Corbin, J. M., & Strauss, J. M. (2007). *Basics of qualitative research: Techniques and procedures for developing grounded theory* (3rd ed.). Thousand Oaks, CA: Sage.

Crenshaw, K. (1995). *Critical race theory: The key writings that formed the movement*. New York: New Press: Distributed by W.W. Norton & Company.

Creswell, J. W. (2008). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research* (3rd ed.). Upper Saddle River, New Jersey: Pearson Education.

Creswell, J. W. (2014). *Research design: qualitative, quantitative, and mixed method approaches*. Thousand Oaks, CA: Sage Publications.

Culatta, R. (2011). *Innovative learning*. Retrieved from http://www.innovativelearning.com/educational_psychology/development/zone-of-proximal-development.html

Darling-Hammond, L. (2010). *The flat world and education: How America's commitment to equity will determine our future*. New York, NY: Teachers College Press.

Delgado, R., & Stefancic, J. (2001). *Critical race theory: An introduction (Critical America).* New York: New York University Press.

Denzin, N., & Lincoln, Y. (2005). *The SAGE handbook of qualitative research* (4th ed.). Thousand Oaks: Sage Publications.

Dimitriadis, G. (2010). Neo-Marxist research. In C. Kridel (Ed.), Encyclopedia of curriculum studies. (pp. 605-609). Thousand Oaks, CA: SAGE Publications, Inc. doi:http://dx.doi.org/10.4135/9781412958806.n326.

District 219 Niles Township. (2017). *Showing the Nation that Public Schools Work.* Retrieved from http://www.niles-hs.k12.il.us/wp-content/uploads/sites/1/2017/02/2015-2019-STRATEGIC-PLAN.pdf.

Driver, R., Newton, P. and Osborne, J. F. (2000). Establishing the norms of scientific argumentation in classrooms. *Science Education, 84*(3), 287–312.

Duflo, E., Dupas, P., & Kremer, M. (2009). Can tracking improve learning? *Education Next*, *9*(3), 64-70.

Duschl, R.A. (2007). Quality argumentation and epistemic criteria. In S.E. Eduran & M. P. Jimenez-Aleixandre (Eds.), *Argumentation in science education: Perspectives from classroom-based research* (159-175). New York, NY: Springer Publishing.

Duschl, R.A., & Osborne, J. (2002). Supporting and Promoting Argumentation Discourse in Science Education. *Studies in Science Education*, *38*(1), 39-72.

Engle, R.A., & Conant, F.R. (2002). Guiding principles for fostering productive disciplinary engagement: Explaining an emergent argument in a community of learners' classroom. *Cognition and Instruction, 20*(4), 399-483.

Ennis, R.H. (1989). Critical thinking and subject specificity: Clarification and needed research. *Educational Researcher, 18*(3), 4-10.

Erduran, S. (2007). Methodological Foundations in the study of argumentation in science classrooms. In S.E. Eduran & M. P. Jimenez-Aleixandre (Eds.), *Argumentation in science education: Perspectives from classroom-based research* (47-68). New York, NY: Springer Publishing.

Eduran, S., & Jimenez-Aleixandre, M.P. (2007). *Argumentation in science education: Perspectives from classroom based research*. New York: Springer.

Finn, C.E. (2002). *Thomas B. Fordham Foundation Five-Year Report*. Retrieved from http://www.edexcellencemedia.net/publications/2002/200205_tbfffiveyear/report.pdf.

Ferrell, E.W., Nance, C.N., Torres, A.L., & Torres, S.M. (2014). Using participatory action research to address absenteeism. *Action Learning: Research and Practice*, *11*(2), 201-214.

Freire, P. (2005). *Pedagogy of the oppressed*: *30th anniversary edition*. (M. B. Ramos, Trans.). New York, NY: The continuum International Publishing Group Inc.

Gee, J.P. (2010). *Introduction to discourse analysis: Theory and method*. New York, NY: Taylor & Francis Group.

Gee, J.P. (1989). Literacy, discourse, and linguistics: Introduction. *The Journal of Education, 171*(1), 5-176.

Gee, J.P., & Green, J.L. (1998). Discourse analysis, learning, and social practice: A methodological study. *Review of Research in Education, 23*, 119-169.

Glaser, B. & Strauss, A. (1995). *The discovery of grounded theory: Strategies for qualitative research*. New York, NY: Transaction Publishers.

Goodnough, K. (2010). Teacher learning and collaborative action research: Generating a "knowledge-of-practice" in the context of science education. *Journal of Science Teacher Education, 21*, 917-935.

Guba, E. G., & Lincoln, Y. S. (1994). Competing paradigms in qualitative research. In N. K. Denzin, & Y. S. Lincoln (Eds.), *Handbook of qualitative research* (pp.105-117). London, UK: Sage Publications.

Guyon, N., Maurin, E., & McNally, S. (2012). The effect of tracking students by ability into different schools: a natural experiment. *Journal of Human Resources*, *47*(3), 684–721. http://doi.org/10.1353/jhr.2012.002.

Hales, P.D. (2017). "Your writing, not my writing": Discourse analysis of student talk about writing. Retrieved from https://www.tandfonline.com/doi/pdf/10.1080/2331186X.2017.1416897.

Hall, S. (2001). *Foucault: Power, knowledge and discourse*. In M. Wetherell, S. Taylor, & S. J. Hallinan, M. T. (1994). Tracking: From theory to practice. *Sociology of Education*, *67*(2), 79. http://doi.org/10.2307/2112697.

Hallinan, M.T. (2004). The detracking movement. Retrieved from http://educationnext.org/the-detracking-movement.

Halpern, D. F. (1993). Assessing the effectiveness of critical thinking. *Journal of General Education, 42*(4), 238-254.

Hammersley, M. (2015, March 27). What is analytic induction? [Video file]. Retrieved from https://www.youtube.com/watch?v=fPJtmQNp6dA.

Heinke, A.J., Ryan, A.M., & Tocci, C. (2015). Teaching, learning, and leading: Preparing teachers as educational policy actors. *Journal of Teacher Education*, *66*(4), 382-394.

Hernandez, C.M., Morales A.R., & Shroyer, G.M. (2013). The development of a model of culturally responsive science and mathematics teaching. *Cultural Study of Science Education*, *8*, 803-820. doi: 10.1007/s11422-013-9544-1.

Herr, K., & Anderson, G.L. (2005). *The action research dissertation: A guide for students and faculty*. Thousand Oaks, CA: SAGE Publications.

Herrenkohl, L. R. (2006). Intellectual role taking: supporting discussion in heterogeneous elementary science classes. *Theory into Practice*, *45*(1), 47–54. http://doi.org/10.1207/s15430421tip4501_7.

Hoek, D.J. & Seegers, G. (2005). Effects of instruction on verbal interactions during collaborative problem solving. *Learning Environments Research*, *8,* 19-39.

Houseal, A., Gillis, V., Helmsing, M., & Hutchinson, L. (2016). Disciplinary literacy through the lens of the Next Generation Science Standards. *Journal of Adolescent & Adult Literacy*, *59*(4), 377-384.

Hsu, C., Chiu, C., Lin, C., & Wang, T. (2015). Enhancing skill in constructing scientific explanations using a structured argumentation scaffold in scientific inquiry. *Computers in Education*, *91*, 46-59.

Hyland, N. E. (2006). Detracking in the social studies: a path to a more democratic education? *Theory into Practice*, *45*(1), 64–71.

Illinois State Board of Education (2018). Illinois Report Card 2016-2017. Retrieved from http://webprod.isbe.net/ereportcard/publicsite/getReport.aspx?year=2017&code=050162900003_e.pdf.

Jardine, G. M. N. (2005). *Foucault education*. New York, NY: Peter Lang.

Jimenez-Aleixandre, M.P. (2007). Designing argumentation learning environments. In S.E. Eduran & M. P. Jimenez-Aleixandre (Eds.), *Argumentation in science education: Perspectives from classroom-based research* (91-112). New York, NY: Springer Publishing.

Kazdin, A.E. (2011). *Single-case research designs: Methods for clinical and applied settings*. New York, NY: Oxford University Press.

Kelly, G. J. (2007). Discourse in science classrooms. In N. Silverman & J. Tatusko (Eds.). *Handbook of Research on Science Education* (digital). Mahwah, NJ: Lawrence Erlbaum Associates, Inc., Publishers.

Kemmis, S. (2009). Action research as a practice-based practice. *Educational Action Research, 17*(3), 463-474.

Kemmis, S., & Wilkinson, M. (1998). Participatory action research and the study of practice. In B. Atweh, S. Kemmis, & P. Weeks (Eds.). *Action research in practice: Partnerships for social justice in education* (pp. 21-36). New York, NY: Routledge.

Kleibard, H. M. (1975). The rise of scientific curriculum-making and its aftermath. In D. J. Flinders & S. J. Thornton (Eds.), *The curriculum studies reader* (3rd ed.) (pp. 52-61). New York, NY: Routledge Taylor & Francis Group.

Klopfenstein, K. (2004). Advanced placement: do minorities have equal opportunity? *Economics of Education Review*, *23*(2), 115–131. http://doi.org/10.1016/s0272-7757 (03)00076-1.

Kozol, J. (1991). *Savage inequalities: Children in America's schools*. New York, NY: Crown Publications.

Kuhn, D. (1991). *The skills of argument*. New York, NY: Cambridge University Press.

Kuhn, D. (1999). A developmental model of critical thinking. *Educational Researcher, 28*(2), 16-48.

Kvale, S., & Brinkmann, S. (2009). *Interviews: Learning the craft of qualitative research interviewing* (2nd ed.). Thousand Oaks, CA: Sage Publications.

Ladson-Billings, G. (1995). But that's just good teaching! The case for culturally relevant pedagogy. *Theory into Practice*, *34*(3), 159-165.

Ladson-Billings, G., & Tate, W. (1995). Toward a critical race theory of education. *Teacher College Record*, *97*, 47-62.

Ladson-Billings, G. (1995). Toward a theory of culturally relevant pedagogy. *American Educational Research Journal, 32*(3), 465-491.

LaForce, M., Noble, E., King, H., Holt, S., & Century, J. (2014). *The 8 elements of inclusive STEM high schools.* Chicago, IL: Outlier Research & Evaluation, CEMSE I The University of Chicago.

Lake, K. (1994). *Integrated curriculum*. Retrieved from: http://educationnorthwest.org/sites/default/files/integrated-curriculum.pdf.

Lemke, J.L. (1990). *Talking science: Language learning and values*. Norwood, New Jersey: Ablex Publishing Corporation.

Lewin, K. (1946). Action research and minority problems. *Journal of Social Issues, 2*(4), 34-46.

Lewin, K. (1947). Frontiers in group dynamics: Concept, method, and reality in social science, social, equilibria and social change. *Human Relations, 1*(1), 5-41. doi: 10.1177/001872674700100103.

Lewis, A.E., & Diamond, J.B. (2015). *Despite the best intentions*. New York, NY: Oxford University Press.

Lincoln, Y.S., Lynham, S.A., & Guba, E.G. (2011). Paradigmatic controversies, contradictions, and emerging confluences revisited. In N.K. Denzin & Y.S.

Lipson, M., Valencia, S., Wixson, K., & Peters, C. (1993). Integration and thematic teaching: Integration to improve teaching and learning. *Language Arts*, *70*(4), 252-264.

Llewellyn, D. & van Zee, E. (2010). Action research: Expanding the role of the classroom teachers to inquirers and researchers. *Science Scope*, *7*, 10-15.

Macagno, F., & Konstantinidou, A. (2013). What students' arguments can tell us: Using argumentation schemes in science education. *Argumentation 27*(3), 225-243.

Merriam, S. B. & Tisdell, E.J. (2016). *Qualitative research: A guide to design and Implementation* (4th ed.). San Francisco, CA: Jossey-Bass.

McLeod, S. A. (2012). *Zone of proximal development*. Retrieved from www.simplypsychology.org/Zone-of-Proximal-Development.html.

McNeill, K. L. (2011). Elementary student's view of explanation, argumentation, and evidence, and their abilities to construct arguments over the school year. *Journal of Research in Science Teaching*, *48*(7), 793-823.

McNeill, K. L., Katsh-Singer, R., Gonzalez-Howard, M., & Loper, S. (2016). Factors impacting teachers' argumentation instruction in their science classrooms. *International Journal of Education*, *38*(12), 2026-2046.

McNiff, J., & Whitehead, J. (2009). *Doing and writing action research*. Thousand Oaks, CA: SAGE Publications.

McVee, M. (2011). Positioning theory and sociocultural perspectives affordances for educational researchers. In M.B. McVee, C.H. Brock & J.A. Glazier (Eds.), *Sociocultural positioning in literacy: Exploring culture, discourse, narrative, and power in diverse educational contexts* (pp. 1-22). Hampton Press.

Michelson, J. (2019). *Making the case: Transforming teacher professional learning*. University of Washington, Center for Educational Leadership: Author.

Moon, S. (2012). Disciplinary images of "Korean-Ness": Autobiographical interrogations on the panopticon. SAGE Open, *2*(3). http://doi.org/10.1177/2158244012455649.

National Center for Education Statistics. (2016). *Projections of Education Statistics 2023*. Retrieved from https://nces.ed.gov/pubs2015/2015073.pdf.

National Research Council. (2007). *Taking science to school: Learning and teaching in grades K-8*. Washington, DC: The National Academies Press.

National Research Council. (2012). *A Framework for K-12 science education: practices, crosscutting concepts, and core ideas*. Washington, DC: The National Academies Press.

National Science Teachers Association. (2010). *Quality science education and 21st -century skills*. Retrieved from: http://www.nsta.org/about/positions/21stcentury.aspx.

National Science Teachers Association. (2014). *Matrix of science and engineering practices*. Retrieved from: http://static.nsta.org/ngss/MatrixOfScienceAndEngineeringPractices.pdf.

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By State*s. Washington, DC: The National Academies Press.

NGSS Lead States. (2013). *Next Generation Science Standards: For States, By States. Appendix F: Science and engineering practices in the NGSS*. Retrieved from: https://www.nextgenscience.org/sites/default/files/Appendix%20F%20%20Scienc S%20and%20Engineering%20Practices%20in%20the%20NGSS%20-%20FINAL%20060513.pdf.

Noguera, P. A., & Wing, J. Y. (Eds.). (2006). *Unfinished business: Closing the racial achievement gap in our schools.* San Francisco, CA: Jossey-Bass A Wiley Imprint.

Nuffield Foundation (2012). *Science and society: Teaching and learning*. Retrieved from http://www.nuffieldfoundation.org/science-society.

Nuffield Foundation (2016). *Argumentation quick start guide*. Retrieved from http://www.nuffieldfoundation.org/practical-work-learning/argumentation-quick-start-guide.

Oakes, J. (2005). *Keeping track: How schools structure inequality (2nd ed.)*. New Haven, CT: Yale University Press.

Oakes, J. (2008). Keeping track: Structuring equality and inequality in an era of accountability. *Teachers College Record*, *110*(3), 700-712.

Oakes, J., Ormseth, T., Bell, R., & Camp, P. (1990). *Multiplying inequalities, the effects of race, social class, and tracking on opportunities to learn mathematics and science.* Retrieved from http://www.rand.org/content/dam/rand/pubs/reports/2006/R3928.pdf.

Osborne, J. (2010). Arguing to learn in science: The role of collaborative, critical discourse. *American Association for the Advancement of Science*, *328*(5977), 463-466.

Osborne, J., Erduran, S., & Simon, S. (2004). *Ideas, Evidence and Argument in Science* (IDEAS) In-service Training Pack, Resource Pack and Video. London: Nuffield Foundation.

Osborne, J. F. and Patterson, A. (2011). Scientific argument and explanation: A necessary distinction? *Science Education, 95*(4), 627–638.

Paik, S., & Shim, W. J. (2013). Tracking and college major choices in academic high schools in South Korea. *The Asia-Pacific Education Researcher Asia-Pacific Edu Res*, *22*(4), 721–730. http://doi.org/10.1007/s40299-013-0079-8.

Patton, M. (2015). *Qualitative research & evaluation methods: Integrating theory and practice* (4th Ed.). Thousand Oaks, CA: Sage. Chapter 5, pp. 244-346.

PBS. Retrieved October 25, 2015, from http://www.pbs.org/wnet/jimcrow/stories_people_booker.html

Pickens, M., & Eick, C. J. (2009). Studying motivational strategies used by two teachers in differently tracked science courses. *The Journal of Educational Research*, *102*(5), 349–362. http://doi.org/10.3200/joer.102.5.349-362

Picower, B. & Mayorga, E. (2015). *What's race got to do with it?* New York, NY: Peter Lang Publishing.

Pinar, W. (2008). Curriculum theory since 1950: Crisis, reconceptualization, internationalization. In F.M. Connelly, M. F. He, & J. Phillion (Eds.), *The SAGE handbook of curriculum and instruction* (pp. 491-513). Thousand Oaks, CA: SAGE Publications.

Pine, G. J. (2009) *Teacher action research: Building knowledge democracies.* Thousand Oaks, CA: Sage Publications.

Price, P.G. (2016). *Critical race theory*. Retrieved from: http://education.oxfordre.com/view/10.1093/acrefore/9780190264093.001.0001/acrefore-9780190264093-e-1?print=pdf.

Quaglia, R.J., & Corso, M.J. (2014). *Student voice: The instrument of change*. Thousand Oaks, CA: Corwin SAGE Publications.

Reason, P. (2006). Choice and quality in action research practice. *Journal of Management Inquiry, 15*(2), 187-203. doi: 10.1177/1056492606288074

Rehg, W., & McCarthy, T. (2008). *Cogent sicne in context: The science wars, argumentation theory, and Habermas*. Cambridge, MA: The MIT Press.

Rollock, N., & Gillborn, D. (2011). *Critical Race Theory (CRT), British Educational Research Association online resource*. Retrieved from: https://www.bera.ac.uk/wp-content/uploads/2014/03/Critical-Race-Theory-CRT-.pdf?noredirect=1.

Rodriguez, A.J. (2015). What about a dimension of engagement, equity, and diversity practices? A critique of the Next Generation Science Standards. *Journal of Research in Science Teaching*, *52*(7), 1031-1051.

Rubin, B. C. (2006). Tracking and detracking: debates, evidence, and best practices for a heterogeneous world. *Theory into Practice, 45*(1), 4-14. doi:10.1207/s15430421tip4501_2.

Rubin, B. C., & Noguera, P. A. (2004). Tracking detracking: Sorting through the dilemmas and possibilities of detracking in practice. *Equity & Excellence in Education, 37*(1), 92-101. doi:10.1080/10665680490.

Sampson, V. & Clark, D.B. (2008). Assessment of the ways students generate arguments in science education: Current perspectives and recommendations for future directions. *Science Education*, *92*, 447-472.

Sampson, V. & Schleigh, S. (2012). *Scientific argumentation in biology: 30 classroom activities*. Virginia: National Science Teachers Association.

Sandoval, W. A. (2003). Conceptual and epistemic aspects of students' scientific explanations. *Journal of the Learning Sciences*, *12*(1), 5-51.

Sandoval, W. A., & Millwood, K. (2005). The quality of students' use of evidence in written scientific explanations. *Cognition and Instruction*, *23*(1), 23-55.

Schneider, R.M. & Plasman, K. (2011). Science teacher learning progressions: A review of science teachers' pedagogical content knowledge development. *Review of Educational Research*, *81*(4), 530-565.

Schwandt, T. A. (2007). *The Sage dictionary of qualitative inquiry* (3rd ed.). Thousand Oaks, CA: Sage Publications.

Schön, D. A. (1983). *The reflective practitioner: How professionals think in action*. New York, NY: Basic Books.

School Superintendents Association. (2016). *National college and careers readiness indicators*. Retrieved from http://www.redefiningready.org

Seiler, G. (2001). Reconstructing science curricula through student voice and choice. *Education and Urban Society*, *45*(3), 362-384.

Shemwell, J.T., & Furtak, E.M. (2010). Science classroom discussion as scientific argumentation: A study of conceptually rich (and poor) student talk. *Educational Assessment*, *15*(3-4), 222-250.

Simon, S., Erduran, S., & Osborne, J. (2006). Learning to teach argumentation: Research and development in the science classroom. *International Journal of Science Education, 28*(2), 235-260.

Smetana, L.K., & Bell R.L. (2014). Which setting to choose: Comparison of whole-class vs. small-group computer simulation use. *Journal of Science Education and Technology, 23*(4), 481-495.

Smetana, L.K., Wenner, J., Settlage, J., & McCoach, D.B. (2016). Clarifying and capturing "trust" in relation to science education: Dimensions of trustworthiness within schools and associations with equitable student achievement. *Science Education*, *100*(1), 78-95.

Solorzano, D. G., & Ornelas, A. (2004). A critical race analysis of latina/o and African American Advanced Placement enrollment in public high schools. *The High School Journal*, *87*(3), 15–26. http://doi.org/10.1353/hsj.2004.0003.

Strauss, J.M., & Corbin, J.M. (1990). *Basics of qualitative research: Grounded theory procedures and techniques*. Newbury Park, CA: Sage.

Stringer, E. T. (2014). *Action research* (4th ed.). Thousand Oaks, CA: Sage Publications.

Student Voice. (n.d.). In *Glossary of Education Reform online.* Retrieved from https://www.edglossary.org/student-voice.

The Equity Project at American Institutes for Research. (2015). *Opening the doors to opportunity for all: Setting a research agenda for the future*. Washington, DC: Mehan.

Thompson, J., Braaten, M., Windschitl, M., Sjoberg, B., Jones, M., & Martinez, K. (2009). Examining student work. *The Science Teacher, 76*(8), 48-52.

Thompson, J., Braaten, M., Windschitl, M. (2014). *Collaborative inquiry into students' evidence-based explanations: How groups of science teachers can improve teaching and learning.* Retrieved from: http://tedd.org/wpcontent/uploads/2014/03/APEX-Collaborative-Inquiry.pdf.

Toulmin, S.E. (1958). *The uses of argument* (updated edition). Cambridge, UK: Cambridge University Press.

Trauth-Nare, A. & Buck, G. (2011). Using reflective practice to incorporate formative assessment in a middle school science classroom: A participatory action research study. *Educational Action Research*, *19*(3), 379-398.

van Eemeren, F.H. (2017). The pragma-dialectical theory under discussion. *Argumentation, 26*(4), 439-457.

van Eemeren, F.H. (2017). Argumentation theory and argumentative practices: A vital but complex relationship. *Informal Logic, 37*(4), 322-350.

Vandenberge, V. (2006). Achievement effectiveness and equity: the role of tracking, grade repetition, and inter-school segregation. *Applied Economics Letters*, *13*, 685-693.

Van Tassel-Baska, J., & Brown, E.F. (2007). Toward best practice: An analysis of the efficacy of curriculum models in gifted education. *Gifted Child Quarterly*, *51*(4), 342-358.

Venville, G. J., & Dawson, V. M. (2010). The impact of a classroom intervention on grade 10 students' argumentation skills, informal reasoning, and conceptual understanding of science. *Journal of Research in Science Teaching, 47*(8), 952-977.

Vygotsky, L.S. (1978). Mind in society: *The development of higher psychological processes* (M. Cole, V. John-Steiner, S. Scribner & E. Souberman, Eds.) Cambridge, MA: Harvard University Press.

Wallace, T., & Brand, B. R. (2012). Using critical race theory to analyze science teachers culturally responsive practices. *Cult Stud of Sci Educ Cultural Studies of Science Education, 7*(2), 341–374. http://doi.org/10.1007/s11422-012-9380-8.

Watanabe, M. (2006). “Some people think this school is tracked and some people don't": Using inquiry groups to unpack teachers' perspectives on detracking. *Theory into Practice*, *45*(1), 24-31. doi:10.1207/s15430421tip4501_4.

Watanabe, M., Nunes, N., Mebane, S., Scalise, K., & Claesgens, J. (2007). “Chemistry for all, instead of chemistry just for the elite”: lessons learned from detracked chemistry classrooms. *Sci. Ed. Science Education*, *91*(5), 683–709. http://doi.org/10.1002/sce.20213

Wilcox, K. C. (2014). An urban secondary school case study of disciplinary writing in tracked classrooms. *Education and Urban Society*, *47*(2), 242-268. http://doi.org/10.1177/0013124514549831.

Wertsch, J.V. (1991). *Voices of the mind: a sociocultural approach to mediated action*. Cambridge, MA: Harvard University Press.

Windschitl, M. (2009). *Proceedings from Workshop on 21st Century Skills: Cultivating 21st century skills in science learners: How systems of teacher preparation and professional development will have to evolve*. National Academies of Sciences.

Windschitl, M., Thompson, J., Braaten, M., & Stroupe, D. (2012). Proposing a core set of instructional practices and tools for teachers of science. *Science Education*, *96*(5), 878-903. doi: 10.1002/sce.21027.

Windschitl, M., Thompson, J., & Braaten, M. (2018). *Ambitious science teaching*. Cambridge, MA: Harvard Education Press.

Yakushko, O., Badiee, M., Mallory, A., & Wang, S. (2011). Insider outsider: Reflections on working with one's own communities. *Women & Therapy, 34*(3), 279-292. doi:10.1080/02703149.2011.580685.

Yerrick, R.K. & Gilbert, A. (2011). Constraining the discourse community: How science discourse perpetuates marginalization of underrepresented students. *Journal of multicultural discourses, 6*(10), 67-91.

Yin, R. K. (2014). *Case study research: Design and methods* (5th ed.). Thousand Oaks, CA: Sage Publications.

Yosso (2005). Whose culture has capital? A critical race theory discussion of community cultural wealth. *Race, Ethnicity, and Education, 8*(1), 69-91. doi: 10.1080/1361332052000341006.

Zohar, A., & Nemet, F. (2002). Fostering students' knowledge and argumentation skills through dilemmas in human genetics. *Journal of Research in Science Teaching*, *39*(1), 35-46.

VITA

Ami LeFevre was born in Chicago, Illinois to Martin John Foley and Kikue Motoi. Ami grew up on the north side of the city and attended Chicago Public Schools: Volta Elementary School and Von Steuben Metropolitan Science Center. Her family, particularly her father, impressed the importance of education upon Ami.

Once Ami graduated from Von Steuben, she attended Eckerd College, a small liberal arts college in Florida, to play volleyball and major in marine biology. The experience away from home was fulfilling, but the standards of academics was lacking. Ami moved on to North Park College in Chicago, Illinois and graduated in 1991. She completed her Bachelor of Science degree in Biology and Chemistry. By the end of her undergraduate years, she realized the joy of teaching and earned her Illinois Type 09 secondary education certificate in Biology and Chemistry. Ami spent her first year of teaching at Gordon Technical High School in the city of Chicago. In addition to teaching Biology at the all-boys Catholic school, she attended DePaul University. In 1994, Ami earned a Master's degree in Education and the Illinois Type 10 Learning Disability and Behavioral Disability certification. Ami continued to earn graduate credit through various professional programs and became a National Board Certified Teacher in 2006. Ami decided to return to North Park University to become certified as an administrator. She completed the leadership program and earned an Illinois Type 75 Administrator license.

Ami has worked in the field of science education for 28 years. She taught different levels of Biology and Chemistry at a suburban high school of Chicago. Over the past five years, Ami has taken on an administrator role as the Director of Science. She lives in a suburb outside of Chicago with her loving husband and two sons she absolutely adores.

DISSERTATION COMMITTEE

The Dissertation submitted by Ami LeFevre has been read and approved by the following committee:

Dr. Lara Smetana
Associate Professor, School of Education
Loyola University Chicago

Dr. Leanne Kallemeyn
Associate Professor, School of Education
Loyola University Chicago

Dr. Elizabeth Ferrell
Adjunct Professor, School of Education
Loyola University Chicago