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Measuring the Effect of Argument-Driven Inquiry on High School Chemistry Students' Process-Oriented Motivation Utilizing the Newly Developed Process-Oriented Motivation Instrument

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Measuring the Effect of Argument-Driven Inquiry on High School Chemistry Students' Process-Oriented Motivation Utilizing the Newly Developed Process-Oriented Motivation Instrument

A Dissertation

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Faculty of Kennesaw State University
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in partial fulfillment of
the necessary requirements for the degree of
Doctor of Education
Department of Secondary and Middle Grades

By

Martel Wisdom
Kennesaw State University
2020

DEDICATION

The Process-Oriented Motivation Instrument is dedicated to every educator that is passionate about motivating students. This instrument will fill a void in the science and the education community at large.

I dedicate this dissertation to my family: Jenel, Morgan, and Taylor. Day by day I was inspired by your presence to complete this task. Jenel's persistence, patience, empathy, care, and love was the driving force behind this dissertation. To my children, you can accomplish anything in this world that your heart desires.

To my parents, I want to dedicate this project to you and your belief in me that endured the test of time. An infallible work ethic built the foundation to my discipline and this is a result of your persistence and faithfulness to God.

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Quality of life is based on the moments that take our breath away. Truly, this four-year journey has left me speechless. Dr. Michelle Head was truly my rock during every step of this process, I could not have chosen a better chair to manifest this idea. You encouraged me, inspired, challenged, and corrected me all in the same empathic tone of voice. I want to thank Dr. Kimberly Cortes who stayed on the phone for me for an hour to ensure that I was at peace with starting this program. Dr. Cortes you truly have a passion and drive that inspired me each day that I wanted to quit. Lastly, Dr. Jihye Kim you are truly blessed with the ability to successfully streamline advanced quantitative statistics to each student's finite mind. Most analysis methods were inspired by your class and the care you placed in teaching that empowered and equipped me to success. Dr. Head I truly now understand the Science and Engineering Practices due to your course. Finally, Dr. Cortes, visual literacy and the assessment course transformed my perspective on how to make, modify, improve my assessments. This paper started with a purpose, motivate student, but culminated into an instrument: Process-Oriented Motivation Instrument. Kenn Barron, you were monumental in the creation of the instrument and added necessary and quality value to it.

My wife, Jenel, you are truly special, and I thank God for you every day. You stood by my side and encouraged me each step of the way. The greatest reward in my life will always begin and end with you. Jenel, thank you for your prayers, support, and patience I could not have done this without you. In the end, local Starbucks, Panera Bread, library were my thinking grounds to my imagination to help shape each chapter of this study.

Lastly, I thank God for his grace that empowers me daily through my weakness to find strength in him and not myself (Philippians 2:13).

ABSTRACT

This study uncovers how secondary high school chemistry process-oriented motivation is altered after implementation of Argument-Driven Inquiry (ADI). ADI is a laboratory instructional model that utilizes four Science and Engineering Practices (SEPs) in a student-centered lab experience. The SEPs are embedded to the current curriculum to help motivate students to learn chemistry (NRC, 2012). This study utilized eleven total chemistry classes, five on-level chemistry and six honors chemistry, with a total of 243 students participating in some facet of the study. Data sources included were View About Scientific Inquiry (VASI), the newly developed Process-Oriented Motivation Instrument (POMI), and student lab reports (achievement). Two goals were necessary to examine student-process-oriented motivation for the control and experimental group. Based on current science education literature, a valid and reliable POMI does not currently exist. Thus, Goal 1 purpose was to create an instrument, POMI, while generating valid and reliable data. A Confirmatory Factor Analysis along with other forms of validity and reliability were completed to find the most valid and reliable model, the revised POMI model. Thus, Goal 2 utilized this revised POMI model to find the effect ADI had on student-process oriented motivation for both groups. The control group, honors chemistry students, utilized a traditional lab. However, the experimental group, on-level chemistry students, participated in the ADI lab to determine if the type of lab implementation caused a significant difference in process-oriented motivation among the groups. Normalized gain scores were used to compare if there was significant difference between the control and experimental groups. Finally, mediation path analysis discovered if process-oriented motivation factors influence how the experimental group or control performed on their lab report. Two conclusions were drawn as a result of Goal 2: (1) after ADI implementation both groups experienced statistically similar changes in each POMI motivation factor and (2) no POMI factor possessed a significant influence on the lab report scores of either group.

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CHAPTER 1: INTRODUCTION

Statement of Problem

"Successful and unsuccessful people do not vary greatly in their abilities. They vary in their desires to reach their potential" - John Maxwell.

Motivation can be defined with various quotes or definitions, while it can be defined as a drive toward a task or job that culminates in a desired outcome or result. According to Carver and Scheier (1998), motivation is a result of psychological forces that enable action. Ryan and Deci (2000) reported that motivated students demonstrated higher achievement, improved comprehension of concepts taught, increased satisfaction in school, and lower dropout rates. Yet, the National Research Council found that more than 40 percent of high school students are characterized as disengaged or unmotivated during school (National Research Council [NRC], 2003). Despite many forms of change within standards, curriculum, testing, and professional development that persist to increase student achievement, motivation is often overlooked as a prime factor to student success. Referencing the two previous studies, efforts to improve student performance in science should focus on enhancing high school students' motivation toward learning science (NRC, 2003; 2012). The student inequality pertaining to motivation that exists in education has been a point of emphasis for the newly implemented framework for science education. The *Framework for K-12 Science Education* prime focus was to prep students for science careers with implementation of scientific practices into grade school curriculum. The vehicle to achieve this primary focus was the Science and Engineering Practices (SEPs). SEPs enable students to perform science by utilizing skills and knowledge that mimic the investigative methods employed by scientists and engineers (NRC, 2012). There are eight SEPs that were deemed essential for students to engage in scientific investigation, which were expected to pique students' curiosity, interest, and motivate them to learn science (NRC, 2012). The following current motivation instruments Intrinsic Motivation Inventory (IMI), Motivation Strategies Learning Questionnaire (MSLQ), Students' Motivation toward Science Learning (SMTSL), SMQ, and SMQ-II (Deci & Ryan, 2007; Glynn, 2009; Glynn, 2011; Pintrich, 2000; Tuan & Chin, 2005) do not measure motivation in terms of this new science curriculum. The relationship between student motivation and performance has been discussed, raising the question: can strategies aligned with the *Framework for K-12 Science Education* effectively motivate students toward learning science? The requirement to motivate students utilizing a reform that empowers such motivation has been established; however, an effective motivation instrument is necessary to measure any impact from implemented strategies derived from the new science curriculum framework.

According to Bandura and Schunk (2001), five motivation factors have been deemed important to students' motivation to learn: intrinsic motivation, extrinsic motivation, goal orientation, task value, and self-determination with assessment anxiety (Bandura, 2001; Schunk, 2001). According to Roth (2013), intrinsic and extrinsic motivation are both effective chemistry motivation measures. Extrinsic and intrinsic are the most used forms of motivation in science education literature, therefore it was necessary to sustain this trend with a novel instrument (Roth, 2013; Sen & Erdogan, 2016; Yilmaz & Geban, 2015). Two goals exist for this study: provide an instrument that effectively measures student motivation towards the SEPs and application of that instrument to assess change in process-oriented motivation due to implementation of new science curriculum strategies. The development of a new instrument described herein will utilize two former factors in valid and reliable motivation instruments: intrinsic motivation and extrinsic motivation. Intrinsic motivation pertains to internal desires when performing a specific task, while extrinsic motivation refers to performing a specific task to receive an external reward (Ryan &

Deci, 2000). Intrinsically motivated students that have learning goals tend to truly understand and master science skills and content (Bandura, 2001; Schunk, 2001). Extrinsically motivated students with performance goals seek to impress people other than themselves by earning high grades (Bandura, 2001; Schunk, 2001). The main difference with the newest curriculum and the previous one is the emphasis on the newly created SEPs. SEPs are intertwined in every single standard in the newly created curriculum to ensure that students are learning science content using the approaches used by scientists and engineers (NRC, 2012). These two specific factors were chosen to measure student motivation pertaining to the implementation of a new science curriculum designed to achieve the elements of the *Framework for K-12 Science Education* (NRC, 2012).

While conducting a literature review on motivation, only 21 articles were founded that related to high school motivation in science. The literature includes studies from the three main secondary subjects: chemistry, physics, and biology. Three prevailing issues are present in current science education literature. First, goals are not clearly defined in current science motivation instruments. A goal must have a definitive beginning and end state (Touré-Tillery & Fishbach, 2014). However, current surveys utilized to measure student's motivation toward science usually have science as the subject of each item. Unfortunately, science appears indefinite and thus requires a specific beginning and end. Therefore, the subject of science can be exchanged with chemistry to remedy this issue. Simply substituting science with chemistry, ensures that there is an intentional goal and finite time period for each item in this instrument. All participants do not have previous chemistry experience, which limits their exposure to chemistry concepts mostly to what they have learned this school year.

Secondly, intrinsic motivation and extrinsic motivation need a third main factor to differentiate students that simply enjoy participating in specific science tasks. Current instruments categorized students into two main pots of motivation, inherent general interest in a task or importance of receiving a reward at the end of the task. For example, an intrinsic motivated student would enjoy science class irrespective of the grade they receive in that course. In contrast, an extrinsic motivated student would appreciate receiving an A in their science class more than attending that class daily. This third factor would be described as students' motivation by a certain science task. It is imperative that teachers can pinpoint specific science tasks students enjoy, which would enable teachers to utilize these tasks more frequently in their classroom. This same student that was intrinsically motivated to attend science class may be most motivated by science lab experiments. A third factor would have items that pinpoint the science task that best motivates this student, identifying the source of the student's motivation.

Thirdly, current motivation instruments are not aligned with the existing science curriculum that have been recently implemented based on the *Framework for K-12 Science Education.* This factor provides an avenue to utilize items by embedding each of the eight SEPs to directly determine which process of learning science motivates students. For example, planning and carrying out an investigation is a SEP to effectively learn science. An item in this third factor would resemble, "I enjoy completing experiments in this chemistry class since they allow me to investigate different problems with my classmates". A student that is motivated by completing experiments would agree with the item. However, a student that is not motivated by experiments may be motivated by another SEP like construction of an explanation. Current instruments lack any reference to the SEPs. This is an essential requirement for the novel third factor. Within current motivation instruments, science is not spoken of as a process, but as a fixed measure. After the *Framework for K-12 Science Education* was created, each state either adopted the Next Generation of Science Standards or altered their own standards based on the framework. The state of the researcher’s locale, Georgia, adapted its own standards by taking the preexisting Georgia Performance Standards and embedding the eight SEPs. The following example was the result of the Science Georgia Standards of Excellence (GSE): “Develop and use models, including electron configuration of atoms and ions, to predict the element’s chemical properties” (NRC, 2012). Georgia Performance Standards (GPS), previous standards, equivalent was “Use the orbital configuration of neutrals atoms to explain its effect on the atom’s chemical properties (NRC, 2003). The new standard differs as it begins with an SEP and connects the practice with the concept to promote student learning. Strategies that utilize the SEPs to achieve student mastery are aligned with the GSE and the novel instrument can measure that strategy’s capability of motivating students toward science.

Argument Driven Inquiry (ADI), lab-based instructional model, is an example of a classroom instruction that utilizes strategies that incorporate four out of the eight SEPs. The education community needs an instrument to determine how implementation of various strategies that are in alignment with the *Framework for K-12 Science Education* (i.e. ADI) affect student motivation. The NRC created a new framework as the guide for the nation’s new science standards. The SEPs are practices that describe how scientists investigate and how engineers design and build models (NRC, 2012). The SEPs that are discussed in the *Framework for K-12 Science Education* are theoretical means to effectively learn science knowledge (NRC, 2012). The original Process-Oriented Motivation Instrument (POMI) would enable teachers to directly measure student motivation toward the SEPs. Therefore, results from such an instrument could identify any student growth in process-oriented motivation due to implementation of various strategies. Currently, an instrument does not exist that exhibits these characteristics. The original POMI is ground-breaking in that it serves as a vehicle to measure how the SEPs influence students’ motivation to learn science. This study has paired a chemistry lab strategy that utilizes the SEPs to evaluate how student motivation may or may not predict student chemistry achievement (Tuan & Chin, 2005).

Purpose and Significance of the Study

The main purpose of this study is to create an instrument that can be effective in measuring motivation based on the *Framework for K-12 Science Education* and newly developed Georgia Standards of Excellence in Science (GSE-Sci). Three significant gaps are revealed in science education literature amongst current motivation instruments: ambiguous goals, lack of a third main factor that assesses student motivation pertaining to specific science tasks, and consideration of scientific processes via SEP implementation into this third main factor. Furthermore, intrinsic and extrinsic motivation has been measured with current instruments but disregards the process of goal pursuit.

Due to the science education literature gaps and the science education community's need for a resolution, a novel instrument can suffice as a necessary answer. This study will compare students' level of motivation when engaged in Argument-Driven Inquiry (ADI), a teaching pedagogy that engages students in the SEP's, compared to a group of students who engage in a traditional experiment after creating their own lab procedure. Growth in motivation for both groups will be collected and analyzed. As mentioned above, the *Framework for K-12 Science Education* was written to motivate students to learn science; however, no current literature has probed emerging teaching pedagogies as they relate to their effect on students' motivation toward science. The results from student motivation growth in this study will inform how effective ADI is towards motivating students in chemistry. Nevertheless, this study will be groundbreaking in that it will be the first study to challenge the *Framework for K-12 Science Education*; specifically, does the current framework create strategies that motivate students in science? While this study will not answer this question with certainty, it will begin this essential discussion amongst the science education community.

Students are the direct recipients and are most responsible for their achievement. However, teachers are the direct influencers of the what, the how, and the when of student learning. Administrators are managers of their teachers to ensure they are effectively disseminating information in a manner that culminates in student achievement. County officials ensure that administrators are good stewards of their teachers. Finally, the community of a local school is indirectly correlated to all these relationships. If all parties are ineffective, then schools scores and ratings may be affected. This could impact the local community property value. However, the opposite can also be true. While this chain of events may seem drastic, it is conceivable. Therefore, assessing students' motivation and appropriately addressing motivation issues can have a widespread effect. The original POMI taps into the root of the problem and attempts to water such roots with solutions. These solutions include finding teaching strategies and other strategies that motivate students. Although this study will be the genesis for process-oriented motivation, its goal is to give rise to new studies that measure process-oriented motivation. New studies can form a new sector of literature on process-oriented motivation and will provide the science education community with strategies that are literature-supported to be effective at motivating students toward learning science.

Research Questions

Before discussing the research questions, it is first imperative to address the three issues that this study is investigating. First, original POMI student responses must demonstrate appropriate validity and reliability before it can be administered in any study. The types of validity that will be examined are construct, content, convergent, and predictive validity. Content validity will ensure that subject matter on the original POMI is indeed appropriate to measure each type of motivation being investigated. Construct validity includes a Confirmatory Factor Analysis (CFA), which will utilize a Structural Equation Model (SEM). Each model has a correlation conducted between factors and their respective items to remove items that poorly correlate, which may culminate in poor goodness-of-fit statistics for a model. Convergent validity, a form of discriminant validity, will compare original POMI scores and Views About Scientific Inquiry (VASI) instrument scores to investigate the relationship between the factors in both instruments. Such an analysis will be performed via a Pearson or Spearman correlation test. The VASI is a survey that assesses the learner's understandings about essential scientific inquiry aspects (Lederman, 2014). Scientific inquiry is a combination of science processing skills utilized with traditional science content along with critical thinking to help develop student's scientific knowledge (Lederman, 2014). The VASI instrument and means-focused motivation factors have certain commonalities and the same purpose: motivation derived from science skills or practice comprehension. Finally, predictive validity will attempt to use a Pearson or Spearman correlation to examine the relationship between student achievement and process-oriented motivation (Tuan & Chin, 2005). Two forms of reliability will be conducted to establish instrument reliability: Cronbach alpha per each factor of the instrument and Cronbach alpha for all items of the instrument. Cronbach alpha factor executes a correlation between items and their respective factors: outcome-focused motivation, intrinsic motivation, and means-focused motivation. The Cronbach alpha for all items will collectively ensure that all items represent process-oriented motivation. In the end, instrument reliability is implemented to determine any sources of measurement error that may negatively affect instrument scores.

Secondly, the goal of this study is to establish valid and reliable data for a novel instrument that can effectively measure student motivation before and after the implementation of the *Framework for K-12 Science Education* aligned teaching pedagogy. This research study will utilize Argument-Driven Inquiry (ADI), a teaching strategy that has been developed to engage students in the SEPs. The overall goal will be to determine if differing teaching pedagogies affects student motivation: traditional labs (the control) versus ADI lab (the experimental group). Data will be collected and analyzed to determine if ADI accounts for a significant effect on student's process-oriented motivation. The second part of Goal 2 uses a mediation path analysis to determine whether process-oriented motivation provides a path or influences the relationship between ADI and student achievement. Any correlation found between these three variables will have vast implications. Additionally, this study will illustrate an understanding of the effect caused by ADI on student achievement. This would provide predictive validity in that if strategies like ADI are utilized; then students should perform better in chemistry and possibly other sciences. Furthermore, if process-oriented motivation effects the experimental group's student achievement, such an effect will provide implications on how the *Framework for K-12 Science Education's* strategies can motivate students. The three research questions for this study that will address the two overarching goals described above are:

Goal 1 Research Questions:

1. How does the data from the Process-Oriented Motivation Instrument establish appropriate validity and reliability for high school chemistry students?
    a. What is the relationship between a student's Views about Scientific Inquiry and the degree to which they are motivated by scientific processes?

Goal 2 Research Questions:

2a. What is Argument-Driven Inquiry's effect on high school chemistry students' process-oriented motivation?

2b. What is the mediation effect of process-oriented motivation and relationship between argument-driven inquiry and student achievement?

Conceptual Framework

The *Framework for K-12 Science Education* is the conceptual framework behind process-oriented motivation. This framework is broken into three dimensions: scientific and engineering practices, crosscutting concepts, and core ideas in science disciplines (NRC, 2012). The purpose of the *Framework for K-12 Science Education* is to empower students to learn how to think like scientists, which is a feat that had been sought after by the National Science Foundation since 1956 when the Sputnik Launch occurred (DeBeor, 1991). According to NRC (2012), a goal of this framework was to give students time to deepen their understanding of SEP's. The *Framework for K-12 Science Education* provides a template for each state to create their science standards. The overarching goal for this framework is to ensure that students graduate high school with enough knowledge of science and engineering to engage in public issues, to learn about science outside of school, and to enable students to enter science, engineering, and technology careers (NRC, 2012).

The Framework describes eight SEP's that are embedded within science standards, GSE. The eight SEPs are asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations and designing solutions, engaging in argument from evidence and obtaining, evaluating, and communicating information (NRC, 2012). These practices assist students to directly experience science for themselves, while studying scientific concepts (NRC, 2012). According to NRC (2012), science is not simply a body of knowledge that reflects an understanding of the world but involves practices that create a foundation to expand and refine such knowledge.

Process-oriented motivation presents a second conceptual framework guiding this research. Process-oriented motivation is the drive to attain or complete a goal (Touré-Tillery & Fishbach, 2014). The current working definition of intrinsic and extrinsic motivation helps to define process-oriented motivation; however, this study will measure these forms of motivation with a goal pursuit perspective (Touré-Tillery & Fishbach, 2014). Current instruments utilize intrinsic motivation as students that are interested in the subject, while extrinsic motivation is intrigued with the reward of the subject. Intrinsic and extrinsic motivation will be utilized in respect to the process of learning science, goal pursuit. The original POMI has two main factors: outcome-focused motivation and process-focused motivation. In comparison to outcome-focused motivation, which is driven by the reward or outcome of goal completion, extrinsic motivation is driven by the reward of task completion (Touré-Tillery & Fishbach, 2014). Process-focused motivation has two sub-factors: intrinsic motivation (process-oriented) and means-focused motivation (Touré-Tillery & Fishbach, 2014). Intrinsic motivation (process-oriented) will be correlated with enjoyment and interest during the process of goal pursuit (Tillery & Fishbach, 2014). Means-focused motivation is a novel factor that utilizes proper means during goal pursuit; proper means are how actions are performed in terms of adherence to rules, principles, and self-set standards (Touré-Tillery & Fishbach, 2014). What means were endured during the process of goal pursuit? The original POMI can link a score with students' behaviors, confirming the type of motivation that predominates for each student.

Local Context

This study will take place at the researcher's locale, a Georgia pubic high school. The sample will include all honors and on-level chemistry students at this high school during the 2019-2020 school year. Researcher's school of interest is a school in the North Metro Atlanta area with approximately 2,000 students. Students at this school range in ages from 13 to 19 and all genders, a blended mix of several races, and socioeconomic statuses that range from low to high are present in this school. All classes are on a period schedule meaning students have the same chemistry teacher for an entire school year. Students see their teachers daily during the same period. On-level chemistry covers students that are in 10th to 12th grade. Most students taking honors chemistry are sophomore students that took on-level or honors biology their freshman year and received an A in that course. All students passed biology, physical science as a prerequisite to any chemistry course, honors or on-level. Chemistry is not a mandatory course for this locale; thus, students enroll in Chemistry with the intent to attend college after graduating high school. The experimental group will be on-level chemistry students, while the control group will consist of honors chemistry students at this locale during the 2019-2020 school year. Due to the advanced statistical analyses necessary to establish data for the novel instrument, the participant number would be insufficient if only one class type was analyzed. Therefore, this study would consist of two varying levels of students within the sample. Furthermore, all on-level teachers at this locale have utilized ADI labs in their classrooms for the past four years, making them more experienced than the honors chemistry teachers who have no experience with ADI.

The Chemistry GSE standard that will be explored during this study is "GSE-Sci SC3: Obtain, evaluate, and communicate information about how the Law of Conservation of Matter is used to determine chemical composition in compounds and chemical reactions" (Woods, 2016).

ADI will be the strategy utilized by the experimental group to investigate this standard due to its alignment with the *Framework for K-12 Science Education* (Grooms & Enderle, 2015). ADI utilizes four SEP's from the *Framework for K-12 Science Education*. Inclusion of these four practices align ADI with the *Framework*, making it an instructional strategy that should motivate students. Argument Driven Inquiry is centered around students developing their argumentation (Practice #7) from scientific evidence pertaining to a laboratory experience (Grooms & Enderle, 2015). However, the eight essential steps to complete an ADI lab involves other practices as well. Students will begin the lab by planning and carrying out an investigation based on the given guiding question within their group (Practice #3). In other words, students are tasked to plan and carry out an experiment that will create the necessary data to answer their guiding question. Next, students must analyze and interpret data by constructing evidence to participate in the argumentation session with their classmates (Practice #4). Students will then obtain (collect) data, evaluate that data, then communicate information which is necessary to prepare for the argumentation session and revision of their rationale for their lab report (Practice #8). Students are expected to communicate how the Law of Conservation of Matter is used to determine the chemical composition in compounds. It is apparent that the *Framework for K-12 Science Education* is built upon eight SEP's, those same practices are embedded in the Science GSE, and ADI utilizes four of these SEP's in their instruction to influence student motivation toward science.

CHAPTER 2: LITERATURE REVIEW

Introduction

This chapter presents a literature review that begins with a summary of the *Framework for K-12 Science Education* and curriculum pertaining to this study, Georgia Standards of Excellence in Science. The literature review serves two purposes: to make evident the need for a motivation instrument pertaining to science and reveal the novelty of process-oriented motivation in any literature. The *Framework* is imperative because it justifies the independent variable, type of instruction, with peer-reviewed articles. Next, the history of science education literature will be presented, which focuses on student motivation. Studies that have been found to measure such motivation will be summarized with a greater emphasis on the factors guiding this investigation, including intrinsic and extrinsic motivation in the absence of goal pursuit. Intrinsic and extrinsic motivation studies will be expanded to all sciences to provide contrast with chemistry studies, while linking student achievement. Finally, the literature review was narrowed to the factors of the original POMI, which are the points of emphasis of this study.

Framework for K-12 Science Education

The National Research Council (NRC) recently published a new framework for science standards to create coherence across K-12 curriculum to enhance students' motivation toward science (NRC, 2012). The goal of this *Framework* was to address the following weaknesses: emphasis on learning discrete facts, lack of consistency with curriculum from state to state, and the absence of student engagement that involve genuine science practices. The *Framework for K-12 Science Education* combined two aspects to achieve the purpose of meaningful learning: four science proficiency strands along with Science and Engineering Practices (SEPs). The four strands achieved science proficiency by requiring several experiences that support students' and inspire science learning (NRC, 2012). The four science proficiency strands include knowing, (using and interpretation of science in the natural world), generation and evaluation of scientific evidence and explanations, comprehension of how scientific knowledge develops, effective engagement in each practice while comprehending norms of creation, presenting scientific models and explanations, defending claims during engaged scientific debates, and improving students' motivation toward science. The SEPs are eight practices that are considered essential for K-12 science learning. Appropriate utilization of the SEPs enable an appreciation of how scientific knowledge was created and supports better student understanding (NRC, 2012). The NRC believed students' motivation and interest in science and engineering practices help improve student achievement and may increase several qualified applicants in pursuit of higher education in science-related fields (NRC, 2012). Since the *Framework* was a manuscript and guideline for K-12 curriculum in Georgia, GSE, each public education class has standards with the eight SEPs embedded throughout each document. Unfortunately, based on this study's literature review, motivation is not a point of emphasis in secondary science education literature. Additionally, most of the literature and instruments utilized in this study are not aligned with the *Framework for K-12 Science Education.*

Argument-Driven Inquiry

Argument-Driven Inquiry (ADI) will be the pedagogy utilized within this study. ADI was chosen specifically due to its alignment with the *Framework for K-12 Science Education*. The *Framework for K-12 Science Education* was explicit in emphasizing "engaging in argument from evidence" as one of the SEP's (NRC, 2012). Argument, critique, and analysis connects the natural world, data collection, theories, models, and formation of hypotheses (Grooms & Enderle, 2015). Engaging in argument was demonstrated only once within the eight practices, but ADI requires the student to engage in additional practices. ADI laboratories empower students to plan and carry out an investigation (Practice #3), then analyze data (Practice #4), develop their argumentation (Practice #7), and obtain, evaluate and communicate information (Practice #8) (Grooms & Enderle, 2015). Utilization of these four practices was ADI's connection to the *Framework for K-12 Science Education*, while creating a lab experience that engages and motivates students toward learning science. ADI is a strategy that has been designed to foster the development of all four strands related to scientific proficiency and practices (strands) of science that is detailed in the *Framework for K-12 Science Education* (Grooms & Enderle, 2015). ADI has been deemed the most pragmatic form of lab instruction because it is the only strategy that is literature-based in its utilization of multiple SEP's.

ADI is an instructional model that promotes student engagement in scientific argumentation. The goal of ADI is to empower students to develop arguments that can support explanations pertaining to research questions (Walker & Sampson, 2012). Eight major steps comprise the ADI instructional model. The first step of the model is student identification of the task. The goal of the teacher during this step is to introduce a major topic being studied while initiating a lab activity. Students are given a handout and a question that can be answered along with a list of usable materials for their investigation (Walker & Sampson, 2012). The second step of the model is data collection. Students will work in collaborative groups to develop an experiment to answer their research question and to collect data. The third step is the creation of an argument. Students will construct an argument that includes claim, evidence, and rationale on a large whiteboard (Walker & Sampson, 2012). The fourth step involves a small group argumentation session. The argumentation session includes each lab group utilizing a six-foot by four-foot white board that has their claim, evidence, and reasoning from their lab. Each group will have their board setup to receive constructive criticism on their board from their peers. The purpose of this session is to allow each group's argument to be polished (Walker & Sampson, 2012). The fifth step is the formation of a basic report. Students will produce a report that answers several questions. The goal of this step is to empower students to learn how to transform data into evidence to create a quality scientific argument (Walker & Sampson, 2012). The sixth step involves a double-blind peer review of students' basic reports. Each student will submit three blind reports, copies of their basic report without names, and those reports will be given to each lab group with a peer review sheet. Each report will be passed or failed by the peer reviewer based on the peer review rubric. Failure would result in a revision of the student's basic report (Walker & Sampson, 2012). The seventh step of ADI is the revision of the basic investigative report from peer review feedback. Students have the option to revise their reports based on feedback and comments given to them on their draft. Both original and final drafts will be submitted to their teachers for evaluation. The eighth and final step will be the submission of the final report. These eight steps encourage students to focus on understanding what claim to make, why they made it, and justify their claim versus others in a science context (Walker & Sampson, 2012). ADI's design is to empower students to move past looking for the correct answer, which is common in traditional labs.

Student Motivation in Science

According to the National Research Council (2012), students' motivation and interest in science are imperative in student achievement and their eventual quest of science-related fields in college and beyond. Therefore, strategies that motivate students are of paramount importance to the learning environment and possibly students' success in that course and in future science education. According to Ekici (2010), a low-performing student had a higher probability to experience low motivation belief. Current instruments focus mainly on two main factors of motivation. Intrinsic and extrinsic motivation measures, which flood the current science education literature, does not acknowledge new science standards and its focus on science being a process in lieu of rote memorization. This study desires to build upon previous motivation studies, while also offering the original POMI that will appropriately assess student motivation with instruction that effectively utilizes new curriculum that have been developed based on the *Framework for K-12 Science Education.* Throughout science secondary education literature, intrinsic and extrinsic motivation were always measured together in studies in the chemistry, physics, and biology classrooms. The following studies used these factors of motivation as dependent variables versus independent variables by utilizing different instructional strategy implementations.

Three main search engines were used to gather articles from the science-education literature. Google Scholar was searched with the keyword *chemistry motivation* and *high School chemistry motivation*. Kennesaw Library System's Education Source and ERIC employed the keywords *chemistry motivation* using the following subjects: Student Motivation, Motivation Techniques, Learning Motivation, Teacher Influence and Chemistry Instruction. More articles were found in Education Source versus ERIC with the same key words and subjects used. Finally, Kennesaw EBSCO host super search was used with keywords *chemistry motivation.* Articles were mostly excluded due to a lack of focus on chemistry content area and motivation being exempt from the introductions or methodologies of each research article. This same exact research protocol was repeated by substituting the search term chemistry with physics or biology. The articles were then further filtered by strategies that induced motivation, subject area (physics, chemistry, or biology) as the content being assessed, and a hypothesis/question that tested student's motivation or performance. Mandatory criteria included for each study included hypothesis or research question, collection of data to answer hypothesis or question, discussion and future actions from the conclusions made.

Upon filtering the search results, 21 articles were included in this study based on the following criteria for all secondary science. Motivation studies were then separated by subject matter: physics, biology, or chemistry. Chemistry had nine articles that fit this search criteria and articles were found in *Journal of Chemical Education* (3 articles), *Journal of Educational Science* (2 articles), *Journal of Theoretical Educational Science* (2 articles), *International Online Chemistry Education Research and Practice* (1 article), and *Journal of Turkish Science Education* (1 article). Each of the following journals contributed one physics article: *Computers in Human Behavior, Educational Studies, International Journal of Science Education, Eurasia Journal of Mathematics* and *Science & Technology Education*. Lastly, a total of five biology articles were found from *Educational Science* (2 articles), *Education and Science* (1 article), *Journal of Education and Training Studies* (1 article), and *International Journal of Higher Education* (1 article). Lastly, three combined sciences articles originated from the following journals: *Learning Science, Science Education,* and *US-China Education Review.*

Physics Education Literature

Articles found in Table 2.1 pertain to secondary high school physics, which provided some evidence on effective instruction, strategies, and learning environments that alter student motivation and achievement. According to Nikou and Economides (2016), students had an increase in their motivation when computers and mobile devices were used for assessments versus traditional paper assessments. Students were given the exact same multiple-choice test on both platforms, pre-test (paper assessment) and post-test (electronic assessment), these results displayed that students intrinsic and extrinsic motivation increased along with student achievement.

Additionally, low-achieving students performed better on an electronic-based assessment as opposed to paper assessments (Nikou & Economides, 2016).

Brain-based teaching, strategies that utilized evidence from neuroscience, were found to provide a stronger conceptual understanding of Newtonian physics and higher motivation versus a conventional teaching method. Brain-based teaching utilized seven steps: activation; clarification of the big picture of lesson, making the connection; student active engagement in learning; student demonstration of understanding; review for student understanding recall; students previewing the new topic. The increase in motivation among the experimental group was based on students making connections, which raised their awareness and motivation pertaining to assigned physics concepts. Learning should involve the whole physiology of the body, which gives each human a huge potential for success (Saleh, 2012).

Askoy and Ozdamli (2016) reported that the flipped classroom approach was more effective for student achievement and student motivation versus a traditional didactic teaching method. The flipped classroom approach is an instructional strategy that is the reverse of the traditional learning environment, where instructional material will be delivered outside of the classroom and class time is spent working in collaborative groups. Similarly, the effectiveness of two different group work instructions were investigated for their influence on student motivation by Berger and Hanze (2009). The type of small group setting, jigsaw classroom versus cyclical rotation method, lacked a significant difference for student intrinsic motivation (Berger & Hanze, 2009). In the jigsaw classroom, lessons are divided into multiple segments. The cyclical rotation method eliminates ‘jigsaw’ and ‘expert’; thus, all learners have the same responsibilities within their respective groups.

Table 2.1

Types of Motivation for Physics Education Literature

Articles Measured	Type(s) of Motivation
The Impact of Paper-Based, Computer-Based, and Mobile-Based Self-Assessment on Students Science Motivation and Achievement (Nikou & Economides, 2016)	Intrinsic and Extrinsic
The Effectiveness of Brain-Based Teaching Approach in Dealing with the Problems of Students 'Conceptual Understanding and Learning Motivation Towards Physics (Saleh, 2012)	Motivation
*Comparison of Two Small-group Learning Methods in 12th-grade Physics Classes Focusing on Intrinsic Motivation and Academic Performance (*Berger & Hanze, 2009)	Intrinsic and Extrinsic
Flipped Classroom adapted to the ARCS Model of Motivation and applied to a Physics Course (Aşıksoy & Özdamlı, 2016)	Motivation

Biology Education Literature

Articles found pertaining to biology classes at the secondary level provided evidence on effective instruction, strategies, and learning environments that altered student motivation and achievement. All five biology articles are present in Table 2.2. According to Ekici (2010), a significant difference between students' intrinsic and extrinsic motivation existed based on the type of biology lesson. In Turkey, rigor of biology lesson was based on the difficulty or the amount of critical thinking that was necessary to complete a lesson. However, varying levels of classes were not mentioned, thus an assumption of the same rigor between classes was made. The higher level of difficulty or critical thinking led to an increased intrinsic and extrinsic motivation for students. Yerdelen and Aydin (2014) discovered that the mastery approach goal-orientation was the best predictor of each sub-dimension of motivation outside of extrinsic motivation for biology students. Sub-dimensions were intrinsic motivation, extrinsic motivation-profession, and extrinsic motivation-social. Mastery approach goal-orientation can be defined as the student's utilization of metacognition to comprehend certain tasks. The student set their own goals based on a task- and monitor-progress until their task or goal has been mastered (Yerdelen & Aydin, 2014). In an expanded study, Aydin (2015) discovered a positive correlation between metacognitive strategies and self-efficacy with students' intrinsic motivation. In other words, once metacognition and self-efficacy were used to teach biology, students were more curious or interested in learning that biology lesson.

According to Kisoglu (2018), the strongest correlation among the four subdimensions of motivation (intrinsic, amotivation(lack of motivation), extrinsic-social, extrinsic-career) from attitude scales was found to be between the intrinsic motivation with interest subdimensions and the intrinsic motivation with pleasure subdimensions. Findings about motivation towards learning biology demonstrated a positive correlation between students with a high level of success in science and their desire to pursue a science career. In other words, the students that were most interested and curious (intrinsic motivation) about learning biology were also students that wanted to pursue a science career (extrinsic motivation-career). On the contrary, student's' willingness to show their success to others (extrinsic motivation-social) was the least effective sub-dimension at motivating them to learn biology.

Table 2.2

Types of Motivation for Biology Education Literature

Article Title	Type(s) of Motivation
Strengthening of The Motivation of High School Students by A Laboratory Experiment in Virology (Szabó & Čipková, 2017)	Intrinsic and Career
Factors Affecting Biology Lesson Motivation of High School Students (Ekici, 2010)	Intrinsic and Extrinsic
Relationship between High School Students' Achievement Goal Orientation and Academic Motivation for Learning Biology: A Path Analysis (Yerdelen & Aydin, 2014)	Intrinsic, amotivation, extrinsic-career, and extrinsic-social
An Analysis of the Relationship Between High School Students' Self-Efficacy, Metacognitive Strategy Use and their Academic Motivation for Learn Biology (Aydin, 2015)	Intrinsic, amotivation, extrinsic-career, and extrinsic-social
An Examination of Science High School Students' Motivation towards Learning Biology and Their Attitude Towards Biology Lesson (Kisoglu, 2018)	Intrinsic, amotivation, extrinsic-career, and extrinsic-social

Chemistry Education Literature

Table 2.3 show nine studies that brought a small contribution to the secondary chemistry-education literature. Five types of active learning strategies were utilized in the secondary chemistry-education literature including: Computer-Assisted Instruction, Case-Based, Context-Based-Inquiry, Lab Inquiry, and Attention Relevance Confidence and Satisfaction (ARCS). Computer-Assisted Instruction (CAI) utilized simulation and tutorials that demonstrated increased student interest, which culminated in improved learning of chemistry concepts. According to Gambari and Gbodi (2016), CAI results demonstrated significant improvements in learning achievements for computer simulation versus traditional instruction. Additionally, the Chemistry Motivation Questionnaire discovered an increase for intrinsic and extrinsic motivation for students in the experimental group that learned chemistry via computer simulation (Gambari & Gbodi, 2016).

Case-based learning provided situational chemistry that gave context to how chemistry is used in the real world. An example of a case-based study would be the effectiveness of car airbags

(Yalçınkaya & Boz, 2012). According to Yalçınkaya and Boz (2012), case-based instruction improved high school students' motivation statistically in most motivation factors except for anxiety. Context-based learning provided perspective by relating chemistry to students' life events. An example of context-based chemistry would be students exploring minimizing production of hazardous material to the environment, green chemistry. Context-based learning resulted in an increase in half of the students' motivation via experiences that gave them a better overall understanding of chemical equilibrium. Finally, the ARCS model used four strategies to provide motivation: Attention, Relevance, Confidence, and Satisfaction (Fend & Tuan, 2005). Students in the experimental groups (ARCS learners) increased intrinsic motivation, student engagement, and achievement post-test results versus the control group (traditional learners) measured by the Students' Motivation toward Science Learning Questionnaire (SMTSL) (Fend & Tuan, 2005). All these studies have one commonality: active learning strategies that improved student motivation and student achievement in chemistry compared to a control.

Table 2.3

Types of Motivation for Chemistry Education Literature

Article Title	Type(s) of Motivation Measured
The Effect of Green Chemistry on Secondary School Students Understanding and Motivation (Roth, 2013)	Intrinsic and Extrinsic
Promoting Intrinsic and Extrinsic Motivation Among Chemistry Students Using Computer-Assisted Instruction (Gambari & Gobi, 2016)	Intrinsic and Extrinsic
Is Case-Based Instruction Effective in Enhancing High School Students' Motivation Toward Chemistry (Yalcinkaya & Box, 2012)	Intrinsic and Extrinsic
Using ARCS Model to Promote 11th Graders' Motivation and Achievement in Learning About Acids and Bases (Feng & Tuan, 2005)	Performance Goal and Achievement Goal
The Effect of Context-Based Chemical Equilibrium on Grade 11 Students' Learning, Motivation and Constructivist Learning Environment (Ilhan & Yildirim, 2016)	Intrinsic and Extrinsic
A Research on the Generative Learning Model Supported by Context-Based Learning (Ulusoy & Onen, 2014)	Intrinsic and Performance
Stimulating Students' Intrinsic Motivation for Learning Chemistry Through the Use of Context-Based Learning Modules (Valon & Holbrook, 2012)	Intrinsic
The Effect of Inquiry-Based Laboratory Application on Students' Motivation and Learning Strategies (Sen & Erdogan, 2016)	Intrinsic and Career
The Effects of Process-Oriented Guided Inquiry Learning Environment on Students' Self-Regulated Learning Skills (Yilmaz & Geban, 2015)	Intrinsic and Extrinsic

Combined Science Education Literature

Three articles were found that utilized more than one field of science within each research article. Combined science articles involved a variety of secondary education courses: biology, environmental science, chemistry, and physics. These subjects were intertwined in each of these three articles as opposed to one subject article. Chow and Yong (2013) presented results that have multiple implications for the participants and the education community. Two additional articles are in Table 2.4. Results suggested that a group of students displayed a moderate level of intrinsic motivation, personal relevance, self-determination and self-efficacy and a high level of extrinsic motivation with assessment anxiety when learning combined science. Results also demonstrated significant differences in motivation orientations towards learning combined science between boys and girls, then amongst high ability versus low ability students. Furthermore, correlation analyses indicated that significant positive associations between students' motivation orientations and science achievement (Chow & Yong, 2013). Students' intrinsic motivation, self-efficacy, self-determination, and achievement were related. Chow and Yong (2013) found that the social cognitive theory and self-efficacy were most related to achievement. Students who wanted to take advanced placement (AP) classes had higher intrinsic motivation than those who did not. Patterns revealed in essays and interviews also identified teachers, career interests, and collaborative-learning activities as strong motivators for this selective group of students. Article results suggested that science teachers should use social modeling and collaborative learning activities to foster students' motivation, achievement, AP intent, and interest in a science career (Bryan & Glynn, 2011). Honors classes that had students with AP intent needed collaborative learning activities that challenged them to work together and to think critically. Such activities facilitated such motivation and created more student interest in science.

Zeyer (2013) discovered a Gender-Systemizing-Motivation model for physics and chemistry in which motivation to learn science is not gender-dependent. Gender had no direct impact on motivation, however systemizing explained almost 30% of the variation in students' motivation. These results recommended that students' cognitive style (systemizer versus empathizer), not gender, enabled a better understanding of student motivation to learn science. A systemizer used cognitive dimensions to perceive physical things and understand these objects and their function in the context of a system. The goal of this person was to identify rules that determined a system, which helped them understand how to predict people's behavior (Zeyer, 2013). Empathizers can identify and understand the feelings and thoughts of others while responding with adequate emotions. On average men tend to be systemizers versus the average women being an empathizer.

Table 2.4

Types of Motivation for Combined Science Education Literature

Article Title	Type(s) of Motivation Measured
Systemizing and Motivation to Learn Science in Different Science Subjects (Zeyer, 2013)	Intrinsic, Career, and Grade
Motivation, achievement, and advanced placement intent of high school students learning science (Bryan & Glynn, 2012)	Intrinsic
Secondary School Students' Motivation and Achievement in Combined Science (Chow & Yong, 2013)	Intrinsic and Extrinsic

Motivation in Laboratory Inquiry

The primary focus of inquiry-based instruction was a student-centered environment in the classroom that promotes discussion via students' critical thoughts. Other active learning strategies provoke inquiry, but inquiry was simply an aspect of the strategy's effectiveness, not its primary goal. Inquiry labs were more effective than traditional labs in helping students rehash previously learned concepts (Sen & Erdogan, 2016). Throughout this portion of the literature review, the focus will be on how lab inquiry is utilized in the science classroom along with how this form of instruction affects student motivation and achievement.

A significant difference existed in post-test motivation scores, as measured by the Chemistry Motivation Questionnaire for inquiry-based lab students, demonstrating an increase in motivation (Sen & Erdogan, 2016). Motivated Strategies for Learning Questionnaire (MSLQ) assessed the motivation of process-oriented inquiry students in a Turkey secondary school via a pre-test and post-test (Yilmaz & Geban, 2015). Students' self-efficacy for learning and performance (extrinsic and intrinsic motivation) differed significantly for students that underwent process-oriented inquiry (Yilmaz & Geban, 2015). Both research articles were executed at the high school level and illustrated the impact on motivation for students who learned chemistry with inquiry versus traditional instruction.

Amongst the other science courses taught in high school only one article measured student motivation as a result of lab inquiry. According to Szabo and Cipkova (2017), a lab that included Alfalfa mosaic virus replication influenced a high school virology class to improve student intrinsic motivation in reference to previous classroom labs. Current literature demonstrates that labs that allow students to utilize inquiry in order to advance their knowledge on specific science matters were effective at increasing student intrinsic motivation.

The science literature for lab inquiry and student motivation was quite scant. It is fair to state that little to no evidence existed regarding how lab inquiry was an effective instructional tool for science students. Within all the active learning strategies utilized in science classrooms, lab inquiry was the least prevalent literature accounting for three studies throughout all founded science education literature. The inclusion of a prevalent strategy was imperative to appropriate diagnosis of student motivation amongst the new wave of instructional tools that had been created to increase student motivation. Lab participation differentiates science courses from other core subjects. Furthermore, these lab experiences are the medium that enables students to explore science in a safe, controlled environment. Therefore, an increase in lab inquiry studies was imperative for the education community to effectively assess instructional strategies that are created to improve student motivation via labs.

Gaps in Current Motivation Instruments

Current instruments utilized in science classrooms have three inherent issues. Table 2.5 below summarizes all instruments that have been used to measure motivation in science classrooms. First, Touré-Tillery and Fishbach (2018) defined a goal as having a clear beginning and end state; however, current instruments that measured student motivation may not have a clear start and end state. Increases in motivation are less likely to occur without a clear end state, due to a lack of closure and reference point (Touré -Tillery & Fishbach, 2011). In other words, motivation was measured in relative terms compared to prior levels of motivation (Touré-Tillery & Fishbach, 2014). For example, the Science Motivation Questionnaire had an item that states: “I enjoy learning the science”. Learning science did not have a specific or definite end state; thus, motivation may fluctuate hourly, daily, or annually. Moreover, science does not differentiate past or present to appropriately measure a change in student motivation. If a teacher implements a new instructional practice that a student enjoys, that same student may still strongly disagree with the “enjoying learning science” item since science remains his or her least favorite subject. The event of a new strategy may not appropriately be factored into their motivation. An altered item would include chemical equilibrium, which indicated the start and completion of the goal being the chemical equilibrium unit. An amended item would read: “I enjoy learning about chemical equilibrium”. Such an example illustrates that a process can be associated with that goal.

Table 2.5

Breakdown of All Motivation Instruments

Motivation Instrument (Reference)	Factors Measured (Item #)	Populations that have shown Validity and Reliability
SMQ (Glynn, 2006)	30 total items Six total factors Intrinsic motivation (5) Extrinsic Motivation (5) Personal relevance of science (5) Self-determination for learning science (5) Self-efficacy (5) Anxiety for assessment items (5)	Voluntary participation Total of 984 students from three sections and 770 participated. 770 were analyzed and 9 were not due to incomplete responses. 74% women and 24% men Ethnicity Caucasian (83%) Asian (6%) African American (6%) Multiracial (3%) Hispanic or Latino (2%) ****minority status was not treated as a statistical variable since numbers for such populations were so small***

Table 2.5 (continued)

Breakdown of All Motivation Instruments

MSLQ (Ilker, 2014)	44 total items Cognitive strategy (13) Self-regulation (9) Sub-scales – Self-efficacy (9) Intrinsic motivation (9) Test anxiety (4)	Voluntary participation 1605 high school students (3 schools) (51.6% female and 48.4% male) Population of Turkish students were not listed.
IMI (Deci & Ryan, 2007)	Intrinsic Motivation	N/A
SMTSL (Tuan & Chin, 2005)	35 total items Six total factors Self-efficacy (7) Active learning strategies (8) Science learning value (5) Performance goal (4) Achievement goal (5) Learning environment stimulation (6)	1407 middle high school students from central Taiwan students. Grades ranged from 7th to 9th grade and students were selected at random.
	25 items 5 total factors Intrinsic motivation (5) Self-determination (5) Self-efficacy (5) Career motivation (5) Grade motivation (5)	Validated at a public university with 25,335 undergraduate students in southern United States. 680 undergraduate students, 367 science majors and 313 non-science majors. Science majors were enrolled in Principles of Biology either fall or spring semester of that school year. Non-science majors were enrolled in Basic Concepts in Biology for non-science majors fall or spring semester. Some of the participating students were from underrepresented groups, African American (7%), Hispanic or Latino (3.1%), Multiracial (0.6%), and Native American (0.2%). These percentages were like those of the university population. Minority status was not treated as a statistical variable
CBCMS (Onen & Ulusoy, 2014)	20 items Three factors Eagerness (9) Efficacy (6) Performance (5)	525 high school students that were randomly chosen high school students. Students were taken from several different high schools in Ankara, Turkey. (Ulusoy & Onen, 2014).

Table 2.5 (continued)

Breakdown of All Motivation Instruments

Questionnaire of Students' Motivation Towards Physics (Tuan & Chin, 2005)	35 total items Six total factors Self-efficacy (7) Active learning strategies (8) Science learning value (5) Performance goal (4) Achievement goal (5) Learning environment stimulation (6)	1407 middle high school students from central Taiwan students. Grades ranged from 7th to 9th grade and students were selected at random.
Learning Experience Questionnaire (Berger & Hänze, 2009).	6 items Three total factors Social Relatedness (2) Experience of competence (2) Experience of autonomy (2) (satisfaction of factors = intrinsic motivation)	The first study 20 different physics classes (12th grade) with a total of 286 students. The second study which happened a half year later had only seven classes with a total of 121 students. However, four new physics classes were added to push the participant total to 223 students.
Biology Lesson Motivation Questionnaire (Cevik & Ekici, 2008)	30 items Six factors a. Internal Motivation b. External Motivation c. Interest in Learning Biology d. Responsibility for learning biology e. Trust in learning biology and anxiety in bio exams	Voluntary participation Total of 984 students from three sections and 770 participated. 770 were analyzed and 9 were not due to incomplete responses. 74% women and 24% men Ethnicity Caucasian (83%) Asian (6%) African American (6%) Multiracial (3%) Hispanic or Latino (2%) ****minority status was not treated as a statistical variable since numbers for such populations were so small**
Academic motivation scale for learning biology (Aydın & Yerdelen, 2014)	19 total items Four total factors Intrinsic motivation (6) Amotivation (5) Extrinsic motivation – Career (4) Extrinsic motivation – Social (4)	472 students 9th to 12th grades of science high school in five Anatolian high school in central district of Kars. This study took place in Turkey. 191 students were used in study one and two, then 281 students from study 3. 240 male and 232 female totals participated in all three study. Median age was 17.2 for all participants within the three studies.

Second, all motivation is separated into two major categories, intrinsic and extrinsic motivation, demonstrating that studies have no interest in the means to complete a goal. Extrinsic motivation can be associated with external benefits to completing a task or an activity (Touré-Tillery & Fishbach, 2014), while intrinsic motivation was connected to enjoyment and interest in completing that same task (Touré-Tillery & Fishbach, 2014). A third factor, means-focused motivation, was imperative to differentiate a low score on both intrinsic and extrinsic motivation measures.

Thirdly, current intrinsic and extrinsic motivation measures do not consider new science standards and their focus on science being a process in lieu of rote memorization (NRC, 2012). The *Framework for K-12 Science Education* was built upon eight SEP's that are embedded from kindergarten to 12th grade. The curriculum facilitates students' mastery of the eight practices and may lead to student motivation to learn science (NRC, 2012). One of the *Framework for K-12 Science Education's* goal was to provide causal explanations appropriate to students' level of scientific knowledge, which aligned with the scientific practice of constructing an explanation (NRC, 2012). This process begins in kindergarten and culminates before the student graduates from high school. Although the goal is over a decade long, standards are in place that allows the goal to be accomplished on a smaller scale within each science course taken. However, most instruments do not acknowledge such a process, as several instruments refer to science as a static entity. The Science Motivation Questionnaire referred to science as the subject of motivation (e.g., I find the science interesting) (Glynn, 2006). "The science" is a phrase that does not embody a process because it denotes only one action, learning science, as opposed to a series of actions that result in a desired end, learning a science topic or completing a scientific goal. Such a phrase is too general and cannot definitively define a process.

Addressing holes, unexplainable gaps in literature research, in current instruments will be accomplished by creating the original POMI. The original POMI will incorporate lab as a specific goal. Additionally, this study will assess any modification in students' motivation after implementation of instruction that utilizes the scientific and engineering practices used in the GSE, e.g., ADI. These two steps will accomplish three feats: acknowledging science as a process by referring to a specific chemistry process, adding a third main factor (means-focused motivation), and measuring the effectiveness of the new standard's ability to motivate students. Creation of the *Framework for K-12 Science Education* must be validated by literature that provides evidence of motivation effectiveness from the framework.

Process-Oriented Motivation Literature

Five common motivation factors are consistent within current motivation instruments: intrinsic, extrinsic, goal orientation, task value, and self-determination with assessment anxiety deemed important to students' motivation to learn (Bandura, 2001; Schunk, 2001). From these factors, intrinsic and extrinsic motivation help to define process-oriented motivation, and this study will measure these motivations with a goal pursuit perspective (Touré-Tillery & Fishbach, 2014). In comparison to outcome-focused motivation, which is driven by the reward or outcome of goal completion, extrinsic motivation is similar and is driven by the reward of task completion (Touré-Tillery & Fishbach, 2014).

The dimension of process-focused motivation is concerned with elements related to the process of goal pursuit and stems from internal benefits such as enjoyment and positive self-concept (Touré-Tillery & Fishbach, 2014). Two sub-dimensions of process-focused motivation are means-focused motivation and intrinsic motivation. Means-focused motivation uses proper or correct means during goal pursuit (Touré-Tillery & Fishbach, 2014). For example, a chemistry student who wants to perfect or master the art of studying with means-focused motivation will focus on bettering their studying habits versus an intrinsically motivated student who will focus on the joyful experience of studying chemistry. A significant difference between intrinsic motivation (process-oriented motivation) and current literature's intrinsic motivation is the attainment of a goal versus a task (Touré-Tillery & Fishbach, 2014).

Process-oriented motivation and its factors in Figure 2.1 relate to the process of goal pursuit (Touré-Tillery & Fishbach, 2014). The point of emphasis for process-focused motivation is proper means or enjoyment during goal pursuit. Process-focused motivation has two sub-factors: intrinsic motivation (process-oriented) and means-focused motivation (Touré-Tillery & Fishbach, 2014). Intrinsic motivation (process-oriented) will be specifically correlated with enjoyment and interest during the process of goal pursuit (Touré-Tillery & Fishbach, 2014). Means-focus motivation is a novel factor that utilizes proper means during goal pursuit; proper means are how actions are performed in terms of adherence to rules, principles, and self-set standards (Touré-Tillery & Fishbach, 2014). In contrast to process-focused motivation, outcome-focus motivation is a focus on the outcome not the process of the goal pursuit (Touré-Tillery & Fishbach, 2014). Outcome-focus motivation is the student's focus on the desired end state, outcome, or reward of the goal completion (Touré-Tillery & Fishbach, 2014).

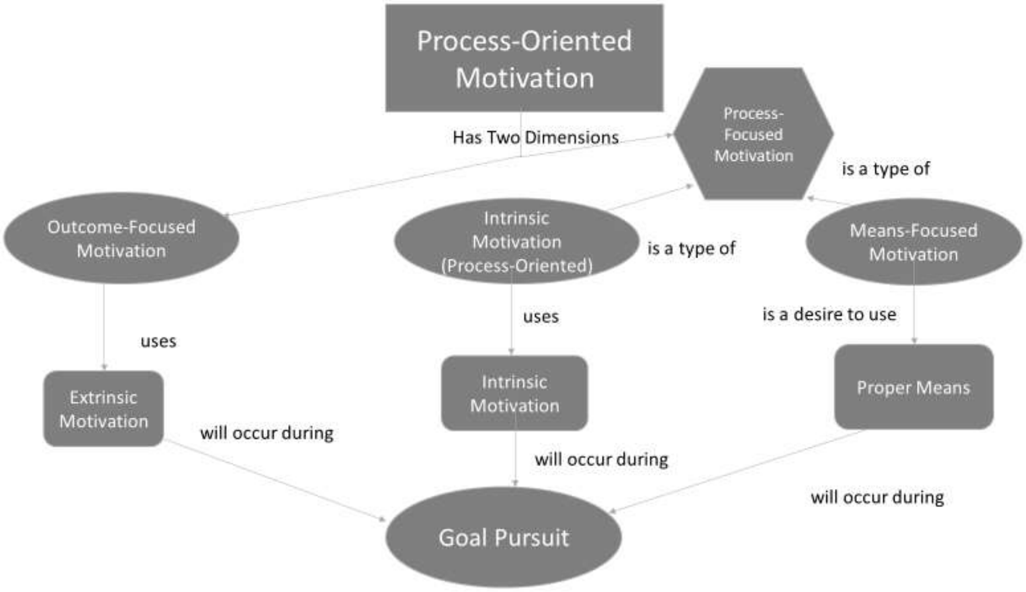

Figure 2.1. *Process-oriented motivation factors and its connections to other motivation factors*

Current literature does not measure process-oriented motivation or utilize process-oriented motivation as a dependent variable. Instead, mental simulation, process, or outcome simulation, was manipulated as the independent variable by Pham and Taylor (1999) and articles that followed while the dependent variable changed based on the study. Mental simulation is a psychological manipulation that emphasized a process to achieve a goal versus the outcome of goal achievement (Pham & Taylor, 1999). The psychological manipulation included reading scripts that simulated a desired goal (outcome simulation) or steps leading to a desired goal (process simulation) (Pham & Taylor, 1999). For example, one of the experimental groups simulated the outcome of receiving a good grade by reading a script that described a person getting an A on their mid-term exam. The totality of process-oriented articles followed the methodology from Pham and Taylor (1999) of researching mental simulation.

Mental simulation enhanced connections between thought and action in order to emphasize a process necessary to accomplish a goal (process-focused) or emphasize an outcome of goal achievement (outcome-focused) (Pham & Taylor, 1999). According to the Pham and Taylor

(1999) study, three groups of college students prepared for a mid-term exam for 5 to 7 days. The first group mentally simulated good study habits, while the second group mentally simulated receiving a good grade on the midterm exam. The third group was a combination of both outcome and process simulation instructions. The procedure for each group included a brief questionnaire that assessed the amount of study time for the class midterm thus far. Every participant had a daily calendar sheet to track hours, days planned, and location of studying. The process simulation exercise included mental simulation of themselves studying for an exam, while they were given a specific item to read about practicing good study habits. The outcome simulation exercise included a mental simulation item that had to be read regarding the importance of getting a good grade. Mental simulation had to be completed five times per day for each group. The combination group had both items and had to undergo both mental simulations. The analysis methods included coding student diaries to find trends in their study times, Cronbach alpha for internal consistency of assessment measures, and two-way ANOVA with simulation versus each assessment measure (Pham & Taylor 1999). The process simulation group enhanced their studying and performed significantly better than the outcome simulation group on the midterm.

Mental simulation shares similar characteristics to process-oriented motivation. Mental simulation has two types of manipulation: process simulation which is the focus on the process of goal pursuit and outcome simulation that is centered around the reward of goal pursuit (Pham & Taylor, 1999). According to Touré and Tillery (2014), process-focused motivation is a result of a participant being transfixed on the process of goal-pursuit. Conversely, outcome-focused motivation describes participants’ focal point as goal completion, reward, or outcome of goal-pursuit. Mental simulation and process-oriented motivation have one significant difference: how they are utilized as variables in their respective research studies. Pham and Taylor (1999) manipulated mental simulation of their participants and measured significant changes in the independent variable measures. However, Touré and Tillery (2014) regard process-focused motivation to be measured as a result of a change to participants. In other words, mental simulation serves as a psychological independent variable, while process-oriented motivation is a dependent variable that results from the implementation of an instructional strategy.

Theoretical Framework

The theoretical framework behind all four research questions was built upon constructivism. According to Piaget (1967), constructivism is a theoretical framework that believes learning and comprehension are born in the mind via personal interaction with the world around the student. Human constructivism describes meaningful learning as an interactive web between thinking, feeling, and acting that culminates in student empowerment (Novak, 1977). Once knowledge has connected across three affective domains (thinking, feeling, and acting), then meaningful learning can occur. Thinking consisted of the cognitive domain, feelings are the attitudes, and acting was the students' active learning experience. Constructivism has been linked to supplementing issues of engagement, motivation, and desire for further concept knowledge (Kahveci & Orgill, 2015). However, if any of the three domains were not achieved via that learning experience, then meaningful learning was absent from the student's learning experience (Novak, 1977). The focus of this study is process-oriented motivation toward chemistry (feeling) and how that may be affected by the implementation of ADI labs (acting). Student achievement will be measured to find the effect of feeling and acting on students' thinking about science. ADI empowers students to use cognition, feeling, and action to inspire meaningful learning. The theory of human constructivism will be present via ADI, and its effect on student motivation will be measured by the original POMI.

According to Piaget's (1967) idea of constructivism, people do not find existing knowledge, but they are always and actively constructing it. Therefore, our study will be driven by the goal to describe the cognitive structures of the concepts held by our participants (Cobern, 1993). Students' affective domain played an important role in the development of meaningful learning of chemistry concepts (Niewswandt, 2007). Through constructivism studies in science education, students' affective domain has become an important aspect of learning that is now inseparable from cognition (McLeod, 1992).

The impetus of the *Framework*'s alteration in its approach to curriculum was transforming student's perspective to science. Strategies that encouraged quantity in learning versus quality in learning experience are no longer the focus of education. Science is not simply a body of knowledge that reflects an understanding of the world but involves practices that create a foundation to expand and refine such knowledge (NRC, 2012). All eight science and engineering practices can be implemented in every facet. Like human constructivism, the *Framework's* goal was to connect thinking and feeling into action to engage students in meaningful learning. *Framework* aligned strategies utilized the eight SEPs, which engaged the students to think about science concepts, feel concepts by development of models, and act on their understanding via planning and engaging in experiments. Therefore, a correlation can be made between *Framework* and constructivism in approach. ADI will empower students to think about how to approach their driving question with a procedure, experience how scientists approach science by executing their procedure, then act on their evidence with justification and argumentation with their peers.

Human Constructivism utilized Ausubel's (1963) cognitive structure theory to provide meaningful learning to the science classroom. Ausubel's cognitive structure theory had three phases to achieve meaningful learning instead of rote memorization (Ausubel, 1963). Phase one began with clarifying the aim of the lesson, presenting the advance organizer, and creating a relationship between students' knowledge and the advance organizer. Phase two was the presentation of a learning task or material. During phase two, the organization of new material was explicit, a logical order was created, and students engage presented material and meaningful learning activities. During phase three, new information was related to an advance organizer and promotion of active reception learning occurs. An example of an advance organizer can be a concept map. Novak (1977) described that the cognitive structure was needed for meaningful learning in science education that connected the three affective domains (thinking, feeling, and acting).

According to Moll (1990), the zone of proximal development addressed the issue of children who differ in their state of development in ways that cannot be assessed by their performance while working individually. Vygotsky (1978) proposed two levels of child development: actual development level and a more advanced proximal level. The actual development level is their individual performance or ability to solve problems by themselves. However, the proximal level of development refers to their performance once they have been aided in a task. Aided performance was usually based on their teacher's assistance with problem-solving. Zone of Proximal development was the contrast between a student working individually or being helped during an assessment. This zone was created as an alternative to individual assessment or IQ testing. Vygotsky (1978) argued that developing mental functions must be assessed via collaborative activities as opposed to unassisted or independent activities. Therefore, if a student was helped with a task persistently, that student will eventually be able to perform the task individually. Zone of Proximal development was confirmed in Human Constructivism based on teacher instruction. Human Constructivism implored the teacher to utilize the student's experience in order to achieve meaningful learning (Bretz, 2001). This theory was founded on the fact that students have not already attained an understanding of a concept, but they can develop a stronger comprehension via their learning experience. Human Constructivism did not account for one aspect from the Zone of Proximal Development: the ability for teachers to assess each student’s ability. Consequently, the effectiveness of the student’s learning experience must be considered with a teacher’s ability to discover each student’s Zone of Proximal development. ADI empowers students to use cognition, feeling, and action to inspire meaningful learning. The theory of human constructivism will be present via ADI, and its effect on student motivation will be measured by the original POMI.

CHAPTER 3: METHODOLOGY

Introduction

The research design for this study was quasi-experimental with controls and treatments that have non-random assignments for all participants; such a design was commonly used in an educational environment (Muijs, 2011). Participants in this study were in one of two groups: experimental or control. The experimental group consisted of on-level chemistry students, while the control group was honors chemistry students. The purpose of this research design was to address two major issues present in the current motivation literature as it relates to science education: establish a motivation instrument that generates data that is valid and reliable to assess students' process-oriented motivation for the researcher's locale and utilization of this instrument.

Research Questions

This study had two main parts that were segmented into two goals. The first goal was to develop the novel Process-Oriented Motivation Instrument (POMI). Once validity and reliability were established among the POMI data, the second goal was to explore how Argument-Driven Inquiry (ADI) effected student's process-oriented motivation and achievement in high school chemistry. To achieve these two goals the following research questions guided this study:

Goal 1 Research Questions:

1. How does the data from the Process-Oriented Motivation Instrument establish appropriate validity and reliability for high school chemistry students?
    a. What is the relationship between a student's Views about Scientific Inquiry and the degree to which they are motivated by scientific processes?

Goal 2 Research Questions:

2a. What is Argument-Driven Inquiry's effect on high school chemistry students' process-oriented motivation?

2b. What is the mediation effect of process-oriented motivation and relationship between argument-driven inquiry and student achievement?

Research Question 1 and its sub-question, 1a, were constructed to achieve Goal 1. Data from the original POMI that established validity and reliability was imperative for any instrument that had new items that were being assessed in a certain demographic (Glynn, 2011). If the original POMI data collected did not demonstrate appropriate validity and reliability, then the original POMI would be deemed not fit for the population where research occurred (Glynn, 2009). While Research Question 1 was designed to confirm validity and reliability from data for the original POMI, Question 1a utilized a similar instrument that assessed congruence with the original POMI. Convergent validity was established by exploration of the relationship between a student's VASI score and the degree to which they were motivated by scientific processes (see Appendix A). A convergent validity test, a subtype of construct validity, seeks to find a correlation between the factors of both instruments (Heale & Twycross, 2015). Means-focused motivation, a novel factor of the original POMI, and the VASI instrument both evaluate an aspect of the process of doing science (Lederman, 2014). However, means-focused measured student motivation on engaging in scientific practices instead of comprehension of those practices. Although both factors seem to be theoretically related, a Pearson or Spearman correlation test confirms if a relationship between means-focused scores and VASI scores in fact exists. A high-performing student that had a high score on both instruments would be an indication of means-focused motivation and VASI's factors being aligned or correlated.

Construction of the POMI

The original POMI, first survey administration during Goal 1, had a grand total of 25 items. Each item utilized the same response scale, a four-point Likert scale that ranges from strongly disagree to strongly agree (See Appendix B). Currently utilized science motivation instruments retained one commonality: the subject for motivation in each item was science. Science referred to any K-12 public education core course that was taken by a student, e.g., ecology. Process-oriented motivation items, excluding those containing means-focused elements, were adapted from previously utilized science instruments including: Intrinsic Motivation Inventory (IMI), Motivation Strategies Learning Questionnaire (MSLQ), Students' Motivation toward Science Learning (SMTSL), SMQ, and SMQ-II (Deci & Ryan, 2007; Glynn, 2009; Glynn, 2011; Pintrich, 2000; Tuan & Chin, 2005). All questions were neither numeric nor open-ended, which enabled the student to avoid misinterpretation of original POMI items. An example of an adapted item used in the original POMI was "I enjoy laboratories in this chemistry class when they allow me to ask questions about the system being studied." Like other original POMI items, this item emphasized the current chemistry class experiences, regardless of students' previous science experience. Moreover, each original POMI item focused on the process involved in completing chemistry activities in their current class versus all of science.

Justification of Factors

Outcome-focused motivation was the first factor that was a part of the original POMI. Items for this factor, listed in Table 3.1 focused on the reward instead of the process of goal pursuit. For example, if two students were taking a chemistry test, the outcome-focused motivated student would be fixated on receiving an A on the test instead of the journey associated with making an A on the test. This item focused on a student achieving the reward or grade regardless of the means. Without the reward, grade, these students may not deem learning activities to be necessary (Touré-Tillery & Fishbach, 2014). Therefore, these items were categorized as outcome-focused motivation due to the emphasis of goal pursuit. Table 3.1 displays the justification for how each extrinsic motivation item was selected and adapted to be outcome-focused motivation. Items were adapted to outcome-focused motivation by substituting “in this chemistry class” as the subject of the students’ motivation. All outcome-focused motivation items in the original POMI were adapted from extrinsic motivation items from current motivation instruments. Some wording may differ from original items due to the inherent focus on their current chemistry class. This alteration brings a definitive goal that is necessary to define items as process-oriented motivation (Touré-Tillery & Fishbach, 2014).

The intrinsic motivation factor shared similarities with the factor used in current instruments. The significant distinction pertaining to intrinsic motivation (process-oriented) in contrast to current literature intrinsic motivation was a process-centered theme. Thus, intrinsic motivation (process-oriented) is identified as a sub-factor of process-focused motivation. While current intrinsic motivation simply measures how interested or curious the student is about science, the original POMI pairs motivation with the process of doing science, specifically chemistry (Glynn, 2011). Intrinsic motivation (process-oriented) measured curiosity and interest distinctly based on the process of the goal pursuit, completion of chemistry activities (Touré-Tillery & Fischbach, 2014). Items were created to allow students to reflect on their chemistry experiences. All intrinsic motivation items that were part of the process-oriented sub-factor were adapted from intrinsic motivation items taken from peer-reviewed articles that reflected the process of doing chemistry. An item from the original POMI states: “I find the topics discussed in this chemistry class interesting.” This item was adapted from Vansteenkiste (2007) by adding the phrase “in this chemistry”. All original POMI items were adapted and were categorized as process-oriented from their original source paper (Pintric & DeGroot, 1990; Vansteenkiste, 2007). Intrinsic motivation (process-oriented) items fixated on students indulging in the process of learning versus the reward or the goal (benefits of learning). Table 3.2 displays the original intrinsic motivation items, adapted original POMI items, and justification for selection and adaption of each item.

Table 3.1

Outcome-Focused Motivation Item Adaption with Justification

Adapted POM Outcome-Focused Item	Original Extrinsic Item (reference)	Justification
I attend this chemistry class only because I am supposed to do so (Vansteenkiste, 2007).	I am studying because I’m supposed to do so (Vansteenkiste, 2007).	This item was chosen due to its focus on the outcome of the process. The focus for this item is on the expectation of forces outside of the student. Without the expectation, the student may not study. The item was modified to highlight students’ attendance to be the subject in lieu of studying.
I attend this class because without taking chemistry I would not find a high-paying job later on.	Because with only a high-school degree I would not find a high-paying job later on (Liu & Ferrel, 2017)	This item was chosen due to its focus on security of a high-paying job after high school. This item was modified to pair student’s attendance with the importance of finding a high-paying job at some point in life. Thus, the correlation is that students are motivated to attend their chemistry class because it may have on their career salary. In other words, an attendance motivator may also be in the importance of chemistry in relation to a student’s career after high school.
I am only motivated in this chemistry class because we get grades (Amabile, 1994).	I am strongly motivated by the grades I can earn (Amabile, 1994).	The outcome or reward of grades is the reason for item selection. Modification of this item added students’ current chemistry class to the subject of their motivation. Strongly was substituted based on its ambiguity; students may not be able to quantify how motivated they truly are by grades in their chemistry class. However, substitution of only shows that grades are the singular motivator within their chemistry course.
I took this chemistry class because it will look good on my high school transcript.	I am keenly aware of the GPA goals I have for myself (Amabile, 1994)	The outcome or reward of Grade Point Average (GPA) is the reason for item selection. Modification of item added students’ current chemistry class to the be the subject of their motivation. Additionally, wording was modified to give students a visual of their high school transcript and how their chemistry class may affect it.
I am strongly motivated by the recognition I can earn from other people in this chemistry class.	I am strongly motivated by the recognition I can earn from other people (Amabile, 1994).	The outcome or recognition was the reason for item selection. Modification of item added students’ current chemistry class to the subject of their motivation.

Table 3.1 (continued)

Outcome-Focused Motivation Item Adaption with Justification

I am strongly motivated to participate in this chemistry class when the teacher pay attention to me.	I participate in science courses to get a good grade (Harackiewicz, 2008). I am strongly motivated by the recognition I can earn from other people (Amabile, 1994).	Both original items are outcome focused motivators. However, these items were combined to focus on participating and recognition specified to their instructor. This item combined two goals outside of the process of chemistry

Note. Four-point Likert response scale utilized for all Original POMI items: Strongly Disagree (1), Disagree (2), Agree (3), and Strongly Agree (4).

Table 3.2
Intrinsic Motivation (Process-Oriented) Item Adaption with Justification

Adapted POM Intrinsic Item	Original Intrinsic Item (reference)	Justification
I find the topics discussed in this chemistry class interesting.	I think that what we are learning in this class is interesting (Pintrich & DeGroot, 1990).	The item was chosen due to its regard for student interest in the concepts, homework, classwork, activities, lessons, labs in chemistry. Class was specified to chemistry, which eliminated competing motivations from previous science courses. Moreover, chemistry is a unique class compared to their previous science.
I like this chemistry class because it is fun.	I'm studying because it's fun (Vansteenkiste, 2007).	This item was chosen due to inherent intrinsic nature. Enjoyment, interest, curiosity are all descriptors of naturally intrinsic items (Ryan & Deci, 2000). The item was modified to include this chemistry class to localize motivation.
I enjoy completing assignments for this chemistry class because they are exciting.	I'm studying because it's an exciting thing to do (Vansteenkiste, 2007).	This item was chosen due to inherent intrinsic nature. Enjoyment, interest, curiosity are all descriptors of naturally intrinsic items (Ryan & Deci, 2000). The item was modified to focus on assignment completion in their chemistry class.
I enjoy this class because I am highly interested in doing chemistry.	I'm studying because I am highly interested in doing this (Vansteenkiste, 2007).	This item was chosen due to inherent intrinsic nature. Enjoyment, interest, curiosity are all descriptors of naturally intrinsic items (Ryan & Deci, 2000). The item was modified to replace this with chemistry to ensure focus of interest was their current chemistry course.

Note. Four-point Likert scale utilized for all Original POMI items: Strongly Disagree (1), Disagree (2), Agree (3), and Strongly Agree (4).

Means-focused motivation was a sub-factor of process-focused motivation that brings a novelty to the education literature. This factor only appears in the psychology literature. How the process of goal pursuit is approached plays an important role in motivation (Touré-Tillery & Fishbach, 2011). However, this has never been considered in any motivation instrument. According to Touré-Tillery and Fischbach (2011), means can be defined as any activity contributing to goal attainment. The science and engineering practices that are embedded in the new science standards represent a means to achieving a goal. The means-focused motivation factor from the original POMI aimed to measure all eight SEP's. According to Touré-Tillery and Fishbach, (2011), using proper means is important for learning new skills or mastering old ones. These items evaluated a student's drive to learn science in a correct manner by mastering techniques, skills, and practices (Touré-Tillery & Fishbach, 2014). Items for this motivational factor were created to measure the means, the SEPs, associated with completing any chemistry activity. There were two sets of means-focused motivation items in the original POMI, original items and expert validated items. The original items had "I enjoy…, and I like…, which were commonly used stems in current intrinsic motivation items (Deci & Ryan, 2000). An example of an original item is "I like communicating my results after I have completed an experiment in this chemistry class'. There were seven total original items in Table 3.3. Expert validation items were created to provide a consistent and concise frame for each means-focused motivation item. These items began with "I enjoy this chemistry class more when I get to (insert SEP)". There were eight items with one for each SEP.

Table 3.3

Means-Focused Motivation Items with Justification

Science and Engineering Practice	Original Seven Means-focused Item	Validation Eight Means-focused Item	Application to Instrument
Asking Questions and Defining Problems	I enjoy laboratories in this chemistry class when they allow me to ask questions about the system being studied.	I enjoy this chemistry class more when I get to research problems.	Motivation was driven by the opportunity to inquire and ask questions that enable the student to grasp concepts pertaining to chemistry.
Developing and Using Models	No Original Item exists for this SEP	I enjoy this chemistry class more when I use figures to make sense of the topics in this chemistry class.	Motivation was connected to how models assisted students' understanding while predicting chemistry concepts via computer simulations
Planning and Carrying Out Investigations	I enjoy completing experiments in this chemistry class since they allow me to investigate different problems with my classmates.	I enjoy this chemistry class more when I get to plan and carry out investigations.	Students found enjoyment in data collection and development of their own personal graphs from that data. .
Analyzing and Interpreting Data	Once I have collected data from a chemistry experiment, I like to search for patterns and trends in the data.	I enjoy this chemistry class more when I get to analyze and interpret data.	Students expressed interest while they searched for trends and patterns in their data.
Using Mathematics and Computational Thinking	I enjoy computer simulations that help me understand, predict, and explain concepts in this chemistry class.	I enjoy this chemistry class more when I get to use math and computational thinking such as math expressions and computer simulations.	Student enjoyment in utilizing computer simulations and math equations to help their comprehension of varying chemistry concepts.
Constructing Explanations and Designing Solutions	I like to use evidence in my explanation to support a claim that I have made in this chemistry class.	I enjoy this chemistry class more when I get to construct explanations about a concept.	Using their own evidence or other evidence, students were motivated to support a claim or formulate an explanation about the concept in question.
Engaging in Argument from Evidence	I enjoy creating supporting arguments for my understanding of the concepts addressed by lab in this chemistry class.	I enjoy this chemistry class more when I get to engage in arguments based on scientific evidence.	Students found motivation while defending a claim that connected their evidence with a reason that justified their position on a chemistry concept.
Obtaining, Evaluating, and Communicating Information	I like communicating my results after I have completed an experiment in this chemistry class.	I enjoy this chemistry class more when I get the opportunity to communicate my lab results.	Students enjoyed sharing their results via lab report, discussion, conclusion, for short answer pertaining to a chemistry concept.

Note. Four-point Likert response scale utilized for all Original POMI items: Strongly Disagree (1), Disagree (2), Agree (3), and Strongly Agree (4).

Revised POMI Validation

Content validity. Before the original POMI was administered in Goal 1 of this study, the instrument underwent face validity, a form of content validity, from three process-oriented motivation experts. Each expert completed a survey that had three parts: clarity of each item, average expected response from the target population, high school chemistry students, and item categorization by each factor based on expert comprehension (Appendix C). Finally, experts added any clarification comments that would enhance the survey. The feedback was utilized to change the Liker scale from Never, Sometimes, about half of the time, Most of the Time, and Always to Strongly Disagree, Disagree, Agree, and Strongly Agree. Below, Table 3.4 was created to portray the evolution of each item from the expert validity item survey to the final survey items, the original POMI items, that were administered in Goal 1. After original POMI administration, validation items were added to the survey to ensure that students read each item on the survey. Student surveys that had incorrect answers for these validation items were considered invalid and consequently such student's data was removed from final data collection. There were four total validation items dispersed throughout the original POMI that stated, "Select agree for this statement" or "Select disagree for this statement". Thus, the final version of this instrument (Appendix D), the revised POMI, had a total of 31 items, the 27 items below in addition to four validation items.

Table 3.4

Evolution of Original Process-Oriented Items from Content Validation to Revised POMI Items

Item Number	Item on Survey	Factor	Expert Feedback	Revised POMI Item
1	I like what we learn in this chemistry class, because it is interesting.	Intrinsic	This question is double-barreled and needs to be two separate questions	I find the topics discussed in this chemistry class interesting.
*	N/A	N/A	N/A	Select disagree for this statement
2	I enjoy this chemistry class more when I get to ask questions and research problems.	Means-Focused	This question is double-barreled, students could enjoy question asking but dislike researching problems.	I enjoy this chemistry class more when I get to research problems.
3	I like developing a model, either as a picture or mathematical equation in this chemistry class.	Means-Focused	Students may not understand the word model, a more concise word should be used.	I enjoy this chemistry class more when I use figures to make sense of the topics in this chemistry class.
4	I like this chemistry class, because it's fun.	Intrinsic	This item is in good standing.	I like this chemistry class because it is fun.
5	I enjoy this chemistry class more when I get to develop and use models such as diagrams, drawings, computer simulations or mathematical equations.	Means-Focused	This question is double-barreled, and student may answer based on one of the questions.	This item was removed from the final version of instrument.
6	I like to use evidence in my explanation to support a claim that has been made in this chemistry class.	Means-Focused	The claim that is being supported should be specified.	I like to use evidence in my explanation to support a claim that I have made in this chemistry class.
7	I enjoy doing activities in this chemistry class, because they are exciting.	Intrinsic	The term activities seem ambiguous and needs to be a direct activity.	I enjoy completing assignments for this chemistry class because they are exciting.
8	I enjoy this chemistry class more when I get to plan and carry out investigations.	Means-Focused	This item is in good standing.	I enjoy this chemistry class more when I get to plan and carry out investigations.

Table 3.4 (continued)

Evolution of Original Process-Oriented Items from Content Validation to Revised POMI Items

9	I find this class interesting, because I enjoy doing chemistry.	Intrinsic	This question is double-barreled and needs to be two separate questions.	This item was removed from the final version of instrument.
10	I enjoy laboratories in this chemistry class when they allow me to ask questions about the system being studied.	Means-Focused	This item is in good standing.	I enjoy laboratories in this chemistry class when they allow me to ask questions about the system being studied.
11	I attend this chemistry class, because I am supposed to do so.	Outcome-Focused	Since high school attendance is generally required, adding only in the item will provide a motivation to students' attendance.	I attend this chemistry class only because I am supposed to do so.
*	N/A	N/A	N/A	Select agree for this statement
12	I enjoy this chemistry class more when I get to analyze and interpret data.	Means-Focused	This item is in good standing.	I enjoy this chemistry class more when I get to analyze and interpret data.
13	I attend this class, because without taking chemistry I would not find a high-paying job later on.	Outcome-Focused	This item is in good standing.	I attend this class because without taking chemistry I would not find a high-paying job later on.
14	I enjoy this chemistry class more when I get to use math and computational thinking such as math expressions and computer simulations.	Means-Focused	This question is double-barreled and needs to be two separate questions	I enjoy this chemistry class more when I get to use math and computational thinking such as math expressions and computer simulations.
15	I am only motivated in this chemistry class, because we get grades.	Outcome-Focused	This item is in good standing.	I am only motivated in this chemistry class because we get grades.
16	I enjoy computer simulations that help me understand, predict, and explain concepts in this chemistry class.	Means-Focused	This item could be three separate items that would focus on understanding, prediction and explanation.	I enjoy computer simulations that help me understand, predict, and explain concepts in this chemistry class.
17	I enjoy this chemistry class more when I get to construct explanations about a concept.	Means-Focused	This item is in good standing.	I enjoy this chemistry class more when I get to construct explanations about a concept.
18	I enjoy engaging in arguments for the understanding of the concepts addressed by labs in this chemistry class.	Means-Focused	Item is verbose and needs to be simplified.	I enjoy creating supporting arguments for my understanding of the concepts addressed by lab in this chemistry class.

Table 3.4 (continued)

Evolution of Original Process-Oriented Items from Content Validation to Revised POMI Items

19	I took this chemistry class because it will look good on my high school transcript.	Outcome-Focused	This item is in good standing.	I took this chemistry class because it will look good on my high school transcript.
20	I enjoy this chemistry class more when I get to engage in arguments from scientific evidence.	Means-Focused	Scientific evidence is ambiguous and consider replacing "from" with "related to" in this item.	I enjoy this chemistry class more when I get to engage in arguments based on scientific evidence.
*	N/A	N/A	N/A	Select disagree for this statement
21	I like collecting data from chemistry experiments in this class and communicating my results after I have completed the experiment.	Means-Focused	Double-barreled question students could like collecting data but not communicating results.	I like communicating my results after I have completed an experiment in this chemistry class.
22	I enjoy this class, because I am highly interested in doing chemistry.	Intrinsic	Double-barreled question student could like what they learn, but not find it interesting.	I enjoy this class because I am highly interested in doing chemistry.
23	I am strongly motivated by the recognition I can earn from other people in this chemistry class.	Outcome-Focused	This item is in good standing.	I am strongly motivated by the recognition I can earn from other people in this chemistry class.
*	N/A	N/A	N/A	Select agree for this statement
24	I enjoy completing experiments in this chemistry class since they allow me to investigate different problems with my classmates.	Means-Focused	Double-barreled question students could like experiments but may not enjoy inquiry.	I enjoy completing experiments in this chemistry class since they allow me to investigate different problems with my classmates.
25	Once I have collected data from a chemistry experiment, I like to search for patterns and trends in the data.	Means-Focused	This item is in good standing.	Once I have collected data from a chemistry experiment, I like to search for patterns and trends in the data.
26	I participate in this chemistry class so that the teacher pays attention to me.	Outcome-Focused	Consider adding "I am strongly motivated by" in this item.	I am strongly motivated to participate in this chemistry class when the teacher pays attention to me.
27	I enjoy this chemistry class more when I get the opportunity to communicate my lab results.	Means-Focused	It is important to specify how students are communicating their data.	I enjoy this chemistry class more when I get the opportunity to communicate my lab results.

Note. *Represents validation items in the revised POMI

Four-point Likert response scale utilized for all Original POMI items: Strongly Disagree (1), Disagree (2), Agree (3), and Strongly Agree (4).

Research Design to Achieve Goal 1

Context of the Research Study for Goal 1

Setting. This study was executed in the place of employment of the researcher. There are 2,000 total students, 55% white, 30% black, 10% Hispanic and 5% other in terms of demographics of the target population for this study. The research study for Goal 1 included a sample size of approximately 250 students from both honors and on-level chemistry after the first week of school had commenced (August 12th, 2019). The control group, honors chemistry students, and experimental group, on-level chemistry students, had six classes respectively that averaged around 28 students per class.

Data Collection

Obtaining of student and parental consent. All data collection methods utilized in this study were preceded by appropriate approval at the researcher's university and place of employment, school district. A human subject's approval was obtained from Kennesaw State's Institutional Review Board (IRB) (Appendix E) and then presented to Fulton County Schools District research department (Appendix F). Fulton County Schools District research department accepted and ratified all details of this dissertation with a confirmation of approval via a research agreement (Appendix F). Consequently, all data collection procedures commenced at the researcher's locale beginning with parental consent and student assent forms being solicited to all eligible students.

Parental consent for this study was sent home with the syllabi on the second day of school (August 13th); thus, the student-given deadline was August 18th to ensure that student consent was received before the start of the research for Goal 1. Parental consent forms were accepted up to September 2nd (see Appendix G). Parental or guardian consent was received via a signed permission form. Each student's assent form was attached to their consent form and submitted after signature together to the participant's chemistry teacher (see Appendix H). Consent/assent forms were collected, recorded by the researcher, and finally stored in a safe location. Any students that did not provide both a student assent and parental consent forms were pulled from this study's data analysis

Sources of data collection. Being a chemistry teacher at the locale in this study permitted the researcher to have unlimited access to complete the appropriate data collection. The first source of data that was required to answer Research Question 1 and 1a came from the VASI. The VASI administration occurred between August 19th and September 3rd. The VASI was a qualitative survey that was coded with a rubric. The online survey was administered via Qualtrics. The VASI online survey was accessible to students via Google classroom, an online classroom website. The survey was done during class only on the first day of VASI administration, but absent students could complete the survey until September 3rd. A sample of students were interviewed in order to demonstrate valid data from the VASI administration. The purpose of the interview was to ensure that students had a full understanding of each question in the VASI instrument. The interview protocol (see Appendix I) included a think-aloud process that allowed the students to share their thoughts for the selected questions with the interviewer. The interview selection process followed that used for the Science Motivation Questionnaire (SMQ) in which 6% of the sample of study participants were invited to participate in this interview protocol (Glynn, 2009). Based on the approximate number of 250 participants in this study, 6% accounted for 13 students. Six students were randomly chosen from the experimental group (on-level chemistry), and seven students were chosen at random from the control group (honors chemistry). Chosen students were notified by their teacher and indicated best date and time based on four choices: lunch, before school, after school, or during study hall time. Each interview took about 10 minutes. All VASI validation interviews were conducted during the dates of September 6th and September 20th. Finally, the interview responses were transcribed and kept on a password protected One-Drive account for later data analysis.

The second source of data pertaining to Research Question 1 was the original POMI. The original POMI administration occurred between September 6th and September 20th. The administration of this instrument was delayed until students could adequately reflect on their chemistry class experience. The online survey was administered via Qualtrics. The original POMI was accessible to students via Google classroom, an online classroom website. The survey was only completed in class on September 6th and was completed outside of the classroom on other days of administration. Students were instructed to complete the survey by September 20th. Validation interviews were used again to modify any ambiguous wording or misunderstandings of the items that students may experience while completing the POMI. A different sample of 12 students were interviewed to help validate the POMI data. The interview selection process mimicked the process for the VASI, which yielded 12 individual interviews. Instead of being chosen at random, students were selected based on their current grade in the class on September 6th. Six total students were chosen that have the highest grade in the experimental group and the same was done for the control group. Afterwards, six other students were selected with the lowest grades from the experimental and control groups. Student selection was based on grades to assess any possible correlation between means-focused motivation scores and student performance in chemistry. Chosen students were notified by their teacher and indicated best date and time based on four choices: lunch, before school, after school, or during study hall time. Each interview took about 10 minutes. All POMI interviews were completed between September 23rd to October 7th.

A four-part interview protocol was completed with this sub-sample of students. In Part 1, a think-aloud protocol on the means-focused motivation items was utilized to ensure student responses matched their interview correspondence (See Appendix J). Students simply walked the interviewer through their thought process while taking the POMI. Part 2 involved students describing each item in their own words to ensure student understanding pertaining to each means-focused motivation item. Part 3 had students matching each means-focused motivation item to an in-class scenarios to measure students' ability to classify each item with the appropriate classroom application. In Part 4, each item was ranked in decreasing motivational order to provide a relative list of items that students deemed motivated them the most in their chemistry class.

Goal 1 Data Analysis Methods

Both questions, research question 1 and 1a, which pertain to Goal 1 data analyses were conducted in STATA (StataCorp, 2019).

Content validity. Content validity was performed on three separate occasions: twice for the POMI and once for the VASI. Both the VASI and the POMI content had to be deemed appropriate for the population before utilization of instrument scores. First, three process-oriented motivation experts completed a survey to ensure that each POMI item was clear, concise, and reasonable for high school students. This technique is also known as face validity, which empowers the experts to confirm that the content on survey matches the intent of survey. Experts were enabled to provide feedback on each item and advice was solicited on how to improve the instrument. Survey feedback was utilized to improve the instrument by editing items to accurately represent each type of motivation, which formed the original POMI.

The second check came from a student subsample four-part interview that examined POMI content validity in which findings were compared to students' POMI survey results. These results were then analyzed to ensure content validity of means-focused motivation items (Glynn, 2009). The four-part interview utilized a subsample of each group, control and experimental, which emphasized the means-focused motivation items that suggested valid and reliable data. In the first part of the interview, student interview responses were matched with the corresponding means-focused motivation responses to ensure that both the interview and the survey had congruent answers. The second part included student descriptions of the selected means-focused motivation items. Students' descriptions were then compared with an objective of the item. Both description and objective were compared to determine student understanding of each item. The third part had students match the means-focused motivation items with in-class scenarios. Students interview answers were graded against a key, item and scenario correctly matched, to quantify accuracy on the seven means-focused motivation items. Lastly, students ranked all means-focused motivation items by decreasing motivation. The first and last motivation items on their list were compared to their POMI interview Likert response, strongly disagree to strongly agree, for congruency between most motivational item and least motivational item POMI interview response.

The third check or content validity assessed the VASI content validity which utilized interview data. Interview responses were matched with VASI responses to check for compatibility with the population for this study. The purpose of the analysis was to determine the legitimacy of the instrument's responses.

Construct validity. Construct validity was assessed by several steps in succession. The specialized form of Structural Equation Modelling (SEM) utilized was the Confirmatory Factor Analysis (CFA). The original POMI had two sets of means-focused motivation items, the original items and the expert validated set. Model 1 had included eight expert validation means-focused items, while Model 2 had the seven-original means-focused items discussed previously in the original POMI construction. A CFA was run for these two separate POMI models. Therefore, Model 1 and Model 2 was evaluated by student responses to distinguish the best set of means-focused motivation items, which were then used to compose the final revised POMI. This route ensured that the means-focused motivation items selected had data that suggested construct validity. Model 1 and Model 2, shown in Figure 3.1 and Figure 3.2, utilized three hypothesized factors, which were examined to find exactly how correlated each item was to its respective factor (Glynn, 2011). In this study, the three process-oriented motivation factors are intrinsic, outcome-focused, and means-focused motivation. For example, Figure 3.1 displays Model 1 that had six outcome-focused motivation items, four intrinsic motivation items, and eight means-focused motivation items. However, Model 2 contained the same identical items for outcome-focused and intrinsic motivation but means-focused motivation has seven distinct items. Below, Figure 3.2 provides a graphic of both models for the original POMI and illustrates how each factor relates to one another. Intrinsic motivation and means-focused motivation contain a double-headed arrow since they were both types of process-focused motivation. Outcome-focused motivation was the opposite of those two factors, so it stands alone on the top of the figure.

The necessary steps for the CFA began with the first index the normed chi-square, which assessed goodness-of-fit. An obtained chi-square value was divided by the degrees of freedom to create a normed chi-square, which reduced any affect from sample size on the chi-square test (Glynn, 2011). The recommended value for a normed chi-square was between 1.0 and 3.0. The second index was the standardized root mean square residual (SRMR); this ranged from 0 to 1. The recommended value for a SRMR was less than 0.08 (Kline, 2012). Next, goodness-of-fit (GFI) index, ranged from 0 to 1, made an approximation for purporting the variability in sample covariance matrix in each model (Glynn, 2011). A good model fit must score a minimum of 0.90. The fourth index, the Bentler comparative fit index (CFI), compared model to a null model that made a zero population for manifest variables. The acceptable model fit for CFI was 0.900 or above (Kline, 2012). Tucker Fit Index (TFI) mimicked the CFI with an acceptable model range of greater than 0.900. Lastly, the Root Means Square Error of Approximation (RMSEA) assessed the lack of fit within population data for the model. The RMSEA was considered a good fit when it is less than 0.005 (Kline, 2012).

Figure 3.1. *Model 1 of process-oriented motivation factors with respective items*

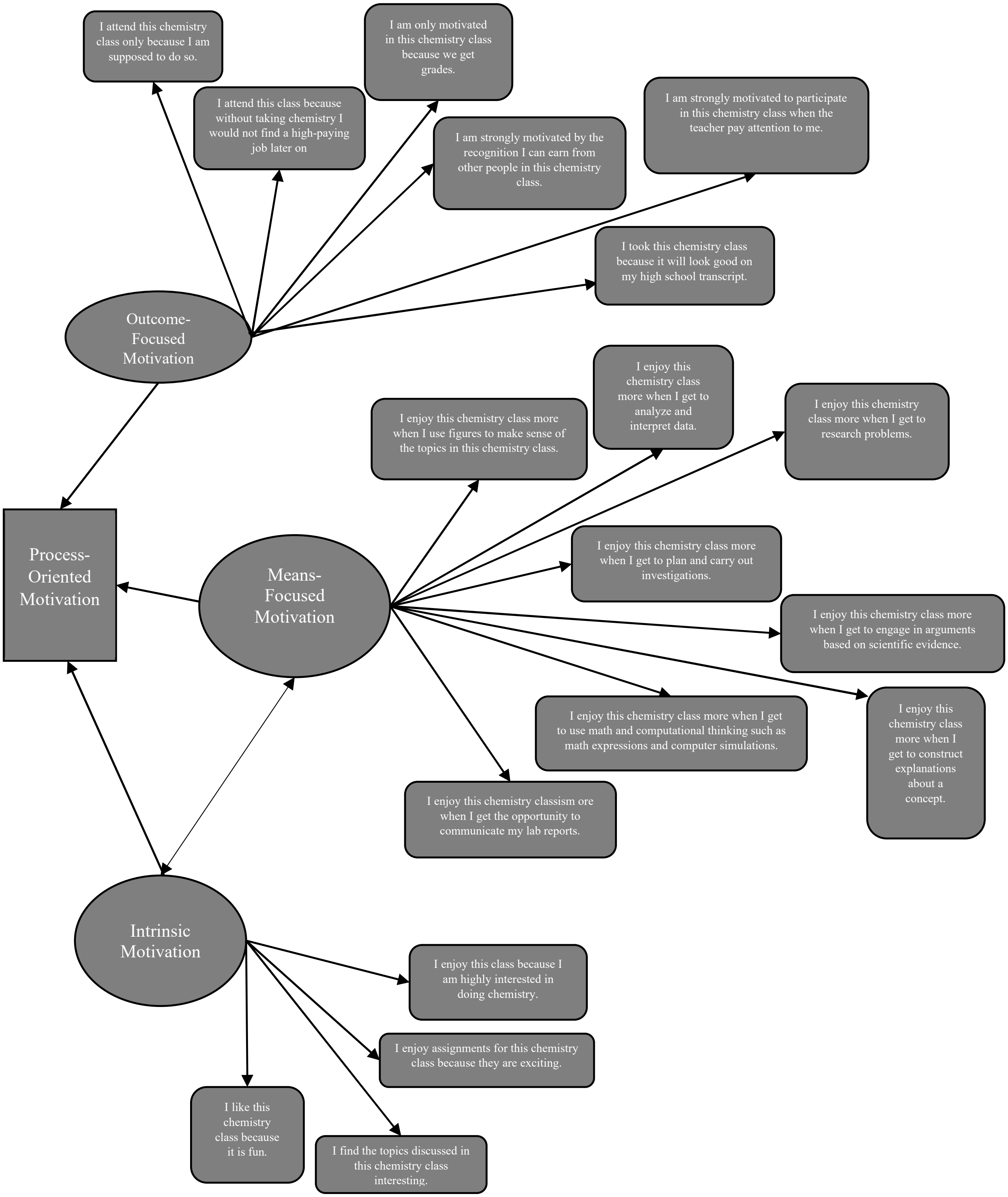

Figure 3.2. *Model 2 of process-oriented motivation factors with respective items*

Convergent validity. A convergent validity test was run to assess any association between the VASI scores and the revised POMI (means-focused motivation scores). VASI and revised POMI survey response data was utilized in order to undergo convergent validation between both instruments. A Kolmogorov-Smirnov test was run for normality to check for normal distribution among both sources of data, VASI and POMI scores. A significant test would lead to a Spearman correlation, while a non-significant test would culminate in a Pearson correlation. Students' VASI responses were coded based on a published rubric in order to categorize results (Appendix K). The dichotomous coding, naive or informed, was translated into numerical values or zero for naive and one for informed rankings. This allowed an individual's score to be summed up to obtain a one numerical value that represented their VASI score (zero or one). The revised POMI had a four-point Likert Scale, (strongly disagree, disagree, agree, strongly agree) which was automatically scored from online Qualtrics platform. The means-focused motivation factor was the only factor compared with VASI factor due to its novelty and theoretical similarities. A correlation test was run on both factors, which ranged from -1 to 1. A strong correlation, 0.70, between means-focused motivation scores and VASI scores would indicate similarity between the factors (Schober & Boer, 2018). A correlation between 0.40 to 0.69 would indicate a moderate relationship between both variables, but a coefficient below 0.39 would be considered a weak coefficient. A statistically significant value of 0.05 or less would suggest there was significance in the correlation that was found between variables. Therefore, data that confirms a relationship between these factors, convergent validity, would assist in making the novel means-focused motivation factor credible.

Predictive validity. Predictive validity describes instrument data that demonstrated high correlations, which may predict future criterions (Heale & Twycross, 2015). The data from the revised POMI was evaluated to find correlation with a chemistry assessment taken after implementation of ADI, i.e., does the revised POMI correlate with student performance on a chemistry lab report? This study paired chemistry lab report scores with process-oriented motivation scores to demonstrate how motivation may or may not predict student achievement (Tuan & Chin, 2005). A Kolmogorov-Smirnov test was run for normality to check for normal distribution among both sources of data, student achievement and means-focused motivation scores. A significant test would lead to a Spearman correlation, while a non-significant test would culminate in a Pearson correlation. The chosen correlation analysis tested both variables means-focused motivation scores and students' chemistry lab report scores (Tuan & Chin, 2005). A high correlation coefficient between variables would be an example of data demonstrating predictive validity between motivation and student achievement (Heale & Twycross, 2015).

Reliability. As the instrument developer, it was necessary to identify sources of measurement error that were detrimental to instrument scores (Kimberlin & Winterstein, 2008). Thus, POMI responses were utilized to test the reliability of the POMI and helped identify any sources of error. A Cronbach alpha was computed to ensure that all items were consistently measuring process-oriented motivation (Kimberlin & Winterstein, 2008). Each item was evaluated and expected to be consistent with each other to ensure that all items were not only testing motivation, but also tested motivation in terms of a process. Cronbach alpha evaluated corresponding items for consistency within each POMI factor. (Kimberlin & Winterstein, 2008). Lack of consistency or items that had a weak correlation, less than 0.40, would be considered for realignment (Gliem & Gliem, 2003). An example of an alteration would be a mean-focused item being realigned as an intrinsic motivation.

Inter-rater reliability occurred between the researcher and a Chemistry Education professor to establish consistency for VASI coding using eight students split evenly between control and experimental group. Both educators went through eight students VASI responses coded and scored them based on the VASI rubric (see Appendix P). Following the first round of coding, differences were discussed until a common understanding of the coding scheme was reached. A second round of coding eight additional students VASI results ensued. This second round of coding resulted in 93% agreement between the two coders, or 83 out of 88 items were scored the same by scorers. Completion of inter-rater reliability was necessary to authenticate the researcher's ability to accomplish two feats: establish an appropriate rubric and develop internal grading consistency. Thus, inter-rater reliability was established, consequently the researcher's scoring of the student VASI results was concluded to be reliable.

Research Design to Achieve Goal 2

If data from the revised POMI was validated and deemed reliable, it could then be used to study how process-oriented motivation affects using various teaching pedagogies. According to the NRC (2012), the new science curriculum facilitates students' mastery of the eight practices and may lead to student motivation to learn science. According to Ryan and Deci (2000), motivation is often correlated to student performance. Results from Goal 2 were imperative in determining if instruction that was based on the *Framework for K-12 Science Education* had been effective at increasing student motivation and achievement towards learning chemistry. Therefore, the results from Goal 2 addressed two gaps that are present in the literature: adding research to the science education literature regarding student motivation and measuring how student motivation toward science may be affected by instructional practices that emphasize the process of doing science.

Context for Goal 2

Population. The study for Goal 2 employed the same exact sample of students enrolled in honors and on-level Chemistry. However, students were excluded from the study that lacked at least one of the following: consent/assent form, original POMI administration, and VASI administration .The intervention that was utilized for Goal 2 was ADI and assisted in answering Research Question 2a and 2b for this study.

Teaching pedagogy. Pacing of instructional material intersected for both honors and on-level chemistry at the mole, unit for research study for Goal 2. Both group's students learned how to calculate molar mass and go to moles from particles, volume, and grams. Students were responsible for knowing percent composition, calculating percent contribution for each element in a compound. This unit lasted about three weeks, and the lab implementation occurred during the last week of instruction after students learned how to calculate molar mass and convert to and from the mole of different compounds. Four SEPs are present in ADI labs: planning and carrying out an investigation (Practice #3), analyzing and interpreting data (Practice #4), argumentation (Practice #7), collection, evaluation, and communication of information (Practice #8). Thus, the experimental group utilized and engaged directly in these four SEPs, while the control group only engaged in one (Practice #3).

The ADI lab was centered around students developing their argumentation (Practice #7) from scientific evidence pertaining to a laboratory experience (Grooms & Enderle, 2015). Unit placement of this lab empowered students to utilize the SEP's and apply their chemistry knowledge to label various substances using only their mass. The four SEP's used in the ADI lab aligned with the *Framework*, which made ADI an instructional strategy that is believed to motivate students.

The specific lab that was investigated focused on the Law of Conservation of Mass and was executed in chemistry labs at the researcher's locale.

Honors chemistry schedule (control group). Day one commenced with the following: planning and creation of a procedure. Students were in cooperative groups and collaboratively wrote a procedure to answer the guiding question, what is the identity of each bag's content? Upon completion of the lab procedure creation, students had their procedure signed off by their chemistry teacher. If the procedure was not appropriate to obtain necessary lab results, then students had to revise their procedure until it was deemed acceptable by their chemistry teacher. On day two, students were in the same groups as the planning step but executed their lab procedure and collected results. Results were filled out in a pre-populated table in their lab packet, and students answered questions from their observations of the lab as well (Appendix L). Observations described the number of grams calculated for each unknown substance. On day three, students analyzed their results and discussed the conclusion from their data. Student analysis was calculation of the molar mass for each unknown substance utilizing grams collected and given moles labeled on each bag. In addition, student analysis involved the molar mass calculation of each unknown substance by dividing the given number of moles, on the container, by weighted mass of unknown substance. Each group finalized and then put their claim, evidence, and rationale in their lab packet to help guide them throughout their lab report. Their claim was the answer to their guiding question based on their results. Evidence was students' collected data with analysis and the rationale was their justification of how the evidence connected with their claim. Finally, students then started typing their lab report individually based on their results and their agreed upon claim, evidence, and reasoning. Their lab report included three sections: introduction with guiding question, the method, and an argument (claim, evidence, and reasoning). On day five, students submitted their final lab report, which was two days later at 11:59 pm. Students' chemistry lab reports were utilized as the assessment data for this study.

On-level chemistry schedule (experimental group). The first step was student identification of the task. Students were given a packet that had the guiding question for their lab (see Appendix M). Based on their answer to the guiding question, students had to create a teacher authorized procedure. On day two, students completed the second step of the model, which was experiment completion with data collection (Practice #3). On day three, students completed the third step, creation of an argument via data analysis (Practice #4). Students constructed an argument to defend their data collection that included: claim, evidence, and rationale (Walker & Sampson, 2012). Day four included the fourth step, which implemented a small group argumentation session (Practice #7). Each group prepared for the argumentation session by putting their claim, evidence and rationale on a six-foot by four-foot white board. Collaborative groups shared their arguments with other groups that critiqued their board to provide constructive feedback. The intent of the argumentation session was for each group to collect feedback that enabled them to improve on their argument (Walker & Sampson, 2012). In the fifth step, completed on day five, original student groups met to discuss what they learned from the argumentation session. Students then modified their tentative argument as necessary. After modifications were completed, a teacher-led class discussion ensued in which students explained what they learned about the phenomenon in question. The point of emphasis for this group council was to improve the reasoning or justification of each group's claim. The argumentation session with peers along with a debriefing roundtable with the chemistry teacher was exclusive to the experimental group students. On day six, the experimental group completed the sixth step, student formation of a basic report. Lab report formation empowered students to learn to transform their data into evidence, which improved the quality of their science argument (Walker & Sampson, 2012). The seventh step, day seven, involved a double-blind peer review of students' basic reports (Practice #8). Each student submitted three blind reports, copies of their basic report without names, and those reports were given to each lab group with a peer-review sheet. Each report was passed or failed by the peer reviewer based on the peer review rubric (see Appendix O). The last step was the submission of students' lab report, which occurred two days after students received feedback from the peer-review session. Students had the option to revise their reports based on feedback and comments given to them on their draft or they chose to submit their paper without revisions. Peer-review editing was also unique to the experimental group. Both original and final drafts were submitted to their teachers for final evaluation. Students' Chemistry lab reports were utilized as the assessment data for this study.

Data Collection

ADI is a form of instruction that attempts to develop students' arguments and exploratory practices. If students took a chemistry test, their score would not be indicative of these practices. All students' scores involved in both groups were quantified by the standard rubric used for ADI lab reports (Appendix N). The ADI rubric was created to effectively measure students' ability to create substantial scientific arguments from lab data (Grooms & Enderle, 2015). Argumentation from evidence involves planning and carrying out an investigation (Practice #3), obtaining, evaluating, communicating information (Practice #8), and analyzing data (Practice #4) (Grooms & Enderle, 2015).

Data necessary for Goal 2 included the student responses to the revised POMI and the students' lab report to assess chemistry achievement that concluded the instructional unit for the mole. Students from both control and experimental group lab reports were graded with the same rubric. The control group and experimental group students answered questions from their lab packet as they executed their experiment. Students used this packet to help them write their lab report as it contained their observations, data, and analysis for the lab.

Administration of the revised POMI. The second survey administered was the revised POMI that measured students' initial process-oriented motivation pertaining to chemistry. During Goal 1 of this study, the original POMI was administered to students to demonstrate that this instrument provided valid data for this population. Based on results, the original POMI was altered to ensure that students could answer each item to the best of their ability. Students completed the revised survey online a month before the unit. This survey was accessible to students via Google classroom. The revised POMI was done during class only on the first day. Students who missed the first day completed the revised POMI up to the fifth day. However, after the fifth day, the revised POMI was closed.

Student administration of the revised POMI. Students took the revised POMI before the lab to measure their growth of process-oriented motivation pertaining to chemistry about a month before the implementation. All students who completed consent forms, the original and revised POMI surveys, and the lab participated in the second revised POMI administration. The survey was accessible to students via Google classroom and completed within the last five days of the mole unit. This commenced in early November. On the first day of administration, students completed the revised POMI during class. Students who were absent on the first day of administration completed the survey for the following four days. However, on the sixth day and thereafter the final survey was not accessible. Students who missed this administration of the revised POMI were excluded from results.

ADI Lab Report Validity and Reliability

Validity. ADI validation was emphasized by the lab report rubric to ensure that lab report content was effective. Therefore, mastery or a high score with this rubric could indicate student mastery or development within these scientific practices. Since the goal of this study was to measure students' comprehension and motivation of the SEP's, a lab report was deemed a more appropriate avenue to verify students' proficiency (Grooms & Enderle, 2015). ADI rubric has been established in the science education field as effective and appropriate in measurement of the four practices embedded in the lab (Grooms & Enderle, 2015).

Reliability. To ensure that all chemistry teachers were consistent with grading of student lab reports, teachers took five lab reports and graded them individually and compared student scores. All teachers gathered and discussed discrepancies amongst each other on each of the five scores, and this process continued until all five teacher scores are +/- two points within each other's scores. Each round of this grading process utilized a new set of five lab reports that were graded by all teachers. This inter-rater reliability procedure occurred in November before the ADI lab described above.

Goal 2 Data Analysis Methods

Both questions, research question 2a and 2b, which pertain to Goal 2 data analyses were conducted in STATA (StataCorp, 2019).

Question 2 analysis. This study investigated how change in instruction would affect motivation within the experimental group. According to Hake (1998), a normalized gain score metric accounted for classes, e.g., honors versus on level, with different pretest averages in which one class has the potential of having less significant gains due to ceiling effects. A normalized gain score utilized each student's before and after lab motivation score per factor, which determined the growth in motivation. The normalized gain was particularly effective for this research study as two different populations of students were utilized in reference to chemistry class rigor, honors vs on-level, which demonstrated different starting points of initial knowledge. Therefore, normalized gain scores were calculated using the pre- and post-administration of the revised POMI.

In order to answer research question 2a, Kolmogorov-Smirnov test was completed for each class that participated in the study to check for normal data distribution of each revised POMI factor mean. A significant p-value for any class statistic indicated non-normal data distribution pertaining to the initial revised POMI scores, which led to nonparametric tests for Goal 2 analysis. Initial revised POMI mean data represented student's scores for each factor before lab implementation. A Kruskal-Wallis, non-parametric test, examined discrepancies between each individual class that comprised the experimental group. Figure 3.3 shows a breakdown of all classes that contributed to the control and experimental group, respectively. First, the class combination for the experimental group was examined via a Kruskal-Wallis test. This test ensured that all classes that contributed to the experimental group had no significant difference in data before comparing to the control. Second, a non-significant Kruskal-Wallis test result would confirm all classes in the experimental group. In contrast, a significant test would lead to alterations of class involvement followed up with another Kruskal-Wallis test until the experimental group data has displayed no statistical difference. This same procedure ensued the control group. After all control group classes were combined, both groups were compared to ensure no significant difference in group data. A non-significant Mann-Whitney U outcome would indicate the control and experimental groups initial motivation data was statistically similar for each revised POMI factor before ADI implementation. Next, normalized gain score was calculated for the three POMI factors, which culminated in three separate sets of normalized gain score tests. Finally, a Mann-

Whitney U test determined if the difference between normalized gain score of control and experimental group was significant. Effect size was only employed if significance was found.

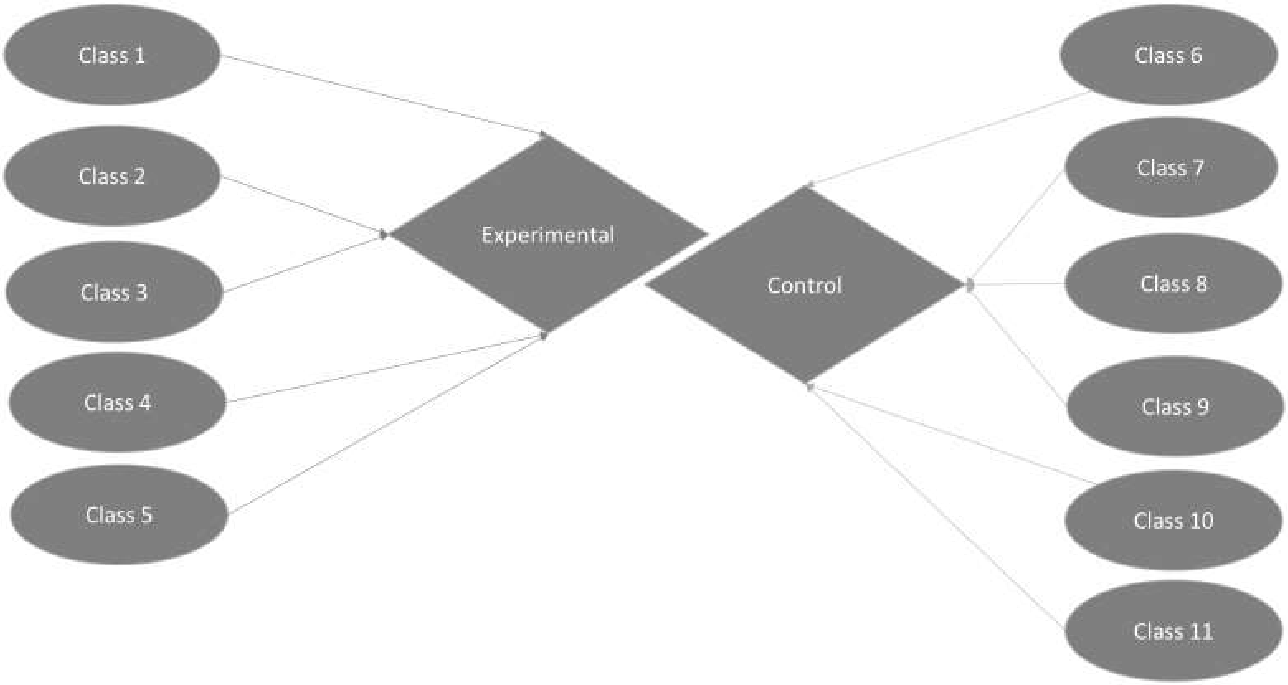

Figure 3.3. *Normalized Gain Score Class combination for Control and Experimental Groups*

Question 2b analysis. Research question 2b required a mediation path analysis to demonstrate ADI's effect on students' process-oriented motivation and how this affects student performance, chemistry lab report scores (Puca & Schmalt, 1999). All students revised POMI scores and chemistry lab report scores underwent a mediation path analysis test to find correlation within the sample. This model was utilized to run a mediation path analysis for each type of motivation: outcome-focused, means-focused, and intrinsic. Students' process-oriented motivation, each revised POMI factor, acted as a mediator that connects a type of instruction with students' achievement. Evidence that validated process-oriented motivation as a mediator between ADI and our experimental group achievements indicated the value of implementation of

Framework for K-12 Science Education aligned practices on students' process-oriented motivation toward chemistry.

Data Security

Students personal information was kept confidential throughout this study by identification of students with assigned numbers paired with the letter S and a number. Students' personal information was anonymously treated. Findings of this study utilized this system of identification to ensure students name were withheld from the published dissertation. All results presented as part of this study aggregated data when possible or this numbering scheme as necessary.

Any paper forms which included: the student assent forms, parental consent forms, lab reports, and lab report rubrics, were stored in a locked filing cabinet at the researcher's enrolled university in the research faculty member's research lab. All electronic data was stored in a designated research folder on a cloud storage and backed up on a password protected research desktop at the same university. Prior to storage all student names were removed and replaced with an appropriate number. All security measures were approved by researcher's university and district of employment.

CHAPTER 4: GOAL 1 AND GOAL 2 FINDINGS

The purpose of Chapter 4 was to utilize findings to establish a version of the POMI as a valid and reliable instrument. This valid and reliable model would then be employed to assess student process-oriented motivation and achievement toward chemistry. Thus, chapter four was split into two parts: Goal 1 and Goal 2. The first half of this chapter, Goal 1, explored the following research questions: (1) How does the data from the original POMI establish appropriate validity and reliability for high school chemistry students? (1a) What is the relationship between a student's Views about Scientific Inquiry (VASI) and the degree to which they are motivated by scientific processes? The second half of Chapter 4 will present the necessary evidence to address Goal 2 via two questions: (2a) What is Argument-Driven Inquiry's effect on high school chemistry students' process-oriented motivation? (2b) What is the mediation effect of process-oriented motivation and relationship between argument-driven inquiry and student achievement? Research questions 2a and 2b were developed to determine if a *Framework* aligned teaching pedagogy, ADI, affected student process-oriented motivation and achievement in high school chemistry.

Goal 1 Findings

How Does the Data from the Process-Oriented Motivation Instrument Establish Appropriate Validity and Reliability for High School Chemistry Students?

Validation and reliability data techniques were utilized to ensure the POMI was an instrument that was precise in its content, items were effective in their measure, and consistently measured process-oriented motivation. Therefore, the following tests utilized POMI and VASI survey data to establish appropriate validity and reliability to determine the best construction of the POMI: content validity, construct validity, predictive validity, convergent validity, and reliability. Table 4.1 displays the Goal 1 research questions along with the purpose and research method or statistical test aligned with each question.

Table 4.1

Goal 1 Research Questions with Respective Analysis

Goal 1 Research Question	Purpose	Research Method/ Statistical Test
Q1: How does the data from the Process-Oriented Motivation Instrument establish appropriate validity for high school chemistry students?	Construct Validity	Confirmatory Factor Analysis
	Content Validity	Triangulation
	Predictive Validity	Pearson Correlation or Spearman Correlation
	Reliability	Cronbach Alpha
Q1a: What is the relationship between a student's Views about Scientific Inquiry and the degree to which they are motivated by scientific processes?	Content Validity	Triangulation
	Convergent Validity	Pearson Correlation or Spearman Correlation
	Reliability	Interrater Reliability*

Note. *Interrater Reliability description and evidence was in Chapter 3.

Construct validity. POMI construct validity utilized a confirmatory factor analysis to inspect the two models, Model 1a and Model 2a, built for the POMI in Chapter 3. This inspection used correlations between POMI factors and their respective items to examine if either model provided credible data on student process-oriented motivation. Goodness-of-fit statistics were employed on data from each POMI model to validate the best model, Model 1a or Model 2a. The best model was administered to students, which evaluated student process-oriented motivation and achievement toward high school chemistry in the second part of this chapter. Therefore, student responses to the 25-item original POMI survey was divvied amongst Model 1a and Model 2a. Model 1a had a total of 18-items split amongst the three POMI motivation factors: six outcome-focused, four intrinsic, and eight means-focused motivation items. Model 2a had a total of 17-items split amongst the three POMI motivation factors: six outcome-focused, four intrinsic, and seven means-focused motivation items. Model 1a and Model 2a contained identical outcome-focused and intrinsic motivation items, while means-focused motivation items were unique to each model.

Progression from Model 1a to Model 1b. Figure 4.1 and 4.2 display Model 1a and Model 1b in addition to correlations between factors and its items based on student responses. A strong correlation has a factor loading of 0.70 or greater, a good relationship was between 0.70 to 0.41, and a weak relationship was less than 0.40 (Keith, 1999). Items that had a factor loading less than 0.40 were deteremined unfit for the model and thus removed (Kine, 2012). Standard error, a measure of statistical accuracy, was located to the right of each POMI item (Kline, 2012).

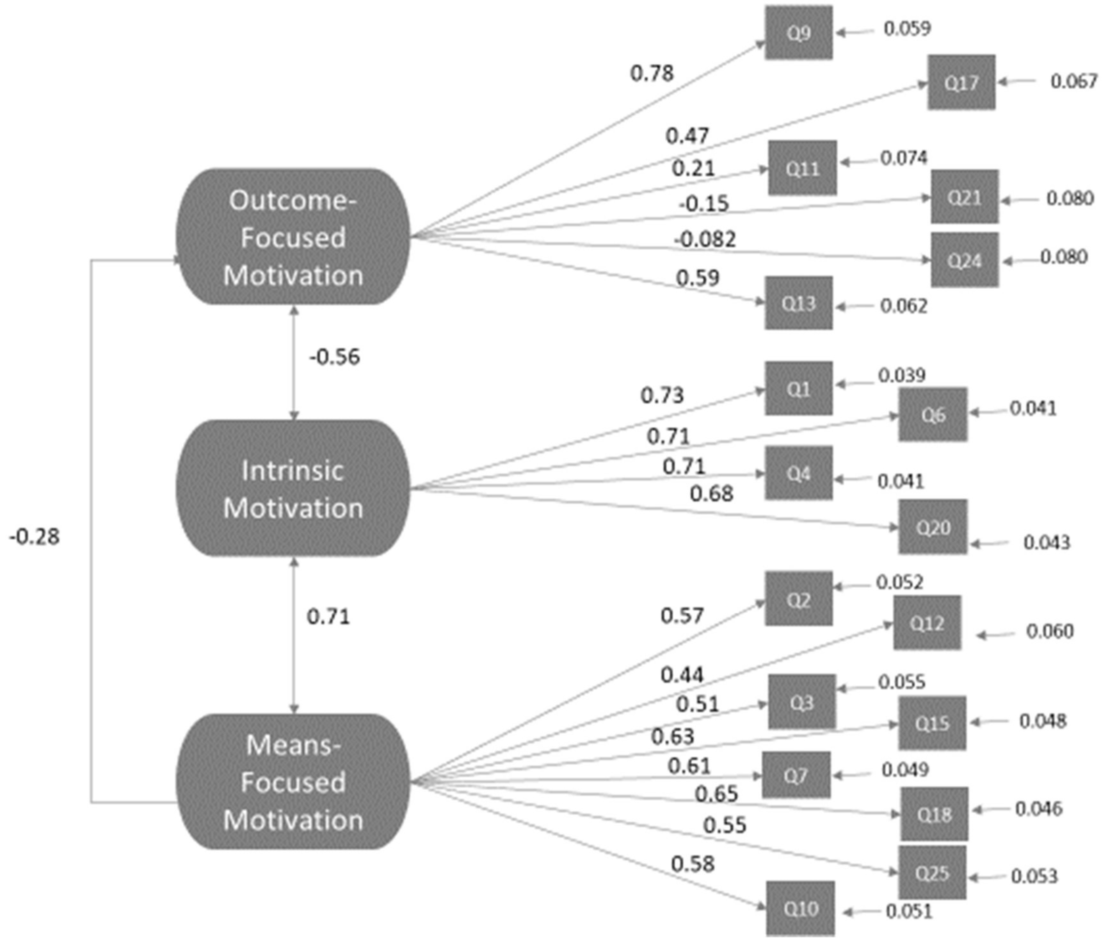

Figure 4.1. *Model 1a Confirmatory Factor Analysis with Factor Loadings and Error*

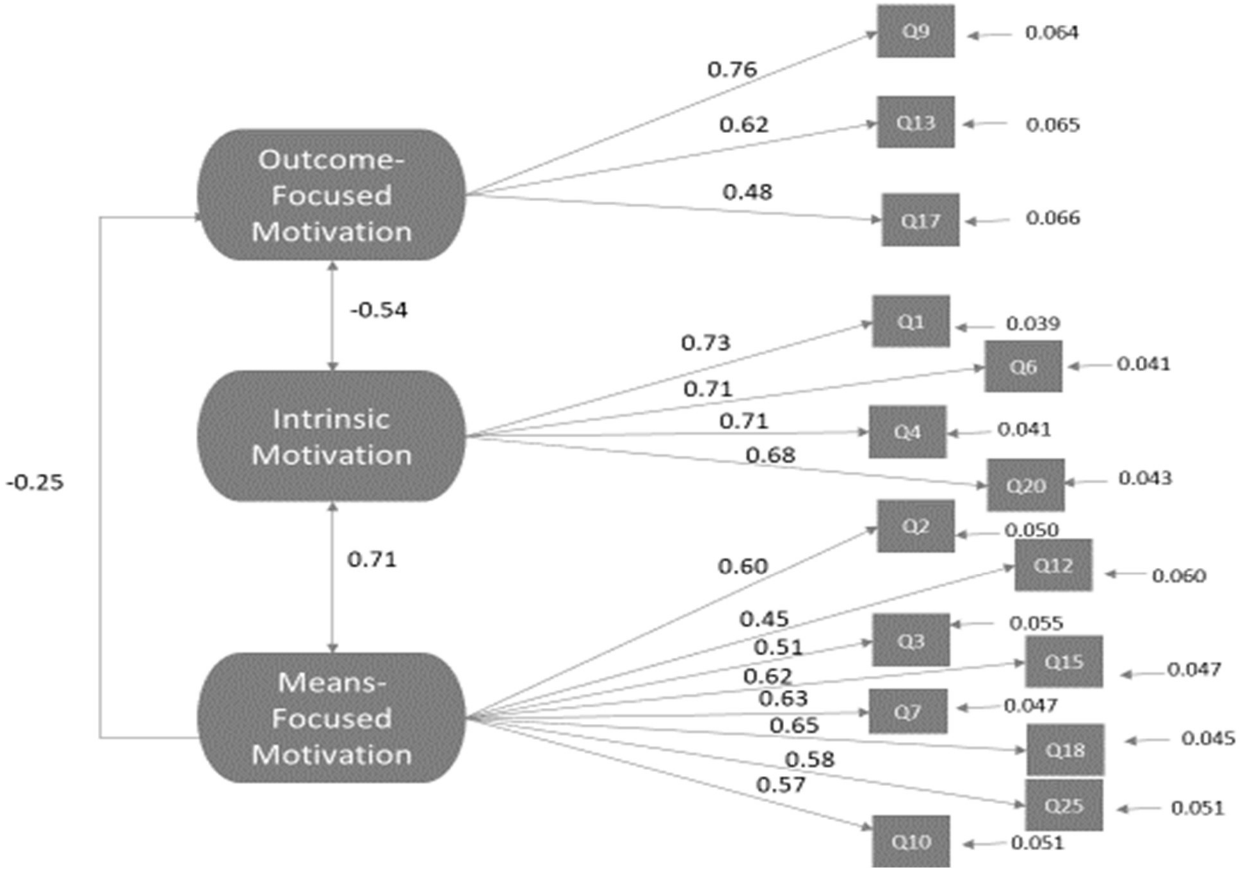

Figure 4.2. *Model 1b Confirmatory Factor Analysis with Factor Loadings and Error*

In Figure 4.2, three items were removed to create Model 1b. Any item with a factor loading less than 0.40 was removed one at a time (Kline, 2012). Values less than 0.40 demonstrated poor correlation within the outcome-focused motivation factor possibly causing a source of misfit in the Model 1a; thus Q11, Q21, and Q24 were removed to produce Model 1b (Kline, 2012). Q11, Q21, and Q24 obtained respective factor loadings of 0.21, -0.15, and -0.05. In other words, data indicated these items do not appropriately represent the intent of outcome-focused motivation items. Item Q11 states "I attend this class because without taking chemistry I would not find a high-paying job later on." Q11 represented an outcome that possibly students had not considered yet since they were still enrolled in high school during data collection. Based on these results, students did not correlate their future career as an outcome they were directly motivated by in this chemistry class. While Q21 states “I am strongly motivated by the recognition I can earn from other people in this chemistry class”. Q24 states “I am strongly motivated to participate in this chemistry class when the teacher pays attention to me.” Finally, Q21 and Q24 represented obtained attention, which was an outcome that one may consider based on an achievement. It was apparent that students did not associate the teacher’s attention as an outcome they were motivated by in this chemistry class. Comparing Model 1a versus Model 1b, factor loadings between factors were not significantly affected by the removal of three items. This was evident by two weakened relationships: outcome-focused motivation to intrinsic motivation and outcome-focused motivation to means-focused motivation. Both relationships experienced a decrease in factor loading from Model 1a to Model 1b.

In Figure 4.2, Model 1b showed that means-focused and outcome-focused motivation had a weak negative relationship with a correlation factor loading of -0.25. This correlation was weaker than Model 1a. Means-focused motivation items were process-focused toward chemistry activities, while outcome-focused motivation items were results-focused toward chemistry activities. The intent of each factor was an inverse relationship and therefore justifies this negative factor loading. However, this weak factor loading indicated both factors may not appropriately measure process-oriented motivation. A large negative factor loading would confirm both factors having opposite intents, while simultaneously measuring process-oriented motivation. In both Figure 4.1 and 4.2, means-focused and intrinsic motivation remained an unchanged means-focused motivation to intrinsic factor loading, which was a result of zero items being removed for either factor. A strong positive relationship between these two factors existed with a factor loading of 0.71, which confirmed both factors are process focused. Model 1b showed a decrease of 0.02 in the factor loading value for intrinsic and outcome-focused motivation, which was considered a moderate negative relationship with a correlation factor loading of 0.54. Outcome-focused motivation is related to the reward of the process, while intrinsic motivation is the enjoyment of the process. These opposite objectives confirmed the negative factor loading between outcome-focused motivation and intrinsic motivation.

Progression from Model 2a to Model 2b. In Figure 4.3, Model 2a shows that means-focused and outcome-focused motivation demonstrated a weak negative relationship with a correlation factor loading of 0.27. Means-focused and intrinsic motivation displayed a good positive relationship with a correlation factor loading of 0.67. Finally, intrinsic and outcome-focused motivation suggested a good negative relationship with a correlation factor loading of 0.56. As described for Model 1a and 1b, the direction of these relationships was expected.

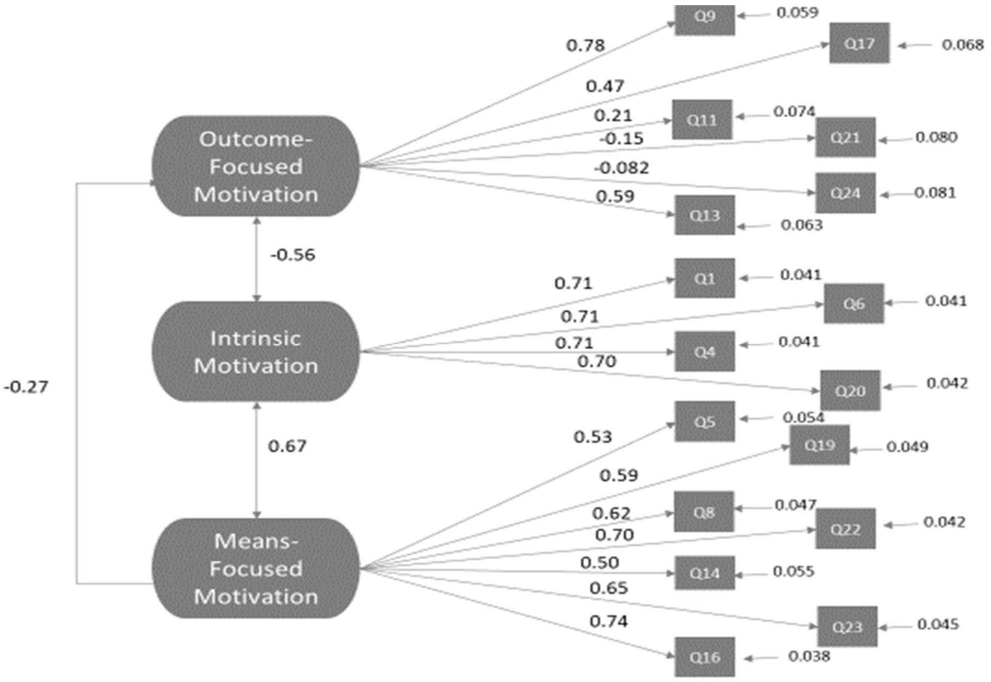

Figure 4.3. *Model 2a Confirmatory Factor Analysis with Factor Loadings and Error*

Model 2a started with 17 items, but three items were removed resulting in an altered Model 2b with 14 items. Comparing the original and altered version, Model 2a and Model 2b, factor loadings between factors were mildly impacted by the removal of three items. In Figure 4.4, means-focused motivation and outcome-focused motivation experienced a factor loading decrease of 0.05. Means-focused motivation and intrinsic motivation remained a good positive relationship with a factor loading of 0.67, which confirmed the intent of these two factors. Finally, intrinsic and outcome-focused motivation decreased in correlation factor loading from -0.56 to -0.54. Items Q24, Q21, and Q11 were removed from Model 2a successively due to factor loadings being under 0.40. These were the same exact items removed from Model 1a to form Model 1b. Therefore, item removal justification utilized above on Model 1b items applied for Model 2b items in the same manner.

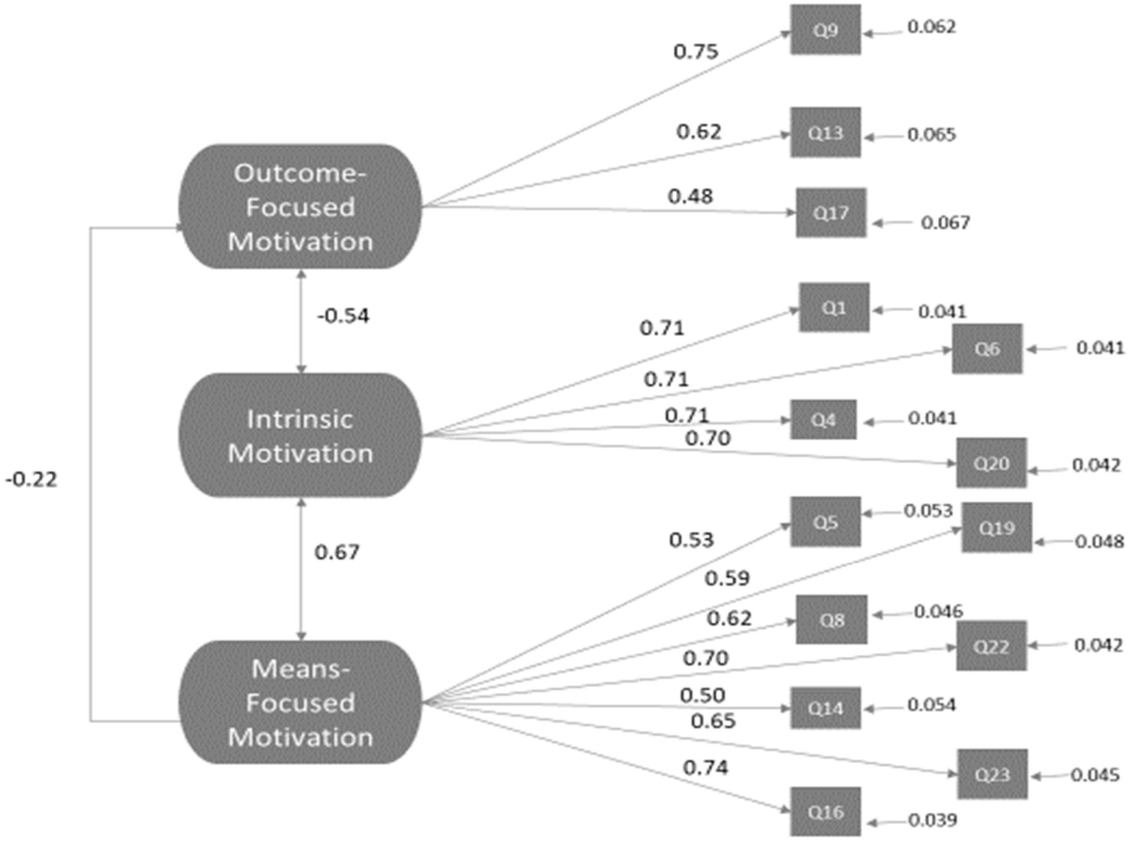

Figure 4.4. *Model 2b Confirmatory Factor Analysis with Factor Loadings and Error*

Comparison Model 1b and 2b. Table 4.2 displayed the comparison for Goodness-of-Fit statistics between Model 1b and Model 2b. All values calculated for goodness-of-fit confirmed that Chi-Square and RMSEA were not acceptable for Model 1b, while Model 2b demonstrated unacceptable statistical values for Chi-Square, RMSEA and TLI. Consequently, these models can be deemed as poorly fit models due to multiple unacceptable values. Results indicated that neither model was capable to provide consistent and credible data pertaining to student's process-oriented motivation for the selected population. Therefore, additional alterations to Model 1b and Model 2b must be completed before another confirmatory factor analysis would verify a valid POMI.

Table 4.2

Goodness-of-Fit Comparison Between Model 1b and Model 2b

Goodness-of-Fit Measure	Model 1b	Model 2b
X^2 (>0.05)	0.00*	0.00*
SRMR (0.08 or below)	0.057	0.059
CFI (.900 or above)	.923	0.917
RMSEA (0.05 or below)	0.059*	0.068*
TLI (Tucker) (.900 or above)	0.907	0.898*

Note. RMSEA = root-mean square error of approximation; CFI = comparative fit index; TLI = Tucker-Lewis index; SRMR= standardized room mean square residual.

Statements in parenthesis refer to number that deems model a good fit by the corresponding indices.

*Statistic is demonstrating a poor model fit

Second CFA Justification. Model 1b and Model 2b did not qualify as good fits to utilize in Goal 2 based on goodness-of-fit measures. Therefore, four validation items were added to the POMI to ensure that all data utilized in the CFA were participants that read each question in the survey. This was a final attempt to ensure findings were an accurate representation of the selected sample's motivation. An example of a revised POMI validation item was "Select disagree for this statement". All four validation items were not considered in relation to the second CFA data analysis. Although failure to respond to the item correctly was used to this disqualify participants from the study. The original POMI with four validated items was renamed to the revised POMI survey. Before Goal 2, participants completed the revised POMI survey. Model 1c and 2c were developed by splitting the mean-focused items, in the same way Model 1a and 1b were developed. The findings were evaluated via CFA and the same three outcome-focused motivation items (Q11, Q21, and Q24) had factor loadings under 0.40; thus, these items were removed from Model 1c and Model 2c. Therefore, Model 1c and Model 2c were disqualified as final POMI models due to poorly fit items. Item removal generated two new models, Model 1d and Model 2d, with three less outcome-focused motivation items and had the exact same items as Model 1b and Model 2b.

Model 1d and Model 2d Comparison. Four conclusions were drawn based on this new data for Model 1d and 2d, presented in Figure 4.5 and 4.6. First, data from Model 2d factor relationships suggested superiority compared to Model 1d data for two paths: outcome-focused to intrinsic motivation and intrinsic to means-focused motivation. In other words, student responses suggested that the relationship between these two paths were stronger pertaining to Model 2d items. Second, Model 1d had five items that were considered strongly correlated to its respective factor, while Model 2d had six items. This conclusion was based on a factor loading greater than 0.70 for an item (Keith, 1999). Third, Model 1d and 2d outcome-focused motivation item, Q9, increased from a 0.77 factor loading to 0.85 as a result of item removal. Such an increase demonstrated the dramatic effect caused by removal of same factor items that may represent misfits in a model. Fourth, Model 1d and Model 2d experienced significant improvements with factor to factor loadings that was representative of the initial original POMI model structure and intent referred to in Chapter 3.

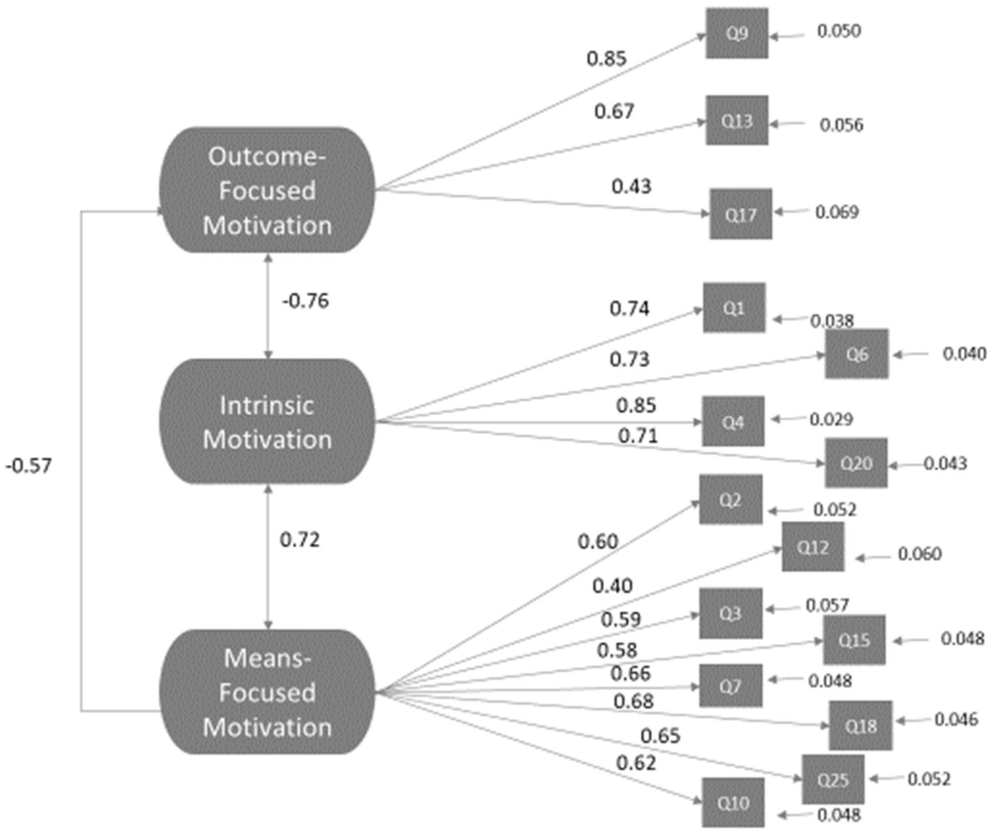

Figure 4.5. *Model 1d Confirmatory Factor Analysis with Factor Loadings and Error*

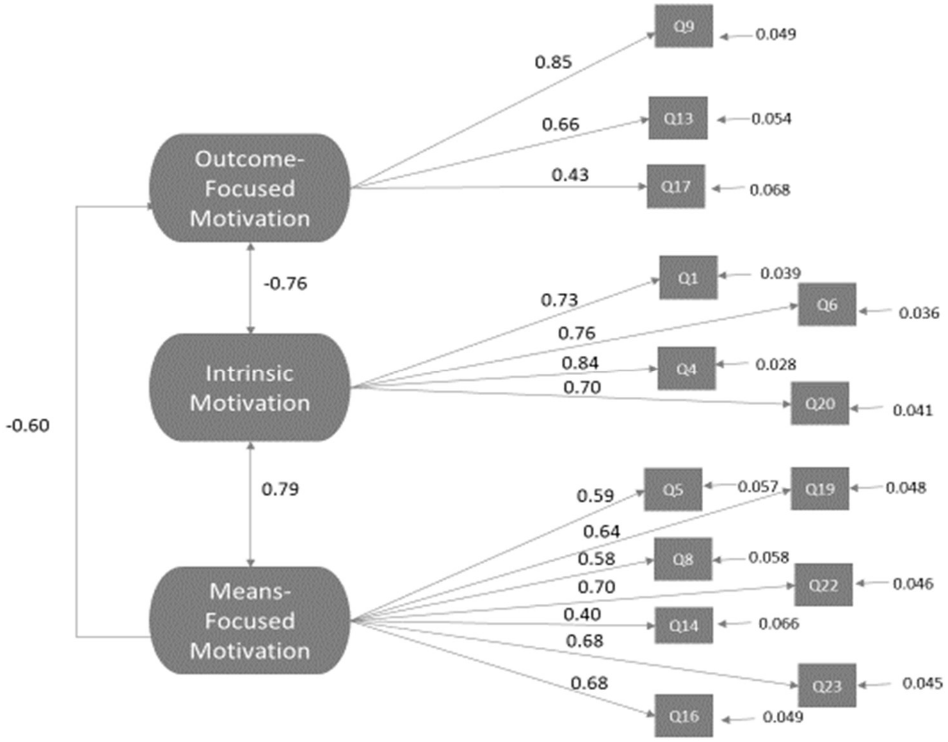

Figure 4.6. *Model 2d Confirmatory Factor Analysis with Factor Loadings and Error*

Most Valid and Reliable POMI Model. Table 4.3 displayed the comparison of goodness-of-fit statistics between Model 1d and Model 2d. In reference to Model 1d, all values calculated for goodness-of-fit indicated that all measures were acceptable apart from Chi-Square and RMSEA values. All values calculated for goodness-of-fit confirmed that all measures except for Chi-Square were acceptable for Model 2d. Consequently, Model 1d can be deemed to have a poorer fit due to two unacceptable values. Although Model 2d did not meet the acceptable value for Chi-Square, this could be a result of a small sample size, a significant limitation of this study (Kline 2012). Therefore, Model 2d was deemed most valid based on the goodness-of-fit measurements, and therefore most capable of providing coherent and credible data pertaining to student's process-oriented motivation toward chemistry at the locale of interest.

Table 4.3

Goodness-of-Fit Comparison Between Model 1d and Model 2d After Item Removal

Goodness-of-Fit Measure	Model 1d	Model 2d
Chi-Square (>0.05)	0.000*	0.000*
SRMR (0.08 or below)	0.057	0.046
CFI (.900 or above)	.918	0.971
RMSEA (0.05 or below)	0.071*	0.044
TLI (Tucker) (.900 or above)	0.901	0.964

Note. RMSEA = root-mean square error of approximation; CFI = comparative fit index; TLI = Tucker-Lewis index; SRMR= standardized room mean square residual.

Statements in parenthesis refer to number that deems model a good fit by the corresponding indices.

*Statistic is demonstrating a poor model fit

Model 2d Covariance. Since Model 2d was selected as the superior model, all future analyses were executed with only Model 2d items. A high Modification Index (MI) suggested that two items within a factor had a close association. In other words, data indicated that students answered two items similarly. MI values were identified as sources of misfits in a model that when appropriately addressed may result in model improvement (Kline, 2012). Selected items within each POMI factor had a greater than 9 MI. The pairs of items that met this criterion to be covaried were the following: Q5 & Q16 (15.578), Q8 & Q22(13.854), Q13 & Q17 (13.364).

The first path justification transpired between items Q5 and Q16: “(Q5) I like to use evidence in my explanation to support a claim that I have made in this class” and “(Q16) I enjoy creating support arguments for any understanding of the concepts addressed by lab in this chemistry class”. Q5 and Q16 had two operative terms, argumentation and explanation, that were distinct but compatible in the education literature. According to Berland and Kuhn (2009), students utilized argumentation to develop their explanations pertaining to a scientific phenomenon. Explanation and argumentation can be viewed as complementary practices (Berland & Kuhn, 2009). Therefore, students could have interpreted these terms to be interchangeable and as a result answered both questions alike. As an alternative, an explanation can be viewed as evidence construction, while argumentation can be viewed as a defense of that same explanation. Finally, Grooms and Enderle (2015) confirmed that explanations provide evidence to support a claim however, argument generation demands higher-level thinking.

The next pair of covaried items in Model 2d were Q8 and Q22: “(Q8) I enjoy laboratories in this chemistry class when they allow me to ask questions about the system being studied” and “(Q22) I enjoy completing experiments in this chemistry class since they allow me to investigate different problems with my classmates.” Asking questions and investigating can be viewed as synonymous terms since they can both be included in the same experiment. Many investigations begin with an observation or a question, thus it is easy to pinpoint how students could have answered these two terms in a similar manner.

The following items represented the final two covaried items: “(Q13) I am only motivated in this chemistry class because we get grades” and “(Q17) I took this chemistry class because it will look good on my high school transcript." Q13 and Q17 are both outcome-focused motivation items that emphasized students' grades as the reward for learning. Data suggested students answered these in a similar manner due to the same single outcome: a grade. As a result, Table 4.4 displays an improved model based on goodness-of-fit statistics. This overall increase compared to Model 2b was attributed to implemented validation items, which enabled only true motivation results into this data set. Moreover, data that skewed results was no longer in the second CFA, which led to an improved model. In addition, covaried items contributed to improved statistics that suggest a better model.

Table 4.4

Goodness-of-Fit for Model 2d After Covariance

Goodness-of-Fit Measure	Model 2
Chi-Square (>0.05)	0.000*
SRMR (0.08 or below)	0.037
CFI (.900 or above)	1.000
RMSEA (0.05 or below)	0.000
TLI (Tucker) (.900 or above)	1.001

Note. RMSEA = root-mean square error of approximation; CFI = comparative fit index; TLI = Tucker-Lewis index; SRMR= standardized room mean square residual.

Statements in parenthesis refer to number that deems model a good fit by the corresponding indices.

*Statistic is demonstrating a poor model fit

Reliability. Cronbach alpha is a reliability measure that provides coefficients, which demonstrate the degree of internal consistency for the items composing a factor, e.g., POMI (Gliem & Gliem, 2003). A reliability coefficient of 0.70 suggested that items for the factor or instrument were consistently representative of the measurement at hand. In Table 4.5, data suggested that all 17 Model 2d items was confirmed to be reliable as a cohesive unit to represent process-oriented motivation. Additionally, all three POMI factors had items that consistently measured intended content.

Table 4.5

Reliability Cronbach Alpha for Model 2d

Form of Reliability Test	Model 2d
Cronbach Alpha all items	0.88*
Cronbach Alpha for Means-Focused Motivation Construct	0.80*
Cronbach Alpha for Outcome- Focused Motivation Construct	0.70*
Cronbach Alpha for Intrinsic Motivation Construct	0.84*

Note. *Cronbach Alpha coefficient that is considered reliably acceptable is 0.70. (Gliem & Gliem, 2003)

Content Validity. Research questions 1 and 1a provided evidence that verified validity and reliability pertaining to VASI and revised POMI surveys. Three forms of content validity were utilized to establish validity from POMI student responses: expert content feedback (face validity), POMI interviews, and VASI interviews. Face validity via process-oriented motivated experts was established in Chapter 3, which culminated in the original POMI survey. The purpose of all three forms of content validity was to confirm that POMI items and data demonstrated that students comprehended the content on the surveys taken, the VASI and the POMI. Such evidence was necessary to determine if both instruments were credible for the target population: high school chemistry students.

Revised POMI content validity. Two hundred and five participants completed the revised POMI before Goal 2. The revised POMI was composed of Likert scale items where students could rank the item between 1, strongly disagree, to 4 strongly agree. Table 4.6 contains a summary of descriptive statistics for each item that composed the revised POMI, grouped by the expected survey factor. The complete instrument can be found in Appendix D.

Revised POMI content validity was established by conducting validation interviews with 12 students (six honors chemistry and six on-level chemistry students) in a four-part interview.

Part 1 enabled students to walk the researcher through their thought process that led them to choose their response. Students then elaborated on their choice. A comparison was made between student's survey selection and their interview for the revised POMI's means-focused motivation items. The point of emphasis was frequency of student's responses going from some form of Agree to Disagree or the opposite direction. Q5, Q8, Q14, Q16, Q19, Q22, Q23 were revised POMI means-focused motivation items that were asked of the students via the online survey and via interview. In Appendix Q, revised POMI survey responses for each question were placed in parentheses and the interview responses to the left of the parenthesis. Moreover, Appendix Q further breaks down details as to how content validity was determined for Part 1. In Table 4.6, three levels of coding existed to help understand any discrepancy between student's POMI survey and POMI interview. To quantify this discrepancy each student was assessed by Level A, Level B or Level C. The Part 1 column categorized students in Level A, B , or C based on how many times each student's interview and survey responses changed from any form of agreement to any form of disagreement, (e.g., a change from strongly agree to disagree would be counted as 1) while a change from strongly agree to agree would not be counted. Level A ranged from 0-1 change; Level B ranged from 2-4 changes; Level C ranged from 5-7 changes. Level C had two students, Level B had six students, and Level A had three students. Thus, only two students changed their answer for five out of seven items on the revised POMI. The rest of the students rarely changed their answers on at least half of the revised POMI items.

Table 4.6

POMI Content Validity: POMI Interview Response (POMI Survey Response)

Student Name	Teacher	Part 1 Score *	Part 2 Score**
S1	Teacher 2	B	X
S2	Teacher 4	B	X
S3	Teacher 4	C	X
S4	Teacher 4	B	X
S5	Teacher 3	B	X
S6	Teacher 3	A	X
S7	Teacher 3	C	X
S8	Teacher 1	B	X
S9	Teacher 1	B	Y(Q5)
S10	Teacher 5	A	X
S11	Teacher 5	B	Y(Q16)
S12	Teacher 5	A	Y(Q19)

*Note. Full table present in Appendix Q

In Part 2, students described each item in a manner appropriate for an elementary student to comprehend. Students were given a piece of paper that had the seven means-focused motivation items of interest. In Table 4.6, content validity was also assessed by Level X, Level Y or Level Z. Level X description demonstrated a complete understanding of all seven items and its intent. Level Y description was based on an understanding of four out of seven items. Finally, Level Z description was based on an understanding of three or less items. Level Z had no students, Level Y contained only three out of twelve students, and Level X was comprised of the remaining nine students that were interviewed. All twelve students understood at least four out of seven items; Part 2's data suggested students had a strong grasp of the purpose of each means-focused motivation item. Furthermore, Table 4.6 displays each misunderstood question in parentheses next to the coded Level X, Level Y, and Level Z.

Part 3 of the validation interview consisted of a matching procedure for students whereby each student matched all seven items with in-class scenarios that best illustrated those items. The complete results for this part were included in Appendix R. Approximately 92% of students matched five out of seven items correctly. Items Q16 and Q23 were mismatched on three occasions, which indicated that students may not be able to consistently differentiate between creating an argument from their data versus finding trends and patterns from their data. Twenty-five percent of the students mismatched these items, which was not enough evidence to alter items.

Part 4 of the validation interview asked the students to rank items in decreasing order based on how motivated they were by each scientific practice that was described. Items placed first or at the top were considered highly motivational and items at the bottom were less motivational to the student. This ranking was then compared with the student's interview response in Part 1 for accuracy. The claim was students that were most motivated by an item would select a higher degree of motivation compared to the least motivational item during Part 1 of the interview. The results of this part of the validation interview were included in Table 4.7. Only two students selected their most motivational item as disagree, while selecting agree or strongly agree for their least motivational item.

Table 4.7

POMI Content Validity for Created Means-Focused Motivation Data (Part 4)

Student Name	Teacher	Agreement in Interview with First and Last Ranked Item
S1	Teacher 2	First - Q5 (D) Last - Q22(A)
S2	Teacher 4	First- Q22(SA) Last - Q19(A)
S3	Teacher 4	First - Q23 (D) Last - Q5 (D)
S4	Teacher 4	First - Q5 (A) Last - Q16 (A)
S5	Teacher 3	First - Q5 (A) Last - Q22(A)
S6	Teacher 3	First - Q16 (A) Last - Q8 (A)
S7	Teacher 3	First - Q16 (SA) Last - Q22 (SD)
S8	Teacher 1	First - Q8 (A) Last - Q19 (D)
S9	Teacher 1	First - Q23 (D) Last - Q22 (A)
S10	Teacher 5	First - Q16 (A) Last - Q14 (A)
S11	Teacher 5	First - Q22(D) Last - Q23(D)
S12	Teacher 5	First - Q16 (SA) Last - Q14(A)

Note. Table focuses on Part 4 of interview that enabled students to rank all seven means-focused motivation items by decreasing order of motivation toward learning chemistry. Please refer to Appendix S for an expanded version of this table.

In summary, all four parts of the revised POMI content validation interview provided adequate evidence to demonstrate that the revised POMI assessed student's means-focused motivation at an adequate level for high school chemistry students. In Part 1, most students were consistent in answering a similar degree of motivation, e.g., Agree or Strongly Agree, between POMI interview and POMI survey. In Part 2, all students accurately described most means-focused motivation items. Part 3 suggested that most students appropriately matched the correct class scenario with the corresponding means-focused motivation item. Finally, Part 4 showed that all but two students' highest ranked means-focused motivation item was aligned with a higher degree of motivation.

VASI content validity. The results of the comparison of VASI responses and student validation interviews are reported in Table 4.8. The purpose of these interviews was to establish that students understood each question they answered before further utilization of data in future analyses. Three VASI items were chosen to be queried during content validity interviews based on significant student feedback on such items being ambiguous. The three chosen VASI items were repeated verbatim during each student interview and allowed students to clarify their answer. Each student received a score based on the VASI rubric that assessed if the student's answer was informed or naive (one or zero points, respectively). Student's survey score was then matched with their interview score to ensure that students provided consistent answers between the survey and interview. Each students VASI interview and survey scores were matched to ensure consistency of student's answers. Eight students matched all three questions from survey to interview. Four students matched two out of three answers accurately and only one student matched one out of three answers. Approximately 85% matched their answers correctly, which displayed an appropriate level of content validity that demonstrated that most students had a conceptually grasp of the survey's content.

Table 4.8

VASI Content Validity Table

Student	Question #3 Score		Question #11 Score		Question #12 Score		Match Between Interview and VASI Score
	Survey	Interview	Survey	Interview	Survey	Interview	
S1	1	1	0	1	1	1	2 out of 3
S2	1	1	0	1	0	1	1 out of 3
S3	0	0	1	1	0	0	3 out of 3
S4	0	0	1	1	0	1	2 out of 3
S5	1	1	1	1	1	1	3 out of 3
S6	1	1	1	1	1	1	3 out of 3
S7	1	1	1	1	1	1	3 out of 3
S8	1	1	1	1	0	1	2 out of 3
S9	1	0	1	1	1	1	2 out of 3
S10	0	0	1	1	1	1	3 out of 3
S11	1	1	1	1	1	1	3 out of 3
S12	0	0	1	1	0	0	3 out of 3
S13	1	1	0	0	1	1	3 out of 3

Note. Please refer to Appendix T for an expanded version of this table with students' quotes.

Convergent Validity. Convergent validity compared revised POMI scores and VASI instrument scores, which explored any correlation between the means-focused motivation factor and the VASI factor. Before the convergent validity test, a Kolmogorov-Smirnov test was utilized to assess normal distribution amongst the means-focused scores and VASI scores, respectively. Thus, a significant difference for either factor's data would suggest non-normal distribution, which would result in a non-parametric correlation test. Means-focused scores were not normally distributed, $D(0) = 1.1$, $p < 0.001$, which confirmed the necessity of a non-parametric test for convergent validity. VASI scores also lacked a normal distribution, $D(0) = 1.6$, $p < 0.01$. Thus, convergent validity between VASI scores and means-focused scores was assessed via Spearman correlation, non-parametric test (Tuan & Chin, 2005). Spearman correlation results indicated no significant difference for the correlation coefficient between means-focused motivation and the VASI factor, which was validated by an extremely weak Spearman correlation coefficient, rs (159) = 0.044, p = 0.71. Therefore, the Spearman correlation test revealed no significant relationship existed between student's means-focused motivation scores and VASI scores. Upon further elaboration, students with a high VASI score were not expected to have a high mean score for means-focused motivation. Hence, convergent validity cannot be assumed between the means-focused motivation factor and the VASI factor.

Predictive Validity. A Kolmogorov-Smirnov test was utilized to confirm the necessary type of correlation test. Means-focused scores and lab report scores both indicated the data was not normally distributed, D (0) = 2.3, $p < 0.001$; D (0) = 3.1, $p < 0.01$. Thus, the predictive validity utilized a Spearman correlation to link student achievement with means-focused motivation scores (Tuan & Chin, 2005). Predictive validity did not exhibit a significantly different correlation coefficient, which indicated that students are not more likely to score high on student achievement if they scored high on means-focused motivation. Means-focused motivation and lab report scores were found to have a small insignificant correlation, rs (159) = 0.082, $p < 0.01$. Furthermore, means-focused motivation cannot be utilized with assurance to predict how students will perform on ADI lab reports. Theoretically, a correlation between these two variables would denote a possible utilization of the novel means-focused motivation factor. Nevertheless, current evidence does not authenticate any imminent predictive validation that would enable science teachers to utilize the revised POMI to predict future success in science.

Goal 1 Conclusion

Based on data, Model 2d was selected as the most valid and reliable version of the POMI after two completed CFA. Thus, Model 2d was renamed the revised POMI and utilized for further analyses in this study. Content validity was established with a four-part interview that demonstrated that students comprehended content being assessed by the revised POMI. Convergent validity was not established between POMI means-focused motivation data and VASI. Therefore, congruency with VASI or means-focused motivation findings cannot be predicted or assumed due to lack of a relationship based on data. Finally, reliability was established for the revised POMI, which meant all items measured process-oriented motivation consistently. Moreover, each item consistently measured content fittingly for their respective motivation factor: outcome-focused, intrinsic, means-focused. In other words, means-focused motivation items can be trusted to give data that aptly measures student motivation toward the SEPs in their chemistry class.

Goal 2 Findings

Three research questions were formulated throughout this study to address two goals: valid and reliable data for the revised Process-Oriented Motivation Instrument (POMI) and exploration of Argument Driven Inquiry (ADI) effect on high school chemistry students' motivation and achievement. At the conclusion of Goal 1, Model 2d was selected as the best model to obtain the most accurate data pertaining to students' process-oriented motivation toward chemistry. Following this the revised POMI, Model 2d, was utilized to evaluate how students' process-oriented motivation was altered by two different pedagogical implementations of a lab. This chapter will present the necessary evidence to address Goal 2 via two questions: (2a) What is Argument-Driven Inquiry's effect on high school chemistry students' process-oriented motivation? (2b) What is the mediation effect of process-oriented motivation and relationship between argument-driven inquiry and student achievement? Research questions 2a and 2b were developed to determine if a *Framework* aligned teaching pedagogy, ADI, affected student process-oriented motivation and achievement in high school chemistry. Question 2a utilized findings to address how each revised POMI factor was affected by ADI implementation. Question 2b obtained data to explore the mediation path effect from outcome-focused motivation, intrinsic motivation, and means-focused motivation to the control and experimental group's lab report scores. Table 4.9 presents the research questions of Goal 2 aligned to the statistical analysis performed to answer each question.

Table 4.9

Goal 2 Research Questions with Respective Analysis

Goal 2 Research Question	Statistical Analysis
Q2a: What is Argument-Driven Inquiry's effect on high school chemistry students' process-oriented motivation?	Kruskal-Wallis or Mann-Whitney U Test
Q2b: What is the mediation effect of process-oriented motivation and relationship between argument-driven inquiry and student achievement?	Mediation Path Analysis

What is Argument-Driven Inquiry's Effect on High School Chemistry Students' Process-Oriented Motivation?

This question measured the effect of the implementation of ADI on students' process-oriented motivation. The goal of ADI is to empower students to develop arguments that can support explanations pertaining to research questions (Walker & Sampson, 2012). The independent variable was based on the presence of ADI in each group's lab experience. The experimental group participated in an ADI lab, while the control group completed a traditional lab. ADI is an instructional model that promotes student engagement via scientific argumentation. The dependent variable for question 2a of the research study was students' process-oriented motivation.

Table 4.10 provided a breakdown of average outcome-focused, intrinsic, means-focused motivation scores aligned with the average achievement scores per individual class examined in this study. Teachers 1, 2 and 3 comprised the experimental group, while Teacher 4 and Teacher 5 represented the control group. Thus, the control group began with a total of five classes, but the experimental group has a grand total of six classes. In the end, a sum of eleven classes were considered to help answer Question 2a.

Table 4.10

Lab Report Statistics for All Teacher and their Classes

	Teacher	Course	Outcome Score Average	Intrinsic Score Average	Means-Focused Score Average	Lab Report Score Average
Experimental Group	Teacher 1	Class 1	2.71	2.50	2.65	77.71
	Teacher 1	Class 2	2.69	3.01	2.75	77.91
	Teacher 2	Class1	2.91	2.91	2.62	75.75
	Teacher 3	Class 1	2.82	2.71	2.56	77.30
	Teacher 3	Class 2	2.91	2.31	2.75	74.11
Control Group	Teacher 4	Class 1	2.91	2.01	2.56	87.18
	Teacher 4	Class 2	3.11	2.11	2.62	87.34
	Teacher 4	Class 3	3.00	2.31	2.54	81.93
	Teacher 5	Class 1	2.91	2.91	2.96	83.12
	Teacher 5	Class 2	2.41	2.83	2.64	82.87
	Teacher 5	Class 3	2.62	2.87	2.91	83.11

Research question 2a investigated if a change in instruction, exposure to ADI, resulted in a statistically significant difference between both groups outcome-focused motivation. Before this comparison, a test for normality was utilized to assess normal distribution of individual classes initial outcome-focused motivation scores. If a significant difference was founded for any class, a non-parametric test would then be utilized to compare control and experimental groups initial-outcome-focused motivation scores. Afterwards, a normalized gain score was calculated for each group and these calculated mean scores were compared via a parametric or a non-parametric test for a significant difference. Normalized gain scores are particularly effective for this research study as two different populations of students were utilized with regards to the class rigor, honors vs on-level, which demonstrated different starting points of initial knowledge. Hake (1998) created the normalized gain score metric to account for classes, e.g., honors versus on level, with varying pretest averages in which one class has the potential to having less significant gains due to ceiling effects.

Comparison of revised Pre-POMI outcome-focused motivation scores. To begin assessing the data collected it was first important to determine if a parametric or nonparametric statistical analysis could be performed. To do so, a Kolmogorov-Smirnov test was run to check for normal distribution among the initial outcome-focused motivation scores. The revised pre-POMI outcome focused motivation scores for each class in this study did not adhere to a normal distribution. The results of the Kolmogorov-Smirnov test were provided in Table 4.11. A significant p-value, p = 0.00, indicated that the distribution was non-normal leading to the use of nonparametric tests being employed to make the statistical comparisons to answer research question 2a.

Table 4.11

Kolmogorov-Smirnov Normality Results for All Teacher and their Classes

Teacher	Course	Degrees of Freedom	Chi-Square Value	P-Value
Teacher 1	Class 1	7	1.99	<0.001
Teacher 1	Class 2	11	1.77	<0.001
Teacher 2	Class1	8	2.25	<0.001
Teacher 3	Class 1	10	2.07	<0.001
Teacher 3	Class 2	22	1.96	<0.001
Teacher 4	Class 1	22	1.83	<0.001
Teacher 4	Class 2	14	1.77	<0.001
Teacher 4	Class 3	23	2.01	<0.001
Teacher 5	Class 4	15	1.73	<0.001
Teacher 5	Class 4	15	1.88	<0.001
Teacher 5	Class 4	13	2.02	<0.001

Next, classes that composed the experimental and control groups had to be combined. To deem that there was no significant difference among the classes prior to combing the data. Thus, a Kruskal-Wallis test was performed to compare the initial outcome-focused motivation values of all classes within its respective group. Five total classes were compared amongst the experimental group and the results suggested no significant difference between classes in the experimental group existed, $X^2(4) = 3.02$ $p = 0.541$. Thus, all experimental group classes were statistically similar, comprising the experimental group. Kruskal-Wallis test displayed no significant difference among the initial outcome-focused motivation scores for the six classes composing control group, $X^2(5) = 9.55$ $p = 0.89$. All classes in the control group were combined for further analysis. According to the Mann-Whitney U test results, the experimental group compared to the control group's initial outcome-focused motivation lacked a statistical difference, $Z = 0.141$, $p = 0.881$. Theoretically, it can be deduced that the experimental group and control group had similar initial outcome-focused motivation scores before ADI implementation.

Determining the effect of ADI on outcome-focused motivation. A normalized gain score was computed for outcome-focused motivation before and after ADI implementation. First, Kolmogorov-Smirnov test assessed the normality of the newly formed control and experimental group, which both groups were determined to have non-normally distributed data, $D(0) = -1.3$, $p = 0.000$; $D(0) = -1.1$, $p = 0.000$. A Mann-Whitney U, non-parametric version of a t-test, revealed no significant difference between the control and experimental group's normalized gain score, $Z = -0.202$, $p = 0.841$. Consequently, the normalized gain scored for outcome-focused motivation was statistically similar despite the implementation of ADI.

Comparison of revised Pre-POMI intrinsic motivation scores. A Kolmogorov-Smirnov test examined sample data for normal distribution amongst the initial intrinsic motivation scores.

The revised pre-POMI intrinsic motivation scores for each class in this study had data that was not normally distributed. In Table 4.12, Kolmogorov-Smirnov results demonstrated a significant p-value, p = 0.000 for all the data of each individual class, which led to nonparametric tests used for statistical comparisons to answer research question 2a pertaining to intrinsic motivation.

Table 4.12

Kolmogorov-Smirnov Normality Results for All Teacher and their Classes

Teacher	Course	Degrees of Freedom	Chi-Square Value	P-Value
Teacher 1	Class 1	7	2.06	<0.001
Teacher 1	Class 2	11	1.87	<0.001
Teacher 2	Class1	8	2.45	<0.001
Teacher 3	Class 1	10	2.00	<0.001
Teacher 3	Class 2	22	1.91	<0.001
Teacher 4	Class 1	22	1.88	<0.001
Teacher 4	Class 2	14	1.74	<0.001
Teacher 4	Class 3	23	1.93	<0.001
Teacher 5	Class 4	15	1.80	<0.001
Teacher 5	Class 4	15	1.84	<0.001
Teacher 5	Class 4	13	2.05	<0.001

A Kruskal-Wallis test was performed to compare the initial intrinsic motivation values of each class within its respective group. Five total classes were compared amongst the experimental group and the result suggested no difference, $X^2(4) = 3.08$ $p = 0.545$, between classes in the experimental groups prior to the implementation of the lab. Thus, all experimental group classes were statistically similar, which enabled all five on-level chemistry classes to represent the experimental group. The Kruskal-Wallis test displayed no significant difference, $X^2(5) = 5.802$, $p = 0.319$, between all six classes in the control group initial intrinsic motivation. Each of the six sections of honors chemistry composed the control group since all classes were statistically similar. A Mann-Whitney U test confirmed no significant difference, $Z = 0.316$, $p = 0.752$, when comparing the pre-POMI scores for the experimental and control groups before ADI implementation, which included all classes from experimental and control group concerning initial intrinsic motivation.

Determining the effect of ADI on intrinsic motivation. A normalized gain score compared intrinsic motivation growth throughout this study. At the outset, Kolmogorov-Smirnov test assessed the normality of the novel control and experimental group, both groups had data that was not normally distributed, D (0) = -1.13, p = 0.000; D (0) = -1.02, p = 0.000. A lack of a significant difference between control and experimental group was discovered by the Mann-Whitney U test, Z = 1.94, p = 0.0524. Ultimately, ADI implementation did not impact students' intrinsic motivation in a manner that resulted in a dramatic change throughout this study.

Comparison of revised Pre-POMI means-focused motivation scores. Assessing the data collected began with determining if a parametric or nonparametric statistical analysis was necessary. A Kolmogorov-Smirnov test was run to check for normal distribution among the initial means-focused motivation scores. Revised pre-POMI means-focused motivation scores for all eleven classes in this study had a significant difference for normality. In Table 4.13, a significant p-value, i.e. p = 0.000, signaled a non-normal distribution.

Table 4.13

Kolmogorov-Smirnov Normality Results for All Teacher and their Classes

Teacher	Course	Degrees of Freedom	Chi-Square Value	P-Value
Teacher 1	Class 1	7	1.99	<0.001
Teacher 1	Class 2	11	1.98	<0.001
Teacher 2	Class1	8	2.79	<0.001
Teacher 3	Class 1	10	2.11	<0.001
Teacher 3	Class 2	22	1.82	<0.001
Teacher 4	Class 1	22	1.87	<0.001
Teacher 4	Class 2	14	1.79	<0.001
Teacher 4	Class 3	23	2.05	<0.001
Teacher 5	Class 4	15	1.90	<0.001
Teacher 5	Class 4	15	1.94	<0.001
Teacher 5	Class 4	13	2.09	<0.001

To assess any statistical difference between the classes a Kruskal-Wallis test was performed to compare the initial means-focused motivation values of each class within the experimental group. Five total classes were compared, and the outcome indicated no difference, $X^2(4) = 0.238$ $p = 0.994$, between classes in the experimental group. Second, a Kruskal-Wallis test between all control group sections determined that there was no significant difference, $X^2(5) = 12.67$ $p = 0.027$, between the six honors chemistry classes. All classes in the control group were combined for further analysis. Mann-Whitney U test indicated a lack of statistical difference between experimental and control initial means-focused motivation, $Z = -0.540$, $p = 0.591$. In theory, it can be concluded that the experimental group and control group had comparable initial means-focused motivation scores before ADI implementation.

Determining the effect of ADI on means-focused motivation. A normalized gain score was calculated for means-focused motivation before and after ADI lab implementation. First, Kolmogorov-Smirnov test measured normal distribution of the newly formed control and experimental group, which determined that the data was not normally distributed, $D\ (0) = -1.27$, $p = 0.000$; $D\ (0) = -1.34$, $p = 0.000$. Thus, a Mann-Whitney U test indicated no significant difference between the control and experimental group's normalized gain score, $Z = 0.199$, $p = 0.842$. A lack of significant difference between normalized gain score for control and experimental groups indicated statistically similarity pertaining to means-focused motivation growth between groups.

What is the Mediation Effect of Process-Oriented Motivation and Relationship Between Argument-Driven Inquiry and Student Achievement?

Three mediation path analyses were conducted to represent the following factors for the revised POMI: outcome-focused motivation, intrinsic motivation, and means-focused motivation. Two items were emphasized for all three mediation path analyses: path coefficient and p-value for that path coefficient. Correlations between connected variables in path and significant difference explained the relevance of that path. Additionally, correlation and p-value supplied necessary evidence to draw conclusions about the effectiveness of each variable. Finally, p-value above 0.05 categorized the path as not significant in difference between variables. On the contrary, p-values below 0.05 categorized the path as producing a significant difference between variables.

Direct effects. Direct Effects demonstrated how each variable in a path influenced the other, via path coefficient, and if a significant difference existed. There were three direct effect tables that represent each type of motivation: outcome, intrinsic, means-focused. ADI to Motivation, Motivation to Score, and ADI to Score were the paths represented in each corresponding direct effect table. Thus, motivation would be replaced with one of the three POMI factors, while a path coefficient and p-value were computed for necessary evidence on path significance.

Indirect effects. Question 2b can be simply answered via each motivation's indirect effect table, which was the motivation's effect on the ADI to Score path. ADI to Score was the only mediation path available since the only mediator can be a form of motivation: outcome-focused, intrinsic, or means-focused. The p-value was paired in all three indirect effect tables to provide evidence necessary to a draw conclusion for Question 2b. A small non-significant p-value under 0.05 provides two conclusions: control and experimental groups scores were impacted in the same manner by motivation despite ADI implementation and any discrepancy in mediation effect was quite small and insignificant (Sullivan & Fenin, 2012). In contrast, a significant p-value provided two conclusions: control and experimental groups scores were impacted in a significantly different manner by motivation due to ADI implementation and this discrepancy gap in mediation effect was large and significant (Sullivan & Fenin, 2012).

Outcome-focused motivation. In Figure 4.7, a non-significant relationship existed between the experimental group, ADI, and outcome-focused motivation. As a result, it can be determined that the experimental group was not significantly more outcome-focused motivated than the control group. Outcome-focused motivation to lab report score had the weakest and smallest correlation in Table 4.14, thus no significant disparity existed between those variables. Outcome-focused motivation did not affect student lab report scores in a substantial manner. Further-motivated students did not score better on their lab report. Finally, Table 4.14 suggested via ADI to Score's significant path that the experimental group scored significantly better than the control group on their lab report irrespective of outcome-focused motivation. These results suggest that the ADI implementation was considerably effective on student achievement, student lab report scores.

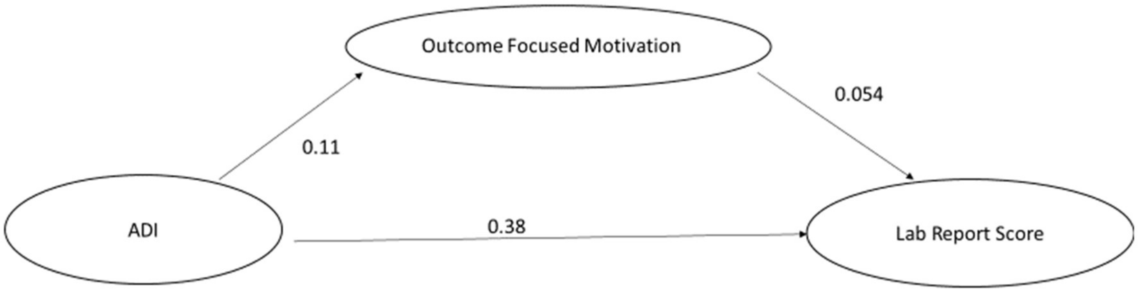

Figure 4.7. *Outcome-focused Motivation Mediation Path Analysis*

Table 4.14

Outcome-Focused Unstandardized Path Coefficients, Standard Errors, and P-value for Theoretical Model

Path	Coefficient	SE	P-value	95% CI
ADI to Outcome	0.11	0.91	0.22	-0.067, 0.29
Outcome to Score	0.05	0.086	0.53	-0.11, 0.22
ADI to Score	0.38	0.077	0.00*	0.23, 0.53

Note. *Significant Difference exists for path

SE=Standard Error; CI= Confidence Interval

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Table 4.15 displayed the direct effects for three distinct paths in conjunction with its coefficient and p-value. Each path can be simply described based on the direct impact of one variable to the other variable in its path. Therefore, a significant p-value for the ADI to Outcome path would indicate that the ADI implementation affected experimental group students' outcome-focused motivation scores. The first path was ADI to Outcome, which lacked a significant difference. Next, Table 4.15 confirmed that higher-motivated students did not score significantly better than their peers who obtained a low outcome-focused motivation score. ADI to Score path was quite significant and displayed a dramatic score improvement from control to experimental groups due to ADI implementation.

Table 4.15

Direct Effects with Respective Confidence Intervals for Outcome-Focused Motivation Path Model

Path	Coefficient	SE	P-value	95% CI
ADI to Outcome	0.46	0.39	0.22	-0.28, 1.21
Outcome to Score	0.35	0.56	0.53	-0.74, 1.44
ADI to Score	10.10	2.30	0.00*	5.61, 14.62

Note. *Significant Difference exists for path

SE=Standard Error; CI= Confidence Interval

In Table 4.16, only one indirect path existed, ADI to Score, which highlighted the experimental group students and their lab report scores. Therefore, p-value and coefficient for this path were based on the effect from outcome-focused motivation scores on the ADI to Score path. In the ADI to Score path, the mediator was one of the revised POMI motivation factors, e.g., outcome focused. The p-value was considerably above the threshold, which meant that outcome-focused motivation did possess a significant effect on the ADI to Score path. An on-level student, experimental group, who scored low for outcome-focused motivation should not be presumed to have scored poorly on the lab report.

Table 4.16

Indirect Effects with Respective Confidence Intervals for Outcome-focused Motivation Path Model

Path	Coefficient	SE	P-value	95% CI
ADI to Outcome	0	No path	-	-
Outcome to Score	0	No path	-	-
ADI to Score	0.16	0.29	0.58	-0.41, 0.73

Note. * No significant difference exists for path

SE=Standard Error; CI= Confidence Interval

Intrinsic motivation. In Figure 4.8, a significant path coefficient existed between the experimental group, ADI, and intrinsic motivation. Consequently, it can be determined that the experimental group was significantly more motivated than the control group due to ADI implementation. This significant p-value can be found in Table 4.17, which confirmed the importance of the ADI to intrinsic motivation path coefficient. Intrinsic motivation did not affect student lab report scores in a substantial manner. Finally, the experimental and control groups had no statistical difference in lab reports. ADI implementation was not dramatically effective on how well students scored on the lab their lab report.

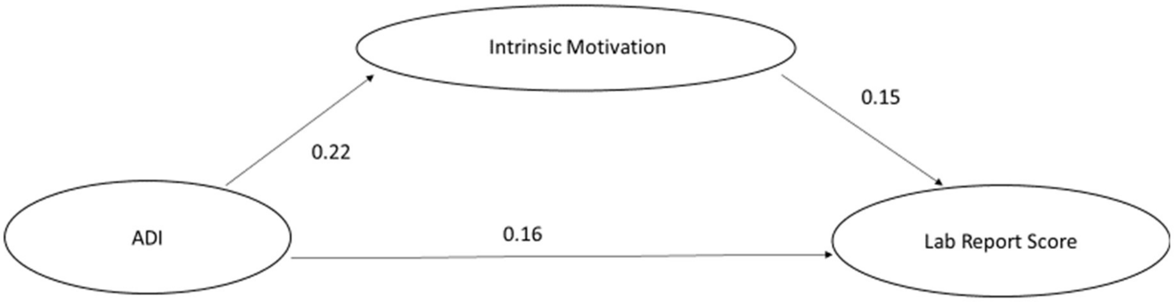

Figure 4.8. *Intrinsic Motivation Mediation Path Analysis*

Table 4.17

Unstandardized Path Coefficients, Standard Errors, and P-value for Theoretical Model

Path	Coefficient	SE	P-value	95% CI
ADI to Intrinsic	0.22	0.93	0.020*	0.34, 0.40
Intrinsic to Score	0.15	0.097	0.13	-0.043, 0.34
ADI to Score	0.16	0.097	0.11	-0.32, 0.35

Note. * Significant Difference exists for path

Three direct effect paths were examined in Table 4.18 based on intrinsic motivation scores amongst experimental and control group students. The first path in Table 4.18, ADI to Intrinsic path, had a significant difference, which illuminated that ADI implementation did affect the experimental group's intrinsic motivation in a significant manner. Next, students that were more intrinsically motivated did not score significantly better than students that had a low intrinsic motivation score. ADI to Score path did not suggest a statistically significant score improvement from control to experimental groups due to the implementation of ADI.

Table 4.18

Direct Effects with Respective Confidence Intervals for Intrinsic Path Model

Path	Coefficient	SE	P-value	95% CI
ADI to Intrinsic	1.49	0.66	0.025*	0.19, 2.80
Intrinsic to Score	0.74	0.49	0.13	-0.22, 1.70
ADI to Score	5.36	3.35	0.11	-1.21, 12

Note. * Significant Difference exists for path

SE=Standard Error; CI= Confidence Interval

In Table 4.19, the ADI to Score path was examined for a significant difference based on the indirect effect of students' intrinsic motivation scores. The p-value was above the threshold, which meant that intrinsic motivation lacked an indirect effect on the experimental group's lab report performance. Intrinsic motivation was not a mediator and did not portray a mediation effect between ADI and lab report scores, which answered Question 2b. The p-value in Table 4.19 indicated that both groups performed statistically similar on lab reports scores in response to intrinsic motivation. Simply put, an honors chemistry or on-level chemistry student, control group, who scored high for intrinsic motivation should not be presumed to have performed well on the lab report.

Table 4.19

Indirect Effects with Respective Confidence Intervals for Intrinsic Path Model

Path	Coefficient	SE	P-value	95% CI
ADI to Intrinsic	0	No path	-	-
Intrinsic to Score	0	No path	-	-
ADI to Score	1.09	0.88	0.21	-0.62, 2.8

Note. * No significant difference exists for path
Dash (-) indicates no value for column of focus
SE=Standard Error; CI= Confidence Interval

Means-focused motivation. In Figure 4.9, a negative path coefficient existed between the experimental group, ADI, and means-focused motivation. A negative coefficient indicated that the control group performed better on means-focused motivation versus the experimental group. This result was the opposite of the expectation from ADI lab implementation. Nevertheless, this result was not statistically significant, which meant that the difference was marginal at best. Means-focused motivation to lab report score had a small correlation in Table 4.20. Means-focused motivation did not affect student lab report scores in a considerable manner based on the above threshold p-value. Therefore, less motivated students did not score worse on their lab report. Finally, the experimental group scored significantly better than the control group on their lab report regardless of their means-focused motivation. A p-value below 0.05 served as evidence that ADI implementation was substantially effective on student achievement or performance.

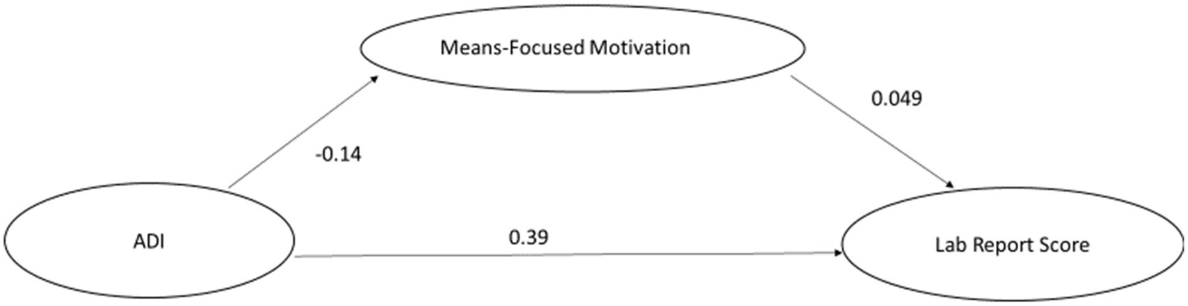

Figure 4.9. *Means-focused Motivation Mediation Path Analysis*

Table 4.20

Unstandardized Path Coefficients, Standard Errors, and P-value for Theoretical Model

Path	Coefficient	SE	P-value	95% CI
ADI to Means-Focused	-0.14	0.091	0.12	-0.32, 0.035
Means-Focused to Score	0.049	0.086	0.56	-0.12, 0.22
ADI to Score	0.39	0.076	0.00*	0.24, 0.54

Note. * Significant Difference exists for path

Table 4.21 explored three direct paths that revolved around students' means-focused motivation scores. Thus, a significant p-value for a path confirmed that a direct influence occurred from one variable to another pertaining to students' means-focused motivation. The first path in Table 4.21 investigated an indirect relationship between means-focused motivation and ADI, however it was not shown to be statistically significant. High-scoring means-focused motivation students scored similarly on lab reports compared to relatively low-score means-focused motivation students. ADI to Score path yielded a statistically significant difference between control to experimental groups due to the implementation of ADI. A 10.46 path coefficient confirmed a sizeable effect: the experimental group scored considerably better on lab reports compared to their control group counter parts due to ADI instruction (Keith, 1999).

Table 4.21

Direct Effects with Respective Confidence Intervals for Means-Focused Motivation Path Model

Path	Coefficient	SE	P-value	95% CI
ADI to Means-Focused	-1.01	0.65	0.12	-2.29, 0.27
Means-Focused to Score	0.18	0.32	0.57	-0.45, 0.82
ADI to Score	10.46	2.31	0.00*	5.94, 14.98

Note. * Significant Difference exists for path

SE=Standard Error; CI= Confidence Interval

Table 4.22 examined the indirect effect means-focused motivation scores had on the ADI to Score path. The p-value was well above the threshold, which led to means-focused motivation having no indirect effect on the experimental group's lab report performance. Means-focused motivation did not facilitate a mediation effect between ADI and lab report scores, which was an emphatic no response to Question 2b. Means-focused motivation did not have a notable impact on how the experimental group students performed on their lab reports. In other words, an on-level student who scored high for means-focused motivation should not be presumed to have a high lab report score.

Table 4.22

Indirect Effects with Respective Confidence Intervals for Means-Focused Motivation Path Model

Path	Coefficient	SE	P-value	95% CI
ADI to Means-Focused	0	No path	-	-
Means-Focused to Score	0	No path	-	-
ADI to Score	-0.19	0.35	0.60	-0.87, 0.50

Note. *Significant Difference exists within Past

SE=Standard Error; CI= Confidence Interval

Goal 2 Conclusion

Research question 2a was answered with a normalized gain score evaluation. Normalized gain score was conducted to compare the experimental and control group for each POMI motivation factor. Findings revealed that there was no significant difference in either group's process-oriented motivation despite utilization of a teaching pedagogy that utilized the SEPs. Therefore, experimental group POMI data indicated that no current evidence and claim can be substantiated that reflected process-oriented motivation being substantially altered or effected by a curriculum aligned teaching strategy.

Research question 2b utilized three variables to conduct a mediation path analysis: ADI, Motivation, and Lab Report Score. ADI represented the type of instruction between the control and experimental group. Motivation represented each factor in the revised POMI instrument. All three revised POMI factors had its own mediation path analysis. Finally, the lab report score represented the student achievement aspect of this study. Any significant difference in a mediation path analysis between two variables, the path, implied one variable had a more substantial effect on the other. Ultimately, the goal for each mediation path analysis was to discover if any process-oriented motivation factors facilitated the relationship between ADI and students' lab report scores. Throughout data collection, an additional path was created between instructional strategy, ADI, and student lab report score to examine any statistically significant effect. Findings suggested that no mediation effect existed from motivation on ADI to Score path. This revelation established that no indirect effect was incurred for outcome-focused, intrinsic, and means-focused motivation. In other words, any significant effect from the ADI to Score path was not influenced by students' process-oriented motivation. However, two inconsequential conclusions were discovered: outcome-focused and means-focused motivation mediation path analysis demonstrated that experimental group students scored higher on their lab reports and the experimental group was more intrinsically motivated compared to the control group.

CHAPTER 5: CONCLUSIONS, IMPLICATIONS, AND RECCOMENDED FUTURE RESEARCH

This chapter presents conclusions, implication and future research pertaining to the revised POMI. A summary of evidence will be presented that addresses Research question 1, 1a, 2a and 2b. Future implication on how the science education community will be affected by the revised POMI. Finally, future research as a result of conclusions will be investigated.

Conclusions

Findings can be deduced down to three major points: a) the revised POMI has valid and reliable survey data for high school chemistry students at the researcher's locale, b) the effect ADI has on process-oriented motivation is not substantial but has a significant effect on student achievement, c) process-oriented motivation does not influence chemistry students' performance on their lab reports.

Valid and Reliable Data for Revised POMI

The newly created revised POMI has data that demonstrates content validity and construct validity. Content validity is first evident by the feedback received from three process-oriented experts. The revised POMI construction is a final product due to this feedback and implementation within the instrument. Face validity is evident by three process-oriented motivation experts' feedback being implemented in the administered original and revised POMI. During this study, a four-part interview protocol for 12 students (six each from control and experimental groups) suggested that most students had a grasp on process-oriented motivation. Construct validity is evident via CFA results. After two complete CFA's, Model 2d had appropriate goodness-of-fit statistics confirming Model 2d as a good model fit. Model 2d includes seven means-focused motivation items that accurately, precisely and reliably reflect the content of students being motivated by the science and engineering practices.

ADI Effect on Process-Oriented Motivation

Our second conclusion is ADI's effect on students' process-oriented motivation is not evident due to the lack of a significant difference in process-oriented motivation during this study. The Mann-Whitney U test was utilized to compare control and experimental group normalized gain scores for a significant difference. Test results suggest that despite ADI implementation, both groups still have a similar change in their process-oriented motivation. Therefore, it is apparent that ADI did not result in a significant change in the experimental group's motivation for all three factors. ADI did however employ a significant effect on students' intrinsic motivation, which meant that students in the experimental group were more motivated in the ADI lab versus a traditional lab. Despite this result, the *Framework for K-12 Science Education's* strategies may not be effective at motivating students to learn science. Outcome-focused motivation mediation path analysis results reveal that ADI affected experimental group lab report scores. Such a finding is present in the means-focused motivation path analysis as well. ADI has not shown substantial evidence to motivate students, but ADI affects students' comprehension of the SEPs.

Process-Oriented Motivation Effect on Experimental Group's Lab Reports

Our last conclusion is none of the three motivation factors for the revised POMI possess a significant influence on how the experimental group students score on their lab report. Outcome-focused and means-focused motivation path analyses had a significant path for ADI to Score. An unexpected finding, but a result that suggests the *Framework for K-12 Science Education* initiates an impact on student learning, more specifically their ability to utilize the SEPs to communicate evidence. ADI implementation resulted in on-level students scoring significantly higher than the control group, which suggests that ADI impacted student's comprehension of the SEP. Drawing this conclusion is a direct connection to the ADI rubric that measured student comprehension of four of the eight SEPs. A higher lab report score quantifies to better comprehension of at least one of the four SEPs. Furthermore, this can be attributed to the peer-review session experienced by the experimental group. The ADI peer-review is manifestation of Science and Engineering Practice number eight in a lab high school setting: obtain, evaluate, communicate information. Thus, the evolution of obtaining, evaluating, and communicating information is evident in writing a lab report and application of feedback that preceded an improved lab report score. In contrast, intrinsic motivation mediation path analysis had only one significant path, ADI to Intrinsic. Experimental group students had significantly more intrinsic motivation than the control group. Additionally, it is evident that ADI implementation had a substantial effect on on-level students' intrinsic motivation. ADI influenced students to become more motivated about science, which was quantified by a significant difference for the ADI to Intrinsic path (Grooms & Enderle, 2015). In conclusion, ADI does not significantly affect student achievement via outcome-focused, intrinsic, or means-focused motivation. Therefore, it can be concluded each revised POMI motivation factor was not effective in mediating a relationship between ADI implementation and lab report score. In other words, each significant difference that occurred between ADI and Score, outcome-focused motivation and means-focused motivation, cannot be attributed to students' process-oriented motivation.

Limitations of the Study

Sample Size

The appropriate sample size necessary to correctly analyze and draw a conclusion for the data resulted in an experimental and control group of different rigors of chemistry class. Ideally, all students would have had a similar rigor to avoid adding an unnecessary variable to this study. However, since the participant number to perform normalized gain test, confirmatory analysis, and similar statistics was less than 300 students, it was necessary to join both honors chemistry and on-level chemistry students. Thus, an insufficient amount of honors chemistry and on-level chemistry students was a limitation of this study that may have had an influence on results of the statistical analysis of both groups. Additionally, the second CFA run before Goal 2 had less than 200 students due to validation items removing unqualified participants. Therefore, CFA results cannot be utilized as absolute but mere suggestion on the model fit.

Novelty of Means-Focused Motivation Factor

Amongst the three main motivation factors, means-focused was the only factor that has not been used in any instrument. The factor was introduced by Touré and Tillery (2014) but has not been implemented to measure participant motivation. Despite the novelty of means-focused motivation, this study seeks to further research on this factor. With more research, means-focused motivation could find its niche in the science-education community and will be modified to measure motivation in several subject areas. Nevertheless, the lack of prior research or literature on means-focused motivation and process-oriented motivation was a limitation that prohibits the researcher from assumptions and hypothesis about the correct utilization of how to measure process-oriented motivation in an instrument. Finally, the lack of process-oriented motivation literature removed the opportunity to compare revised POMI with similar instruments.

Researcher Bias

Honors and on-level chemistry students were lost to sampling bias, which influenced the demographics of the sample in this study (Smith & Noble, 2019). These students were removed for one of two reasons: lack of participation in any survey administration or the failure to complete their lab report. The selection of ADI as the independent variable presented intervention and experience bias within this study. Although ADI satisfied the need for a lab with alignment with the current framework, bias existed in the fact that this strategy is modeled at the researcher's district. Furthermore, positive experience bias existed with the experimental group that utilized ADI labs in their classrooms for four years. Such bias is positive since comfort within that group of teachers was present to execute ADI within their classrooms versus inexperienced teachers who had never utilized this strategy in their locale. Bias also existed from the *Framework for K-12 Science Education*. Research bias from the framework was apparent in the initiative to motivate students to pursue careers in science, engineering, and technology.

Implications for Practice

During this study, the revised POMI survey demonstrated valid and reliable data in a high school chemistry setting. This instrument is of paramount importance to the science community due to its ability to measure how students are motivated by the process or practice to complete science, SEPs. Means-focused motivation, novel POMI factor, embeds seven out of eight SEPs in each item, resulting in a measurement of how scientific practices motivate students to learn chemistry content. Moreover, the revised POMI can assess how effective strategies are at motivating students, especially those aligned with the new *Framework.* According to Ryan and Deci (2000), students performed better in science after their motivation increased. Thus, the revised POMI can simply help teachers and administrators comprehend which strategies are effectively motivating students. Like this study, some strategies may not motivate students, but lead to stronger understanding. Nonetheless, educators need to be able to identify strategies and practices that empower students learning, which is measured via summative assessments.

In this study, a definitive model was not specified until completion. The revised POMI, Model 2d, is more effective since it is shorter, and evidenced to be the most valid and reliable POMI model. A simple comparison of the CFA's goodness-of-fit statistics for the original Model 2c versus the final Model 2d is a strong indication that Model 2d had more valid data. Such a result can lead to students providing evidence that is more concise on their process-oriented motivation. Future teacher use would provide definitive findings with the assurance that the revised POMI data has demonstrated validity and reliability in various K-12 public school settings. This is especially true at the researcher's locale where all chemistry students were administered the original and revised POMI.

Argument-Driven Inquiry utilizes four SEP's from the Framework for K-12 Science Education, which aligns with the current curriculum in Georgia (Grooms & Enderle, 2015). Teachers that currently utilize this lab instruction hold a confirmation with this study's lab results. Moreover, teachers that do use other strategies should consider utilizing ADI or aspects of ADI in their classroom. ADI completion takes approximately five days, which may not be feasible based on many school variables. Aspects of ADI such as peer-review, argumentation, procedure creation from a driving question can assist with student understanding via the SEPs (Grooms & Enderle, 2015). ADI may only intrinsically motivate students in a substantial manner, while improving student's ability to effectively communicate their evidence to their peers and their teacher. This ability can lead to high lab report scores as evidenced in this study's mediation path analysis for both outcome-focused and means-focused motivation.

Recommendations for Future Research

Strategies that are aligned with the current curriculum, like ADI, should be measured by revised POMI to quantify change in student motivation. Multiple studies would generate a few narratives: the revised POMI does not effectively measure student motivation, strategies effectively motivate students toward learning science, or strategies improve student achievement. Additional literature would provide additional evidence to assist teachers to utilize strategies that help students. In addition, this would provide fuel to educators to perform professional development on effective strategies in science as well.

The revised POMI can find utilization for all science courses due to its ability to easily adapt. One revised POMI item states “I like to use evidence in my explanation to support a claim that I have in this chemistry class”. This item can be adapted to “I like to use evidence in my explanation to support a claim that I have in this biology class” by switching chemistry to biology. Adaptation in items are imperative to enable multiple uses. SMQ and SMQ-II are two instruments by Glynn (2009 & 2011) that are utilized in chemistry, biology and physic since the items are easily adapted. Therefore, most high school science courses are taken for the first time in K-12 education, which enables this adaption to measure students’ motivation in multiple courses. The revised POMI can also be utilized for future research that will add to the science literature catalog.

Predictive validity was not evident with the revised POMI, means-focused motivation, and student achievement, lab report scores, but the revised POMI has future potential to predict student’s performance in a course. Enrollment in AP courses usually utilize, PSAT scores, to help predict student’s success in their AP course. PSAT scores could be the borderline score that may allow student to take an AP course if other metrics are borderline. However, means-focused motivation helps facilitate students’ interest and curiosity in the SEPs at the highest-level of understanding. Methods to test future predictive validity could be an AP Biology administering the revised POMI and executing predictive validity for all students at the beginning of the course. A Spearman or Pearson correlation for predictive validity could be examined between the means-focused motivation score and students' final grade and AP score, respectively. A significant difference would suggest that means-focused motivation can predict student performance in an Advanced Placement science course. If predictive validity is found with these methods, the means-focused motivation could spread to be utilized on a science department basis at the researcher's locale and further spread to other schools.

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Appendices

Appendix A: VIEWS ABOUT SCIENTIFIC INQUIRY

Views about Scientific Inquiry (VASI)

The following questions are asking for your views related to science and scientific investigations. There are no right or wrong answers.

Please answer each of the following questions. You can use all the space provided to answer a question and continue on the back of the pages if necessary.

1. A person interested in birds looked at hundreds of different types of birds who eat different types of food. He noticed that birds who eat similar types of food, tended to have similar shaped beaks. For example, birds that eat hard-shelled nuts have short, strong beaks, and birds who eat insects have long, slim beaks. He wondered if the shape of a bird's beak was related to the type of food the bird eats and he began to collect data to answer that question. He concluded that there is a relationship between beak shape and the type of food birds eat.

    a. Do you consider this person's investigation to be scientific? Please explain why or why not.

    b. Do you consider this person's investigation to be an experiment? Please explain why or why not.

    c. Do you think that scientific investigations can follow more than one method?
        If no, please explain why there is only one way to conduct a scientific investigation.
        If yes, please describe two investigations that follow different methods, and explain how the methods differ and how they can still be considered scientific.

2. Two students are asked if scientific investigations must always begin with a scientific question. One of the students says "yes" while the other says "no". Whom do you agree with and why?

3. (a) If several scientists ask the ***same question*** and follow the ***same procedures*** to collect data, will they necessarily come to the *same conclusions*? Explain why or why not.

    (b) If several scientists ask the ***same question*** and follow ***different procedures*** to collect data, will they necessarily come to the same conclusions? Explain why or why not.

4. Please explain if "data" and "evidence" are different from one another.

5. Two teams of scientists are walking to their lab one day and they saw a car pulled over with a flat tire. They all wondered, "Are certain brands of tires more likely to get a flat?"

    Team A went back to the lab and tested various tires' performance on one type of road surfaces.

    Team B went back to the lab and tested one tire brand on three types of road surfaces.

    Explain why one team's procedure is better than the other one.

6. The data table below shows the relationship between plant growth in a week and the number of minutes of light received each day.

Minutes of light each day	Plant growth-height (cm per week)
0	25

5	20
10	15
15	5
20	10
25	0

Given this data, explain which one of the following conclusions you agree with and why.

Please circle one:

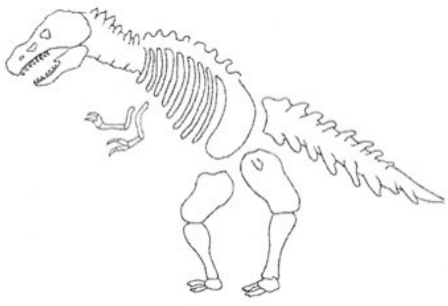
a) Plants grow taller with **more** sunlight.

b) Plants grow taller with **less** sunlight.

c) The growth of plants is **unrelated** to sunlight.

Please explain your choice of a, b, or c below:

7. The fossilized bones of a dinosaur have been found by a group of scientists. Two different arrangements for the skeleton are developed as shown below.



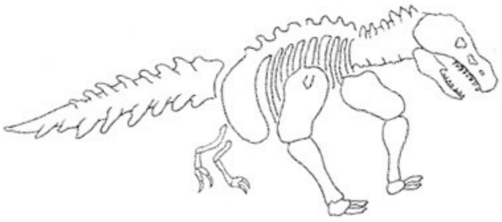


Figure 1

Figure 2

a) Describe at least two reasons why you think most of the scientists agree that the animal in *figure 1* had the best sorting and positioning of the bones?

b) Thinking about your answer to the question above, what types of information do scientists use to explain their conclusions?

Appendix B: THE PROCESS-ORIENTED MOTIVATION INSTRUMENT

Please complete the following information about yourself

○ First Name (1) ____

○ Last Name (2) ____

Who is your chemistry teacher this semester?

○ Prelac (1)
○ Bishop (2)
○ Lau (3)
○ Wisdom (4)
○ Harhay (5)

	Strongly Disagree (1)	Disagree (2)	Agree (3)	Strongly Agree (4)
I find the topics discussed in this chemistry class interesting. (1)	○	○	○	○
I enjoy this chemistry class more when I get to research problems. (24)	○	○	○	○
I enjoy this chemistry class more when I use figures to make sense of the topics in this chemistry class. (3)	○	○	○	○
I like this chemistry class because it’s fun. (4)	○	○	○	○
I like to use evidence in my explanation to support a claim that I have made in this chemistry class. (5)	○	○	○	○
I enjoy completing assignments for this chemistry class because they are exciting. (7)	○	○	○	○
I enjoy this chemistry class more when I get to plan and carry out investigations. (8)	○	○	○	○
I enjoy laboratories in this chemistry class when they allow me to ask questions about the system being studied. (9)	○	○	○	○
I attend this chemistry class only because I am supposed to do so. (10)	○	○	○	○

I enjoy this chemistry class more when I get to analyze and interpret data. (12)	○	○	○	○
I attend this class because without taking chemistry I would not find a high-paying job later on. (13)	○	○	○	○

End of Block: Default Question Block

Start of Block: Block 1

Page Break

	Strongly Disagree (1)	Disagree (2)	Agree (3)	Strongly Agree (4)
I enjoy this chemistry class more when I get to use math and computational thinking such as math expressions and computer simulations. (2)	○	○	○	○
I am only motivated in this chemistry class because we get grades. (4)	○	○	○	○
I enjoy computer simulations that help me understand, predict, and explain concepts in this chemistry class. (5)	○	○	○	○
I enjoy this chemistry class more when I get to construct explanations about a concept. (6)	○	○	○	○
I enjoy creating supporting arguments for my understanding of the concepts addressed by labs in this chemistry class. (7)	○	○	○	○
I took this chemistry class because it will look good on my high school transcript. (8)	○	○	○	○
I enjoy this chemistry class more when I get to engage in arguments based on scientific evidence. (9)	○	○	○	○

I like communicating my results after I have completed an experiment in this chemistry class. (10)	○	○	○	○
I enjoy this class because I am highly interested in doing chemistry. (11)	○	○	○	○
I am strongly motivated by the recognition I can earn from other people in this chemistry class. (12)	○	○	○	○
I enjoy completing experiments in this chemistry class since they allow me to investigate different problems with my classmates. (13)	○	○	○	○
Once I have collected data from a chemistry experiment, I like to search for patterns and trends in the data. (24)	○	○	○	○
I am strongly motivated to participate in this chemistry class when the teacher pays attention to me. (25)	○	○	○	○
I enjoy this chemistry class more when I get the opportunity to communicate my lab results. (26)	○	○	○	○

End of Block: Block 1

Appendix C: CONTENT EXPERT VALIDATION SURVEY FOR ORIGINAL POMI

Consent Form for the Process-Oriented Motivation Instrument Content Validation Survey

My signature below indicates that I have read the information provided and have decided to participate in the content validation for the study titled “Measuring the Effect of Argument-Driven Inquiry on High School Chemistry Students’ Process-Oriented Motivation utilizing the Newly Developed Valid and Reliable Process Oriented Motivation Instrument”. I understand the purpose of this survey will be to assist with content validity for the Process-Oriented Motivation Instrument to ensure that its content is appropriate and valid for a high school chemistry classroom.

Sample Instructions: Thanks again for agreeing to participate in our expert review of the items on the Process-Oriented Motivation Instrument that we are developing. Below is a description of the larger research project, the construct definitions, and then a list of questions about each of the items on the survey. Please begin by familiarizing yourself with this background information and the construct definitions, and then review the specific instructions for completing the content validation.

Research project: The Framework for K-12 Science Education’s prime goal is to motivate students in the science classroom with standards that utilize science and engineering practices (SEP’s) that prepare students for science careers (NRC, 2012). The requirement to motivate students, and reform that empowers such motivation, has been established; however, an appropriate instrument is needed to measure any change in the degree of motivation that results from new science framework. Therefore, the purpose of this study is to develop the novel Process-Oriented Motivation Instrument (POMI) which will be validated and deemed reliable for a high school chemistry student. Once the instrument has been constructed, the survey will be given before and after a unit taught using argument-driven inquiry, a pedagogy that supports that Framework. Anticipated in findings of this study will aid in confirming that teaching using methods supported by the Framework do in fact improve student’s motivation towards learning science.

Construct definitions: Process-Oriented Motivation has three constructs that is focused on the process of goal attainment. A goal must have a definitive beginning and end state (Touré-Tillery & Fishbach, 2014).

a) Outcome-Focused Motivation is driven by the reward or outcome of goal completion, but extrinsic motivation is driven by the reward of task completion (Touré-Tillery & Fishbach, 2014).
b) Intrinsic motivation (process-oriented) will be correlated with enjoyment and interest during the process of goal pursuit (Tillery & Fishbach, 2014). A significant difference between intrinsic motivation (process-oriented motivation) and current literature’s intrinsic motivation is the attainment of a goal versus fulfillment of a task (Touré-Tillery & Fishbach, 2014).
c) Means-focus motivation is a novel construct that utilizes proper means during goal pursuit; proper means are how actions are performed in terms of adherence to rules, principles, and self-set standards (Tillery & Fishbach, 2014). What means were endured during the process of goal pursuit? There are no known risks or anticipated discomforts that have been identified by this research protocol.

This study will be guided by the following research questions:

1. How does the data from the Process-Oriented Motivation Instrument establish appropriate validity for high school chemistry students?

1a. What is the relationship between a student’s Views about Scientific Inquiry and the degree to which they are motivated by scientific processes?

2. What is Argument-Driven Inquiry’s effect on high school chemistry students’ process-oriented motivation?
3. What is the mediation effect of process-oriented motivation and relationship between argument-driven inquiry and student achievement?

Participants personal information will be kept confidential in this survey. All participant data will be deidentified with a code that does not include the participant's name. For this online survey, Internet Protocol addresses WILL NOT be collected. Results from this survey will only be used to improve the survey and will not be included in the dissertation. Such results will be the overall potential benefit of this survey. Participation in this survey is voluntary and will be pulled from consideration for the analysis of this instrument if I decide to withdraw permission after the survey is completed via email to Martel Wisdom or Dr. Michelle Head.

If further information is needed regarding this survey, I can contact Martel Wisdom or Dr. Michelle Head at the following emails: wisdomm@fultonschools.org or mhead24@kennesaw.edu. Research at Kennesaw State University that involves human participants is carried out under the oversight of an Institutional Review Board. Address questions or problems regarding these activities to the Institutional Review Board, Kennesaw State University, 585 Cobb Avenue, KH3417, Kennesaw, GA 30144-5591, (470) 578-6407.

Participant Consent

○ I agree and give my consent to participate in this research project. I understand that participation is voluntary and that I may withdraw my consent at any time without penalty. (1)

○ I do not agree to participate and will be excluded from the remainder of the questions (2)

In this section, we would like to know how comprehensible each item is for our anticipated respondent population. Select how understandable each of the following items is by using the scales below. If you have ideas for how to clarify the meaning of an item, please note your thoughts beneath each item via suggestions.

Each item below will be ranked by the participants on a 5-Point Likert Scale. The five-point Likert scale will be as follows: a. Always b. Most of the time c. About half the time d. Sometimes e. Never

Item 1 - I like what we learn in this chemistry class, because it is interesting.

○ Not at all understandable (1)

○ Slightly understandable (2)

○ Somewhat understandable (3)

○ Quite understandable (4)

○ Extremely understandable (5)

Suggestions for Item 1 ____

Item 2 - I enjoy this chemistry class more when I get to ask questions and research problems.

○ Not at all understandable (1)

○ Slightly understandable (2)

○ Somewhat understandable (3)

○ Quite understandable (4)

○ Extremely understandable (5)

Suggestions for Item 2 ____

Item 3 - I like developing a model, either as a picture or mathematical equation in this chemistry class.

○ Not at all understandable (1)

○ Slightly understandable (2)

○ Somewhat understandable (3)

○ Quite understandable (4)

○ Extremely understandable (5)

Suggestions for Item 3 ____

Item 4 - I like this chemistry class, because it's fun.

○ Not at all understandable (1)

○ Slightly understandable (2)

○ Somewhat understandable (3)

○ Quite understandable (4)

○ Extremely understandable (5)

Suggestions for Item 4 ____

Item 5 - I enjoy this chemistry class more when I get to develop and use models such as diagrams, drawings, computer simulations or mathematical equations.

○ Not at all understandable (1)

○ Slightly understandable (2)

○ Somewhat understandable (3)

○ Quite understandable (4)

○ Extremely understandable (5)

Suggestions for Item 5 ____

Item 6 - I like to use evidence in my explanation to support a claim that has been made in this chemistry class.

○ Not at all understandable (1)

○ Slightly understandable (2)

○ Somewhat understandable (3)

○ Quite understandable (4)

○ Extremely understandable (5)

Suggestions for Item 6 ____

Item 7 - I enjoy doing activities in this chemistry class, because they are exciting.

○ Not at all understandable (1)

○ Slightly understandable (2)

○ Somewhat understandable (3)

○ Quite understandable (4)

○ Extremely understandable (5)

Suggestions for Item 7 ____

Item 8 - I enjoy this chemistry class more when I get to plan and carry out investigations.

○ Not at all understandable (1)

○ Slightly understandable (2)

○ Somewhat understandable (3)

○ Quite understandable (4)

○ Extremely understandable (5)

Suggestions for Item 8

____

Item 9 - I find this class interesting, because I enjoy doing chemistry

- ○ Not at all understandable (1)
- ○ Slightly understandable (2)
- ○ Somewhat understandable (3)
- ○ Quite understandable (4)
- ○ Extremely understandable (5)

Suggestions for Item 9 ____

Item 10 - I enjoy laboratories in this chemistry class when they allow me to ask questions about the system being studied.

- ○ Not at all understandable (1)
- ○ Slightly understandable (2)
- ○ Somewhat understandable (3)
- ○ Quite understandable (4)
- ○ Extremely understandable (5)

Suggestion for Item 10 ____

Item 11 - I attend this chemistry class, because I am supposed to do so.

- ○ Not at all understandable (1)
- ○ Slightly understandable (2)
- ○ Somewhat understandable (3)
- ○ Quite understandable (4)
- ○ Extremely understandable (5)

Suggestion for Item 11 ____

Item 12 - I enjoy this chemistry class more when I get to analyze and interpret data.

- ○ Not at all understandable (1)
- ○ Slightly understandable (2)
- ○ Somewhat understandable (3)
- ○ Quite understandable (4)
- ○ Extremely understandable (5)

Suggestions for Item 12 ____

Item 13 - I attend this class, because without taking chemistry I would not find a high-paying job later on.

- ○ Not at all understandable (1)
- ○ Slightly understandable (2)
- ○ Somewhat understandable (3)
- ○ Quite understandable (4)
- ○ Extremely understandable (5)

Suggestions for Item 13____

Item 14 - I enjoy this chemistry class more when I get to use math and computational thinking such as math expressions and computer simulations.

- ○ Not at all understandable (1)
- ○ Slightly understandable (2)
- ○ Somewhat understandable (3)
- ○ Quite understandable (4)
- ○ Extremely understandable (5)

Suggestion for Item 14 ____

Item 15 - I am only motivated in this chemistry class, because we get grades.

○ Not at all understandable (1)

○ Slightly understandable (2)

○ Somewhat understandable (3)

○ Quite understandable (4)

○ Extremely understandable (5)

Suggestions for Item 15 ____

Item 16 - I enjoy computer simulations that help me understand, predict, and explain concepts in this chemistry class

○ Not at all understandable (1)

○ Slightly understandable (2)

○ Somewhat understandable (3)

○ Quite understandable (4)

○ Extremely understandable (5)

Suggestions for Item 16 ____

Item 17 - I enjoy this chemistry class more when I get to construct explanations about a concept.

○ Not at all understandable (1)

○ Slightly understandable (2)

○ Somewhat understandable (3)

○ Quite understandable (4)

○ Extremely understandable (5)

Suggestions for Item 17 ____

Item 18 - I enjoy engaging in arguments for the understanding of the concepts addressed by labs in this chemistry class

- ○ Not at all understandable (1)
- ○ Slightly understandable (2)
- ○ Somewhat understandable (3)
- ○ Quite understandable (4)
- ○ Extremely understandable (5)

Suggestions for Item 18 ____

Item 19 - I took this chemistry class because it will look good on my high school transcript.

- ○ Not at all understandable (1)
- ○ Slightly understandable (2)
- ○ Somewhat understandable (3)
- ○ Quite understandable (4)
- ○ Extremely understandable (5)

Suggestions for Item 19 ____

Item 20 - I enjoy this chemistry class more when I get to engage in arguments from scientific evidence.

- ○ Not at all understandable (6)
- ○ Slightly understandable (7)
- ○ Somewhat understandable (8)
- ○ Quite understandable (9)
- ○ Extremely understandable (10)

Q88 Suggestions for Item 20 ____

Q87 Item 21 - I like collecting data from chemistry experiments in this class and communicating my results after I have completed the experiment.

- ○ Not at all understandable (1)
- ○ Slightly understandable (2)
- ○ Somewhat understandable (3)
- ○ Quite understandable (4)
- ○ Extremely understandable (5)

Q89 Suggestions for Item 21 ____

Q86 Item 22 - I enjoy this class, because I am highly interested in doing chemistry.

- ○ Not at all understandable (1)
- ○ Slightly understandable (2)
- ○ Somewhat understandable (3)
- ○ Quite understandable (4)
- ○ Extremely understandable (5)

Q90 Suggestions for Item 22____

Q85 Item 23 - I am strongly motivated by the recognition I can earn from other people in this chemistry class.

- ○ Not at all understandable (4)
- ○ Slightly understandable (5)
- ○ Somewhat understandable (6)
- ○ Quite understandable (7)
- ○ Extremely understandable (8)

Q91 Suggestions for Item 23____

Q71 Item 24 - I enjoy completing experiments in this chemistry class since they allow me to investigate different problems with my classmates.

○ Not at all understandable (1)

○ Slightly understandable (2)

○ Somewhat understandable (3)

○ Quite understandable (4)

○ Extremely understandable (5)

Q92 Suggestions for Item 24 ____

Q72 Item 25 - Once I have collected data from a chemistry experiment, I like to search for patterns and trends in the data

○ Not at all understandable (1)

○ Slightly understandable (2)

○ Somewhat understandable (3)

○ Quite understandable (4)

○ Extremely understandable (5)

Q93 Suggestions for Item 25____

Q73 Item 26 - I participate in this chemistry class so that the teacher pays attention to me.

○ Not at all understandable (1)

○ Slightly understandable (2)

○ Somewhat understandable (3)

○ Quite understandable (4)

○ Extremely understandable (5)

Q94 Suggestions for Item 26____

Q74 Item 27 - I enjoy this chemistry class more when I get the opportunity to communicate my lab results.

- ○ Not at all understandable (1)
- ○ Slightly understandable (2)
- ○ Somewhat understandable (3)
- ○ Quite understandable (4)
- ○ Extremely understandable (5)

Q95 Suggestions for Item 27____

In this section, we would like your help to anticipate which of our items will produce an adequate range of means. Please select what you think the average (mean) response for each item will be given from our audience (Ages 15 and 16).

Item 1 - I like what we learn in this chemistry class, because it is interesting.

○ Always (13)

○ Most of the time (14)

○ About half the time (15)

○ Sometimes (16)

○ Never (17)

Item 2 - I enjoy this chemistry class more when I get to ask questions and research problems.

○ Always (1)

○ Most of the time (2)

○ About half the time (3)

○ Sometimes (4)

○ Never (5)

Item 3 - I like developing a model, either as a picture or mathematical equation in this chemistry class

○ Always (1)

○ Most of the time (2)

○ About half the time (3)

○ Sometimes (4)

○ Never (5)

Item 4 - I like this chemistry class, because it's fun.

○ Always (1)

○ Most of the time (2)

○ About half the time (3)

○ Sometimes (4)

○ Never (5)

Item 5 - I enjoy this chemistry class more when I get to develop and use models such as diagrams, drawings, computer simulations or mathematical equations.

○ Always (1)

○ Most of the time (2)

○ About half the time (3)

○ Sometimes (4)

○ Never (5)

Item 6 - I like to use evidence in my explanation to support a claim that has been made in this chemistry class.

○ Always (1)

○ Most of the time (2)

○ About half the time (3)

○ Sometimes (4)

○ Never (5)

Item 7 - I enjoy doing activities in this chemistry class, because they are exciting.

○ Always (1)

○ Most of the time (2)

○ About half the time (3)

○ Sometimes (4)

○ Never (5)

Item 8 - I enjoy this chemistry class more when I get to plan and carry out investigations.

○ Always (1)

○ Most of the time (2)

○ About half the time (3)

○ Sometimes (4)

○ Never (5)

Item 9 - I find this class interesting, because I enjoy doing chemistry

○ Always (1)

○ Most of the time (2)

○ About half the time (3)

○ Sometimes (4)

○ Never (5)

Item 10 - I enjoy laboratories in this chemistry class when they allow me to ask questions about the system being studied.

○ Always (13)

○ Most of the time (14)

○ About half the time (15)

○ Sometimes (16)

○ Never (17)

Item 11 - I attend this chemistry class, because I am supposed to do so.

○ Always (1)

○ Most of the time (2)

○ About half the time (3)

○ Sometimes (4)

○ Never (5)

Item 12 - I enjoy this chemistry class more when I get to analyze and interpret data.

○ Always (1)

○ Most of the time (2)

○ About half the time (3)

○ Sometimes (4)

○ Never (5)

Item 13 - I attend this class, because without taking chemistry I would not find a high-paying job later on.

○ Always (1)

○ Most of the time (2)

○ About half the time (3)

○ Sometimes (4)

○ Never (5)

Item 14 - I enjoy this chemistry class more when I get to use math and computational thinking such as math expressions and computer simulations.

○ Always (1)

○ Most of the time (2)

○ About half the time (3)

○ Sometimes (4)

○ Never (5)

Item 15 - I am only motivated in this chemistry class, because we get grades.

○ Always (1)

○ Most of the time (2)

○ About half the time (3)

○ Sometime (4)

○ Never (5)

Item 16 - I enjoy computer simulations that help me understand, predict, and explain concepts in this chemistry class

○ Always (1)

○ Most of the time (2)

○ About half the time (3)

○ Sometimes (4)

○ Never (5)

Item 17 - I enjoy this chemistry class more when I get to construct explanations about a concept.

- ○ Always (1)
- ○ Most of the time (2)
- ○ About half the time (3)
- ○ Sometimes (4)
- ○ Never (5)

Item 18 - I enjoy engaging in arguments for the understanding of the concepts addressed by labs in this chemistry class

- ○ Always (1)
- ○ Most of the time (2)
- ○ About half the time (3)
- ○ Sometimes (4)
- ○ Never (5)

Item 19 - I took this chemistry class because it will look good on my high school transcript.

- ○ Always (1)
- ○ Most of the time (2)
- ○ About half the time (3)
- ○ Sometimes (4)
- ○ Never (5)

Q97 Item 20 - I enjoy this chemistry class more when I get to engage in arguments from scientific evidence.

- ○ Always (11)
- ○ Most of the time (12)
- ○ About half the time (13)
- ○ Sometimes (14)
- ○ Never (15)

Q98 Item 21 - I like collecting data from chemistry experiments in this class and communicating my results after I have completed the experiment.

○ Always (18)

○ Most of the time (19)

○ About half the time (20)

○ Sometimes (21)

○ Never (22)

Q99 Item 22 - I enjoy this class, because I am highly interested in doing chemistry.

○ Always (13)

○ Most of the time (14)

○ About half the time (15)

○ Sometimes (16)

○ Never (17)

Q100 Item 23 - I am strongly motivated by the recognition I can earn from other people in this chemistry class.

○ Always (13)

○ Most of the time (14)

○ About half the time (15)

○ Sometimes (16)

○ Never (17)

Q101 Item 24 - I enjoy completing experiments in this chemistry class since they allow me to investigate different problems with my classmates.

○ Always (13)

○ Most of the time (14)

○ About half the time (15)

○ Sometimes (16)

○ Never (17)

Q102 Item 25 - Once I have collected data from a chemistry experiment, I like to search for patterns and trends in the data

○ Always (13)

○ Most of the time (14)

○ About half the time (15)

○ Sometimes (16)

○ Never (17)

Q103 Item 26 - I participate in this chemistry class so that the teacher pays attention to me.

○ Always (13)

○ Most of the time (14)

○ About half the time (15)

○ Sometimes (16)

○ Never (17)

Q104 Item 27 - I enjoy this chemistry class more when I get the opportunity to communicate my lab results.

○ Always (18)

○ Most of the time (19)

○ About half the time (20)

○ Sometimes (21)

○ Never (22)

Q1 Please group each item in the following boxes based on the constructs they are related to and if the item is unrelated place item in the other box. Below are the definitions for each category/construct.

a. Outcome-Focused Motivation is driven by the reward or outcome of goal completion, but extrinsic motivation is driven by the reward of task completion (Touré-Tillery & Fishbach, 2014).
b. Intrinsic motivation (process-oriented) will be correlated with enjoyment and interest during the process of goal pursuit (Tillery & Fishbach, 2014). A significant difference between intrinsic motivation (process-oriented

motivation) and current literature's intrinsic motivation is the attainment of a goal versus fulfillment of a task (Touré-Tillery & Fishbach, 2014).

c. Means-focus motivation is a novel construct that utilizes proper means during goal pursuit; proper means are how actions are performed in terms of adherence to rules, principles, and self-set standards (Tillery & Fishbach, 2014). What means were endured during the process of goal pursuit?

Intrinsic Motivation (Process-Oriented)	**Outcome-Focused Motivation**	**Means-Focused Motivation**	**Other**
______ I like what we learn in this chemistry class, because it is interesting. (1)			
______ I enjoy this chemistry class more when I get to ask questions and research problems. (2)			
______ I like developing a model, either as a picture or mathematical equation in this chemistry class. (3)			
______ I like this chemistry class, because it's fun. (4)			
______ I enjoy this chemistry class more when I get to develop and use models such as diagrams, drawings, computer simulations or mathematical equations. (5)			
______ I like to use evidence in my explanation to support a claim that has been made in this chemistry class. (6)			
______ I enjoy doing activities in this chemistry class, because they are exciting. (7)			
______ I enjoy this chemistry class more when I get to plan and carry out investigations. (8)			

______ I find this class interesting, because I enjoy doing chemistry (9)

______ I enjoy laboratories in this chemistry class when they allow me to ask questions about the system being studied. (10)

______ I attend this chemistry class, because I am supposed to do so. (11)

______ I enjoy this chemistry class more when I get to analyze and interpret data. (12)

______ I attend this class, because without taking chemistry I would not find a high-paying job later on. (13)

______ I enjoy this chemistry class more when I get to use math and computational thinking such as math expressions and computer simulations. (14)

______ I am only motivated in this chemistry class, because we get grades. (15)

______ I enjoy computer simulations that help me understand, predict, and explain concepts in this chemistry class (16)

______ I enjoy this chemistry class more when I get to construct explanations about a concept. (18)

______ I took this chemistry class because it will look good on my high school transcript. (19)

______ I enjoy this chemistry class more when I get to engage in arguments from scientific evidence. (20)

______ I like collecting data from chemistry experiments in this class and communicating my results after I have completed the experiment. (21)

______ I enjoy this class, because I am highly interested in doing chemistry. (22)

______ I am strongly motivated by the recognition I can earn from other people in this chemistry class. (23)

______ I enjoy completing experiments in this chemistry class since they allow me to investigate different problems with my classmates. (24)

______ Once I have collected data from a chemistry experiment, I like to search for patterns and trends in the data (25)

______ I participate in this chemistry class so that the teacher pays attention to me. (26)

______ I enjoy this chemistry class more when I get the opportunity to communicate my lab results. (27)

______ I enjoy engaging in arguments for the understanding of the concepts addressed by labs in this chemistry class (28)

Q2 Please explain any items placed in the other category. Please write the item number and the comment justifying other placement and press enter for the next submission within this text box.

____
____
____
____
____

Q3 Please think about all the items for a moment. We hope this survey scale fairly represents the entire process-oriented motivation dimension. Please indicate below any aspects or characteristics that you feel are important parts of the Process-Oriented Motivation Instrument which are not represented or are inadequately represented by this survey scale.

____
____
____
____

Appendix D: THE PROCESS-ORIENTED MOTIVATION INSTRUMENT POST-SURVEY WITH VALIDATION ITEMS

Q25 Please complete the following information about yourself

○ First Name (1) ____

○ Last Name (2) ____

Q26 Who is your chemistry teacher this semester?

- ○ Prelac (1)
- ○ Bishop (2)
- ○ Lau (3)
- ○ Wisdom (4)
- ○ Harhay (5)

Q22 Please rate each of the following items regarding your motivation towards learning in your current chemistry course.

	Strongly Disagree (1)	**Disagree (2)**	**Agree (3)**	**Strongly Agree (4)**
I find the topics discussed in this chemistry class interesting. (1)	○	○	○	○
Select disagree for this statement (8)	○	○	○	○
I enjoy this chemistry class more when I get to research problems. (24)	○	○	○	○
I enjoy this chemistry class more when I use figures to make sense of the topics in this chemistry class. (3)	○	○	○	○
I like this chemistry class because it's fun. (4)	○	○	○	○
I like to use evidence in my explanation to support a claim that I have made in this chemistry class. (5)	○	○	○	○
I enjoy completing assignments for this chemistry class because they are exciting. (7)	○	○	○	○

	Strongly Disagree (1)	**Disagree (2)**	**Agree (3)**	**Strongly Agree (4)**
I enjoy this chemistry class more when I get to plan and carry out investigations. (1)	○	○	○	○
I enjoy laboratories in this chemistry class when they allow me to ask questions about the system being studied. (24)	○	○	○	○
I attend this chemistry class only because I am supposed to do so. (3)	○	○	○	○
Select agree for this statement (8)	○	○	○	○
I enjoy this chemistry class more when I get to analyze and interpret data. (4)	○	○	○	○
I attend this class because without taking chemistry I would not find a high-paying job later on. (5)	○	○	○	○
I enjoy this chemistry class more when I get to use math and computational thinking such as math expressions and computer simulations (7)	○	○	○	○

	Strongly Disagree (1)	**Disagree (2)**	**Agree (3)**	**Strongly Agree (4)**
I am only motivated in this chemistry class because we get grades. (1)	○	○	○	○
I enjoy computer simulations that help me understand, predict, and explain concepts in this chemistry class. (24)	○	○	○	○
I enjoy this chemistry class more when I get to construct explanations about a concept. (3)	○	○	○	○
I enjoy creating supporting arguments for my understanding of the concepts addressed by lab in this chemistry class (4)	○	○	○	○
I took this chemistry class because it will look good on my high school transcript. (5)	○	○	○	○
I enjoy this chemistry class more when I get to engage in arguments based on scientific evidence. (7)	○	○	○	○
Select disagree for this statement (25)	○	○	○	○

	Strongly Disagree (1)	**Disagree (2)**	**Agree (3)**	**Strongly Agree (4)**
I like communicating my results after I have completed an experiment in this chemistry class. (1)	○	○	○	○
I enjoy this class because I am highly interested in doing chemistry. (24)	○	○	○	○
I am strongly motivated by the recognition I can earn from other people in this chemistry class. (4)	○	○	○	○
Select agree for this statement (25)	○	○	○	○
I enjoy completing experiments in this chemistry class since they allow me to investigate different problems with my classmates. (5)	○	○	○	○
Once I have collected data from a chemistry experiment, I like to search for patterns and trends in the data. (7)	○	○	○	○
I am strongly motivated to participate in this chemistry class when the teacher pays attention to me. (27)	○	○	○	○
I enjoy this chemistry class more when I get the opportunity to communicate my lab results. (28)	○	○	○	○

Appendix E: KENNESAW STATE UNIVERSITY IRB APPROVAL

5/16/2019

Martel Wisdom, Student

Secondary and Middle Grades

RE: Your follow-up submission of 5/16/2019, Study #19-542: Measuring the Effect of Argument-Driven Inquiry on High School Chemistry Students' Process-Oriented Motivation utilizing the Newly Developed Valid and Reliable Process Oriented Motivation Instrument

Hello Mr. Wisdom,

Your application for the new study listed above has been administratively reviewed. This study qualifies as exempt from continuing review under DHHS (OHRP) Title 45 CFR Part 46.101(b)(2) - Educational tests, surveys, interviews, observations of public behavior. The consent procedures described in your application are in effect. You are free to conduct your study.

NOTE: All surveys, recruitment flyers/emails, and consent forms must include the IRB study number noted above, prominently displayed on the first page of all materials.

Please note that all proposed revisions to an exempt study require submission of a Progress Report and IRB review prior to implementation to ensure that the study continues to fall within an exempted category of research. A copy of revised documents with a description of planned changes should be submitted to irb@kennesaw.edu for review and approval by the

IRB.

Please submit a Progress Report to close the study once it is complete.

Thank you for keeping the board informed of your activities. Contact the IRB at irb@kennesaw.edu or at (470) 578-6407 if you have any questions or require further information.

Sincerely,

Christine Ziegler, Ph.D.

KSU Institutional Review Board Director and Chair

Appendix F: FULTON COUNTY IRB APPROVAL

Fulton County Schools
Where Students Come First

BOARD OF EDUCATION

Linda P. Bryant, *President*

Julia C. Bernath, *Vice President*

Gail Dean • Kimberly Dove• Linda McCain Katie Reeves • Katha Stuart

Mike Looney, Ed.D., *Superintendent*

RESEARCH AGREEMENT

This agreement between Martel Wisdom ("the Applicant") and the Fulton County School District ("the

District") is made for purpose of the study to be conducted entitled: *" Measuring the Effect of Argument-Driven Inquiry on High School Chemistry Students' Process-Oriented Motivation Utilizing the Newly Developed Valid and Reliable Process Oriented Motivation Instrument*

The Application for Research Study and all attachments submitted by the Applicant outline the purpose of the study, the scope of the student, and the information to be disclosed to the Applicant for purposes of this study. This Application and attached documents are specifically incorporated by reference into this Research Agreement ("the Agreement").

Except as discussed in Section 1, below, no changes to the information provided in the application and research proposal documents may be made without written consent of the District.

1. **STATEMENT OF WORK.** The research proposal submitted in the application dated May 28, 2019 is accepted with the following modifications/stipulations:

-IRB approval letter must be submitted to DPE

2. **PERIOD OF RESEARCH.** The Research shall be conducted during the period July 2, 2019 to July 1, 2020.

3. **COSTS.** There is no cost to the District to participate in this research.

4. **REPORTING OF DATA.** The Applicant must submit a report summarizing the outcomes of their research conducted with the District. The purpose of this requirement is to enable the District to share the findings to inform the practice of our school leaders and teachers. This report is to be submitted as soon as practicable, but no later than 6 months after completion of the research study.

5. **CONFIDENTIALITY.** Student, parent, guardian and personnel privacy is and must be a paramount concern. The Applicant must, in all respects comply with the provisions of privacy law including, but not limited to, the Family Educational Right to Privacy Act ("FERPA") 20 USC 1232g; the Protection of Pupil Rights Amendment ("PPRA"), 20 U.S.C. 1232h; and

O.C.G.A. 50-18-72(a)(34), as applicable. The Applicant may not maintain, use, disclose, or share student record information in a manner not allowed under Federal or state law or regulation. Student and personnel information gathered by Applicant during this research can be used for no other purpose other than the research described in this Research Agreement. Access to data will be limited only to those representatives of the Applicant's institution with legitimate interests under the research described in this Agreement. Except as may be required by law, the Applicant will not share information received under this Agreement with any other entity or person without prior written approval from the District. The data continues to be owned by the District.

6. SECURITY AND DATA PROTECTION. Upon termination of this Agreement or three months after the publication of reports generated under the Research, whichever is sooner, the Applicant will destroy all data obtained under the agreement that contains any personally identifiable information as that term is defined in FERPA. The Applicant will promptly notify the District when they or their subcontractors become aware of any actual or potential security or data breach relating to the information shared under this Agreement. All steps to mitigate and rectify the consequences of such a breach, including notification to impacted parties, shall be undertaken by the Applicant at its sole expense. The District will be entitled as a matter of right to seek injunctive relief to prevent commencing or continuing a breach of security or data protection violation without having to post a bond or other security and without having to prove the inadequacy of any other available remedies. Nothing will be deemed to limit or abridge any other remedy available to the District at law or in equity.

7. SCHOOL ENVIRONMENT. All visitors to school property will comply with the directions of the school principal or site director. Any visitor may be requested to leave school property, and the District reserves the right to refuse access to any individual on school property.

8. PUBLICATIONS. The Applicant must have written approval prior to identifying the District in any publications or releases about the research. All publications and written releases will be provided to the District one month prior to the release or publication. The Applicant will not share information in any manner that could identify any individual school, student, parent, guardian, or personnel member. All publications will include appropriate methods of disclosure avoidance, including but not limited to, suppression, blurring, recoding the ends of the distribution, protecting underlying contents, collapsing across outcome categories, perturbation techniques, and establishing minimum subgroup sizes.

9. HUMAN SUBJECTS. The use of human subjects in the Project shall comply with Department of Health and Human Services (DHHS) policies and regulations on the protection of human subjects (45 CFR 46, as amended. The Applicant will not ask the Subcontractor to engage in the research activities. The Applicant is responsible for ensuring that all research activities comply with applicable law, will inform the District of any requirements under this paragraph, and will assist the District with steps necessary to ensure compliance.

10. TERMINATION. Either party may terminate the research at any time upon written notice to the other party.

11. COMPLIANCE. The Applicant will ensure that this research conforms to all requirements of this Agreement, of Board Policy and Procedure ICC, and of all applicable federal, state and local laws, rules and regulations. All permission slips and consent forms will be approved by the Department of Research and Program Evaluation for the District.

12. INDEPENDENT CONTRACTOR. For the purposes of this Agreement and research, the Applicant and the District shall be, and shall be deemed to be, independent contractors and not an agent or employee of the other Party.

13. ASSIGNMENT. The activities under this Agreement shall not be assigned without the written consent of the other Party and any attempt to assign without such consent shall be void.

14. MODIFICATION. No modification of this Agreement will be valid unless in writing and executed by authorized representatives of both the District and the Applicant.

15. CONTACTS. Written notices and other questions about the research should be directed to:

programevaluation@fultonschools.org.

16. LIABILITY. To the extent permitted by law, the Applicant shall hold harmless and indemnify the District, its past, future and current Board of Education, and its past, future, and current employees, agents, volunteers or assignees ("the District Indemnitees") from any and all claims, suits, actions, damages, liability and expenses including attorney fees in connection with (a) claims, demands, or lawsuits with respect to any activities related to this Agreement that are undertaken by the Applicant, the Applicant's subcontractors, the District, or the District's representatives or staff as a result of this Agreement; (b) the failure of the Applicant or its subcontractors to comply with any law or regulation, including FERPA or PPRA; (c) the loss, misappropriation or other unauthorized disclosure of data by Applicant or its subcontractors; and (e) any security breach involving data in Applicant's or a subcontractor's possession, custody or control, or for which Applicant or a subcontractor accesses or is otherwise responsible. The Applicant's obligation shall not be limited by, or in any way to, any insurance coverage or by any provision in or exclusion of omission from any policy of insurance.

17. CHOICE OF LAW. This Agreement shall be interpreted, construed and given effect in all respects according to the laws of the State of Georgia.

District Authorized Representative:	**Applicant Authorized Representative:**
James Yerich	Martel Wisdom
(signature)	(signature)
Researcher, FCS Chemistry Teacher	

Appendix G: CONSENT FORM

My signature below indicates that I have read the information provided and have decided to allow my child to participate in the study titled “Measuring the Effect of Argument-Driven Inquiry on High School Chemistry Students’ Process-Oriented Motivation utilizing the Newly Developed Valid and Reliable Process Oriented Motivation Instrument” to be conducted at my child’s school between the dates of 08/12/2019 and 05/22/2020.

I understand the purpose of the research project will be to learn about process-oriented motivation and how it is affected by different instructional strategies and that my child will participate in the following manner:

1. Participants will be asked to complete the Process-Oriented Motivation (15 minutes to complete) and Views about Scientific Inquiry (30 minutes to complete). These are both online surveys and the chemistry teacher may ask for them to be completed outside of class time. The results of the VASI may be used to provide discussion points for class regarding scientific inquiry.
2. Participants may be invited by their chemistry teacher to a focus group interview or individual interview to make sure that students understood each survey. These interviews will be scheduled outside of instructional time and will take between 20-35 minutes to complete.
3. All participants in the sample will complete a lab report based on the molar mass lab and it will be graded by their teacher using a valid and reliable rubric. This is part of normal classroom instruction.

There are no known **risks or anticipated discomforts** that have been identified by this research protocol.

I understand that the following **data** pertaining to my child will be requested/collected:

1. Student responses to the Process-Oriented Motivation Instrument that will assess students’ motivation toward science.
2. Student responses to the Views about Scientific Inquiry instrument that will measure student comprehension of scientific inquiry.
3. Student responses to individual and focus group interviews that will aid in validating the surveys described in #1 and #2 above. Interviews may be audio recorded only if permission from student is received. Audio recording is strictly to create an interview transcript for the researcher to collect data and find trends in interviews. Individual interviews will take approximately 20 minutes but focus group interviews could take up to 35 minutes.
4. Lab reports will be utilized to assign a grade for each student’s lab reports and is part of the normally planned curriculum. This will reveal how well students understood the lab. Scores for students will be kept confidential. Completion of lab report could take up to two days for participants to complete.

If I wish to **review any instrument or instructional material** used in connection with any protected information or marketing survey, I may submit a request to the school principal. The school principal will notify me of the time and place where I may review these materials. I have the right to review a survey and/or instructional materials before the survey is administered to my student.

Students personal information will be kept confidential in the study. All student data will be deidentified by replacing the student’s name with an assigned number. All audio recordings will be deleted once a transcript has been produced. Students and teachers will not identify themselves on audio recordings. The online surveys will be delivered using Qualtrics and Internet Protocol addresses WILL NOT be collected. Electronic data will be kept on a private OneDrive account and physical data will be stored in a secure location at Kennesaw State University. Once the results of this research study are produced, data will be presented in aggregate when possible.

Overall **potential benefits** of this study are that the results will inform best practices used by chemistry educators. More specifically, based on this study’s findings, it could be determined that Argument-Driven Inquiry (experimental group’s instructional strategy) motivates students to learn chemistry and leads to improved chemistry performance.

Participation in the study is voluntary and will not affect either student grades or placement decisions (or if staff is involved, will not affect employment status or annual evaluations.) If I decide to withdraw permission after the study begins, I will notify the school of my decision in writing. Removal from that research study does not remove the student from participation from the laboratory experiment that has been embedded in the research protocol. Students will still need to complete this lab experiment. However, their data will not be collected as part of this study.

Age groups in this study will consist of minors, which will represent the **Vulnerable Participants**. Therefore, all students must have signed consent and assent forms to fully participate in this study.

If **further information** is needed regarding the research study, I can contact Martel Wisdom or Dr. Michelle Head at the following emails: wisdomm@fultonschools.org or mhead24@kennesaw.edu.

This also serves as assurance that the Fulton County School District complies with requirements of the Family Educational Rights and Privacy Act (FERPA) and the Protection of Pupil Rights Amendment (PPRA) and will ensure that these requirements are followed in the conduct of this research. The District provides parents/guardians information regarding rights under FERPA and PPRA annually in the Code of Conduct & Discipline Handbook. Additional information regarding compliance of research studies with FERPA and PPRA may be found in District Policy / Procedure ICC – Educational Research.

By signing this letter, you are disclosing you are aware of those rights.

Parental Consent to Participate

I give my consent for my child, ____, to participate in the research project described above. I understand that this participation is voluntary and that I may withdraw my consent at any time without penalty. I also understand that my child may withdraw his/her assent at any time without penalty.

____
Signature of Parent or Authorized Representative, Date

____
Signature of Investigator, Date

PLEASE SIGN BOTH COPIES OF THIS FORM, KEEP ONE AND RETURN THE OTHER TO THE INVESTIGATOR

Research at Kennesaw State University that involves human participants is carried out under the oversight of an Institutional Review Board. Address questions or problems regarding these activities to the Institutional Review Board, Kennesaw State University, 585 Cobb Avenue, KH3417, Kennesaw, GA 30144-5591, (470) 578-6407.

Appendix H: CHILD ASSENT FORM

My name is Martel Wisdom. I am inviting you to be in a research study about process-oriented motivation and how it is affected by different instructional strategies used by teachers. Your parent has given permission for you to be in this study, but you get to make the final choice. It is up to you whether you participate.

If you decide to be in the study, I will ask you to complete the Process-Oriented Motivation survey (15 minutes to complete) and Views about Scientific Inquiry survey (30 minutes to complete). You may be invited by your chemistry teacher to a focus group interview or individual interview to make sure that you understood each survey.

These interviews will be scheduled outside of instructional time and will take between 20-35 minutes to complete. Interviews may be audio recorded only if you give us permission to do so. Audio recordings are strictly to create an interview transcript for the researcher to collect data and find trends in interviews. Finally, you will complete a lab report based on the molar mass lab and it will be graded by your teacher using a valid and reliable rubric.

Overall potential benefits of this study are that the results will tell us about instructional strategies used by chemistry teachers. More specifically, based on this study's findings, it could be determined that Argument-Driven Inquiry (on-level Chemistry's instructional strategy) motivates students to learn chemistry and lead to better chemistry grades.

There are no known **risks or anticipated discomforts** that have been identified by this research protocol.

You do not have to answer any question you do not want to answer or do anything that you do not want to do. Everything you say and do will be private, and your parents will not be told what you say or do while you are taking part in the study. When I tell other people what I learned in the study, I will not tell them your name or the name of anyone else who took part in the research study.

Interviews may be audio recorded, please indicate if you do or do not grant permission to be recorded

☐ Yes, I grant permission for you to audio record me during any form of interview

☐ No, I do not grant permission for you to audio record me during any form of interview

If anything in the study worries you or makes you uncomfortable, let me know and you can stop. No one will be upset with you if you change your mind and decide not to participate. You are free to ask questions at any time and you can talk to your parent any time you want. If you want to be in the study sign, date, and print your name on the lines below:

________________________________ ____________________
Child's Signature Date

____
Child's Printed Name

Check which of the following applies *(completed by person administering the assent.)*

☐ Child is capable of reading and understanding the assent form and has signed above as documentation of assent to take part in this study.

☐ Child is not capable of reading the assent form, but the information was verbally explained to him/her. The child signed above as documentation of assent to take part in this study.

____
Signature of Person Obtaining Assent, Date

Appendix I: VASI INTERVIEW PROTOCOL

Question Outside of VASI - How can you define scientific inquiry in your own terms?

3. Do you think that scientific investigations can follow more than one method?

If no, please explain why there is only one way to conduct a scientific investigation.

If yes, please describe two investigations that follow different methods, and explain how the methods differ and how they can still be considered scientific.

11. Describe at least two reasons why you think most of the scientists agree that the animal in figure 1 had the best sorting and positioning of the bones?

12. Thinking about you answer to the question above what types of information do scientists use to explain their conclusions?

Appendix J: PROCESS-OREINTED MOTIVATION STUDENT INTERVIEW PROTOCOL

1. Walk me through your thought process that led you to choose (Strongly Disagree, Disagree, Agree, Strongly Agree) for the (number) _____________ item.

2. Describe what this item means in your own words. (How would you describe this item to an elementary age student?)

3. Please match scenarios that students engage in this classroom with the seven items.
    a. Please put the card scenarios next to the corresponding item
    b. Take picture

4. Rank the items from which motivates me the most to the least in this chemistry class. Please shuffle cards from most to least. Take picture of card order for each student and document. Decreasing order (Top-Most Motivated and Bottom-Least Motivated)

Appendix K: VASI SCORING RUBRIC

Aspect of Scientific Inquiry	Question on VASI	Definition of an Informed Response	Informed quotes	Definition of a Naïve Response	Naïve Quotes
1 Scientific Investigations all begin with a question and do not necessarily test a hypothesis	1a (1)	The student should answer the question as yes and explain that the investigation is scientific due to its purpose in testing via question or hypothesis referring to the birds.	"Yes, I do, as the person used an experiment to test a hypothesis that they created. Furthermore, the prosses if gathering research made scientific sense."	The student would answer the question as no and explain how the investigation is not scientific.	"No, because there isn't a lot of detail to explain."
	1b (2)	The student should include yes in their answer while explaining that a question was answered in some form, while reasoning was applied due to the evidence collected. Furthermore, student can explain how the theory was tested.	"Yes, they can test their theory on whether beaks developed over time"	Student answered no to the question and made a justification on why it is not an experiment.	"I do not, as there was no independent and manipulated variables, the person just collected data from nature. Therefore, this is an observation, not an experiment."
	2 (4)	The student's answer must explain the necessity of a thought being led into a question in any format. Yes or no does not qualify for a correct answer.	"The student that said no because you can make an observation that leads to a question."	The student's explanation describes a lack of necessity in a question before a scientific investigation.	"No, you don't need a scientific question to be able to be to undergo an experiment"
2 There is no single set of steps followed in all investigations	1b (2)	The student should include in their answer a yes and explain that a question was answered in some form, while reasoning was applied due to the evidence collected. Furthermore, student can explain how the theory was tested.	"Yes, they can test their theory on whether beaks developed over time"	Student answered no to the question and made a justification on why it is not an experiment.	"I do not, as there was no independent and manipulated variables, the person just collected data from nature. Therefore, this is an observation, not an experiment."
	1c (3)	The student should answer yes while explaining that the scientific method is not tied to a specific order that is followed by a conclusion. Instead the scientific method has various methods.	"Yes, such as the prosses seen above in which an observation was first made and later tested, or in common claim evidence reasoning investigated investigations used by biologists."	The student's answer may state that the scientific method must be followed in an exact order.	"No, there is only way to conduct the scientific method."

3 Inquiry procedures are guided by questions asked	5 (8)	The student's answer included Team A testing multiple brands of tires. This inclusion by Team A appropriately answered the question posed.	"Team A's procedure is better because they tested multiple tire brands"	The student answered Team B and described their thought process.	"Teams B has too much data to prove"
4 All scientists performing same procedures may not get the same results	3a (5)	The student answered no and explained that different scientists may get different results despite the same procedure.	"No, because they could each have different thought processes and would interpret the results differently."	The student answered yes and described that all scientist should get the same results.	"Yes, because they need to try different methods."
5 Inquiry procedures can influence results	3b (6)	The student answered no and described that different procedures may produce different results.	"No, because they could use different thought processes and use different experimentation to find results."	The student answered yes or did not have a definitive answer to the question. Student's answer included an explanation that justified that different procedures did not affect results of multiple scientists.	"They will get the same results from different methods".
6 Research conclusions must be consistent with collected data	6 (9)	The student answered B and described that less sunlight resulted in more plant growth.	"B, Plants grew taller with less sunlight."	The student answered A or C and described that more sunlight resulted in more plant growth or the variables were unrelated.	"a) Plant grow taller with more sunlight." "c) The growth of plant is unrelated to sunlight."
7 Scientific data are not the same as evidence	4 (7)	The student stated a significant difference between data and evidence and included data are results without an explanation.	"They are different, data is numerical, but evidence is anything that supports your claim."	The student stated there was no difference between data and evidence. Student did not articulate the difference between two items.	"A because the plant that grew the tallest had more sunlight."
8 Explanations are developed from a combination of collected data and what is already known	7 (11)	The student selected figure one and described how Figure 1 was effective or why Figure 2 was ineffective. Answer accurately utilized data or prior knowledge to comprehend the choice of Figure 1.	"I think figure one is more prominent because it has a more symmetrical bone layout. Furthermore, figure two does not appear to be fit for any environment."	The student selected figure two and explained their reasoning. Another student may also select figure one and have a poor explanation that lacks any reference to data.	"Figure 2 has a better structure."
	7 (12)	The student's answer includes data, information, evidence or reasoning.	"Evidence and Reasoning"	The student answer includes opinions, vague references to logic, and lacks any reference to any semblance of data.	"Scientist do not need any evidence or reasoning behind decisions."

Appendix L: CONTROL GROUP ADI LAB PACKET

Lab 14. Molar Relationships: What Are the Identities of the Unknown Compounds?

The concept of the mole is important for understanding chemistry. The mole provides a measure of the number of atoms present in a sample of a compound. One mole of an element or compound contains 6.02×10^{23} atoms or molecules. This quantity is referred to as the Avogadro constant. Knowing the amounts of particles allows chemists to understand how different chemicals behave during chemical reactions and predict the outcomes of reactions. Moles provide a standardized way of comparing elements. Using the Avogadro constant, chemists can use other measures, such as mass or volume, to determine the number of particles a sample has.

To use mass to determine the number of moles of an element or molecule in a sample, you must also know the molar mass of that element or molecule. The molar mass refers to the total mass of an element present in one mole of that element. The unit for these masses is grams per mole (g/mol). The molar mass of an element is easily identified on most periodic tables, where it is typically listed in the box provided for a particular element. Examples of molar mass include carbon (C), 12.011 g/mol; oxygen (O), 15.994 g/mol; and gold (Au), 196.967 g/mol. To determine the molar mass for a compound made of larger molecules, you must add up the molar masses of all the atoms present in the molecular formula. For example, the molar mass of CO2 is 43.999 g/mol, which is calculated by 12.011 g/mol (C) + 15.994 g/mol (O) + 15.994 g/mol (O). Remember that you have to include the total number of atoms in the molecular formula when calculating molar mass, so be mindful of the subscripts in those formulas.

By knowing the molar mass of a compound and the mass of a sample of that compound, you can determine the number of moles in the compound. Continuing from the example above, if you have a sample of CO2 whose mass is 2.523 g, then you can determine the number of moles in that sample by dividing the actual mass by the molar mass (e.g., 2.523 g / 43.999 g/mol = 0.0573 moles of CO2).

You will now use your understanding of the relationships between moles, molar mass, and mass of a sample to identify some unknown compounds. Remember, moles provide a standardized unit of measure (based on the Avogadro constant) so that chemists can compare a wide variety of substances, including the amount of substances needed and produced by a chemical reaction.

Your Task

You will be given seven sealed bags. Each bag will be filled with a different powder and will be labeled with the number of moles of powder that is inside the bag. Your task will be to identify the powder in each bag. The unidentified powders could be any of the following compounds:

- Calcium acetate, Ca(C2H3O2)2
- Calcium oxide, CaO
- Potassium sulfate, K2SO4
- Sodium acetate, NaC2H3O2
- Sodium carbonate, Na2CO3
- Sodium chloride, NaCl
- Zinc (II) oxide, ZnO

The guiding question of this investigation is, **what are the identities of the unknown compounds? Materials**

You may use any of the following materials during your investigation:

Consumables	**Equipment**
• Sealed plastic bags of unknown compounds • Empty plastic bags	• Electronic or triple beam balance • Periodic table

Follow all normal lab safety rules. Your teacher will explain relevant and important information about working with the chemicals associated with this investigation. In addition, take the following safety precautions:

- Wear indirectly vented chemical-splash goggles while in the laboratory.
- Wash your hands with soap and water before leaving the laboratory.

To answer the guiding question, you will need to design and conduct an investigation. To accomplish this task, you must first determine what type of data you need to collect, how you will collect the data, and how you will analyze the data.

To determine *what type of data you need to collect*, think about what type of measurements you will need to make during your investigation.

To determine *how you will collect the data*, think about the following questions:

- How will you make sure that your data are of high quality (i.e., how will you reduce error)?

- How will you keep track of the data you collect and how will you organize it?

To determine *how you will analyze the data*, think about the following questions:

- What type of table or graph could you create to help make sense of your data?
- What types of calculations will you need to make?

As you work through your investigation, be sure to think about

- the importance of identifying patterns,
- which proportional relationships are critical to the understanding of this investigation,
- how scientific knowledge changes over time in light of new evidence, and
- the difference between data and evidence.

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections that provide answers to the following questions:

1. What question were you trying to answer and why?
2. What did you do during your investigation and why did you conduct your investigation in this way?
3. What is your argument?

Your report should answer these questions in two pages or less. The report must be typed, and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!

ADI Laboratory Investigation Proposal A: Descriptive Studies

The Guiding Question...

↓

What data will you collect?

↓

How will you collect your data?

Your Procedure

What safety precaution will you follow?

↓

How will you analyze your data?

I approve of this investigation. ______________________________ ____________

Instructor's Signature

Date

ADI Argument-Driven Inquiry

Your Actual Data

↓

Your Analysis of the Data

↓

The Claim you will Make

Deep learning in science requires students to gather, reason with, and communicate scientific information. These skills will also prepare students for college and career success. Because of the importance of these skills, the new Georgia Milestones Assessment System will require students to demonstrate their ability to comprehend, reason with, and respond to textual and graphical information through a combination of selected-, constructed-, and extended-response items. At the heart of these skills lies students' ability to make and evaluate claims based on various types of evidence and on their understanding of key ideas and concepts within various science disciplines. Teachers in all science classrooms can apply writing tasks designed around the ***Claim-Evidence-Reasoning (CER)*** framework as both learning and assessment tasks for students.

Q-CER Graphic Organizer
Use this graphic organizer to support student thinking within the CER framework and as a ***pre-writing*** organizer for extended-response items. After completing the graphic organizer, students should be ready to develop a clear, coherent, and complete written argument that draws on core science concepts and crosscutting ideas.

<table>
<tr><td colspan="2">Question: (This is the question provided in the task.)</td></tr>
<tr><td>Claim: (Often you can use part of the question to formulate your claim. In an extended response, this will be your topic or thesis sentence.)</td><td>Evidence: (This is data gathered from text or graphics that help you answer the question provided in the task. Choose a quote or other evidence that directly supports your claim. If you use a quote, then be sure to credit the quote properly.)</td></tr>
<tr><td colspan="2">Reasoning: (This is the most important part of your answer. It provides your reader with the explanation for your claim, and it explains how your evidence supports your claim. This is also where you should draw on key ideas and concepts from the discipline to tie your evidence to your claim.)

The evidence shows:

I know (relevant disciplinary ideas – i.e., scientific facts and concepts that help answer the question):

I can apply (relevant crosscutting concepts – i.e., big ideas that connect the concepts and evidence):

Therefore, I can conclude that:</td></tr>
</table>

Practice

Select a writing item from the OAS sample items that is most relevant to your subject area. Then use the Q-CER graphic organizer to analyze both an extended-response test item.

<table>
<tr><td colspan="2">Question:</td></tr>
<tr><td>Claim:</td><td>Evidence:</td></tr>
<tr><td colspan="2">Reasoning:
The evidence shows:
I know (relevant disciplinary ideas – i.e., scientific facts and concepts that help answer the question):
I can apply (relevant crosscutting concepts – i.e., big ideas that connect the concepts and evidence):
Therefore, I can conclude that:</td></tr>
</table>

ADI Investigation Report – Sentence Starters

We have been studying ______________________________ in class. At

the beginning of the investigation, we knew ______________________________

____

____

____

My goal for this investigation was to ______________________________

____

____

The guiding question was ______________________________

____

Method

In order to gather the data I needed to answer this question, I ______________________________

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I then analyzed the data I collected by

My claim is

The figure at right shows

This analysis indicates

When I analyzed the data I collected, I assumed

Appendix M: EXPERIMENTAL GROUP ADI LAB PACKET

Lab 14. Molar Relationships: What Are the Identities of the Unknown Compounds?

The concept of the mole is important for understanding chemistry. The mole provides a measure of the number of atoms present in a sample of a compound. One mole of an element or compound contains 6.02×10^{23} atoms or molecules. This quantity is referred to as the Avogadro constant. Knowing the amounts of particles allows chemists to understand how different chemicals behave during chemical reactions and predict the outcomes of reactions. Moles provide a standardized way of comparing elements. Using the Avogadro constant, chemists can use other measures, such as mass or volume, to determine the number of particles a sample has.

To use mass to determine the number of moles of an element or molecule in a sample, you must also know the molar mass of that element or molecule. The molar mass refers to the total mass of an element present in one mole of that element. The unit for these masses is grams per mole (g/mol). The molar mass of an element is easily identified on most periodic tables, where it is typically listed in the box provided for a particular element. Examples of molar mass include carbon (C), 12.011 g/mol; oxygen (O), 15.994 g/mol; and gold (Au), 196.967 g/mol. To determine the molar mass for a compound made of larger molecules, you must add up the molar masses of all the atoms present in the molecular formula. For example, the molar mass of CO2 is 43.999 g/mol, which is calculated by 12.011 g/mol (C) + 15.994 g/mol (O) + 15.994 g/mol (O). Remember that you have to include the total number of atoms in the molecular formula when calculating molar mass, so be mindful of the subscripts in those formulas.

By knowing the molar mass of a compound and the mass of a sample of that compound, you can determine the number of moles in the compound. Continuing from the example above, if you have a sample of CO2 whose mass is 2.523 g, then you can determine the number of moles in that sample by dividing the actual mass by the molar mass (e.g., 2.523 g / 43.999 g/mol = 0.0573 moles of CO2).

You will now use your understanding of the relationships between moles, molar mass, and mass of a sample to identify some unknown compounds. Remember, moles provide a standardized unit of measure (based on the Avogadro constant) so that chemists can compare a wide variety of substances, including the amount of substances needed and produced by a chemical reaction.

Your Task

You will be given seven sealed bags. Each bag will be filled with a different powder and will be labeled with the number of moles of powder that is inside the bag. Your task will be to identify the powder in each bag. The unidentified powders could be any of the following compounds:

- Calcium acetate, Ca(C2H3O2)2
- Calcium oxide, CaO
- Potassium sulfate, K2SO4
- Sodium acetate, NaC2H3O2
- Sodium carbonate, Na2CO3
- Sodium chloride, NaCl
- Zinc (II) oxide, ZnO

The guiding question of this investigation is, **what are the identities of the unknown compounds? Materials**

You may use any of the following materials during your investigation:

Consumables	**Equipment**
• Sealed plastic bags of unknown compounds	• Electronic or triple beam balance
• Empty plastic bags	• Periodic table

Follow all normal lab safety rules. Your teacher will explain relevant and important information about working with the chemicals associated with this investigation. In addition, take the following safety precautions:

- Wear indirectly vented chemical-splash goggles while in the laboratory.
- Wash your hands with soap and water before leaving the laboratory.

To answer the guiding question, you will need to design and conduct an investigation. To accomplish this task, you must first determine what type of data you need to collect, how you will collect the data, and how you will analyze the data.

To determine *what type of data you need to collect*, think about what type of measurements you will need to make during your investigation.

To determine *how you will collect the data*, think about the following questions:

- How will you make sure that your data are of high quality (i.e., how will you reduce error)?

- How will you keep track of the data you collect and how will you organize it?

To determine *how you will analyze the data*, think about the following questions:

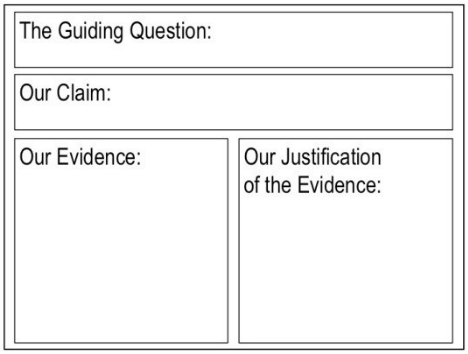
- What type of table or graph could you create to help make sense of your data?
- What types of calculations will you need to make?

As you work through your investigation, be sure to think about

- the importance of identifying patterns,
- which proportional relationships are critical to the understanding of this investigation,
- how scientific knowledge changes over time in light of new evidence, and
- the difference between data and evidence.

FIGURE L14.1

Argument presentation on a whiteboard



Once your group has finished collecting and analyzing your data, you will need to develop an initial argument. Your argument must include a *claim*, which is your answer to the guiding question. Your argument must also include *evidence* in support of your claim. The evidence is your analysis of the data and your interpretation of what the analysis means. Finally, you must include a *justification* of the evidence in your argument. You will therefore need to use a scientific concept or principle to explain why the evidence that you decided to use is relevant and important. You will create your initial argument on a whiteboard. Your whiteboard must include all the information shown in Figure L14.1.

The argumentation session allows all of the groups to share their arguments. One member of each group stays at the lab station to share that group's argument, while the other members of the group go to the other lab stations one at a time to listen to and critique the arguments developed by their classmates. The goal of the argumentation session is not to convince others that your argument is the best one; rather, the goal is to identify errors or instances of faulty reasoning in the initial arguments so these mistakes can be fixed. You will therefore need to evaluate the content of the claim, the quality of the evidence used to support the claim, and the strength of the justification of the evidence included in each argument that you see. To critique an argument, you might need more information than what is included on the whiteboard. You might therefore need to ask the presenter one or more follow-up questions, such as:

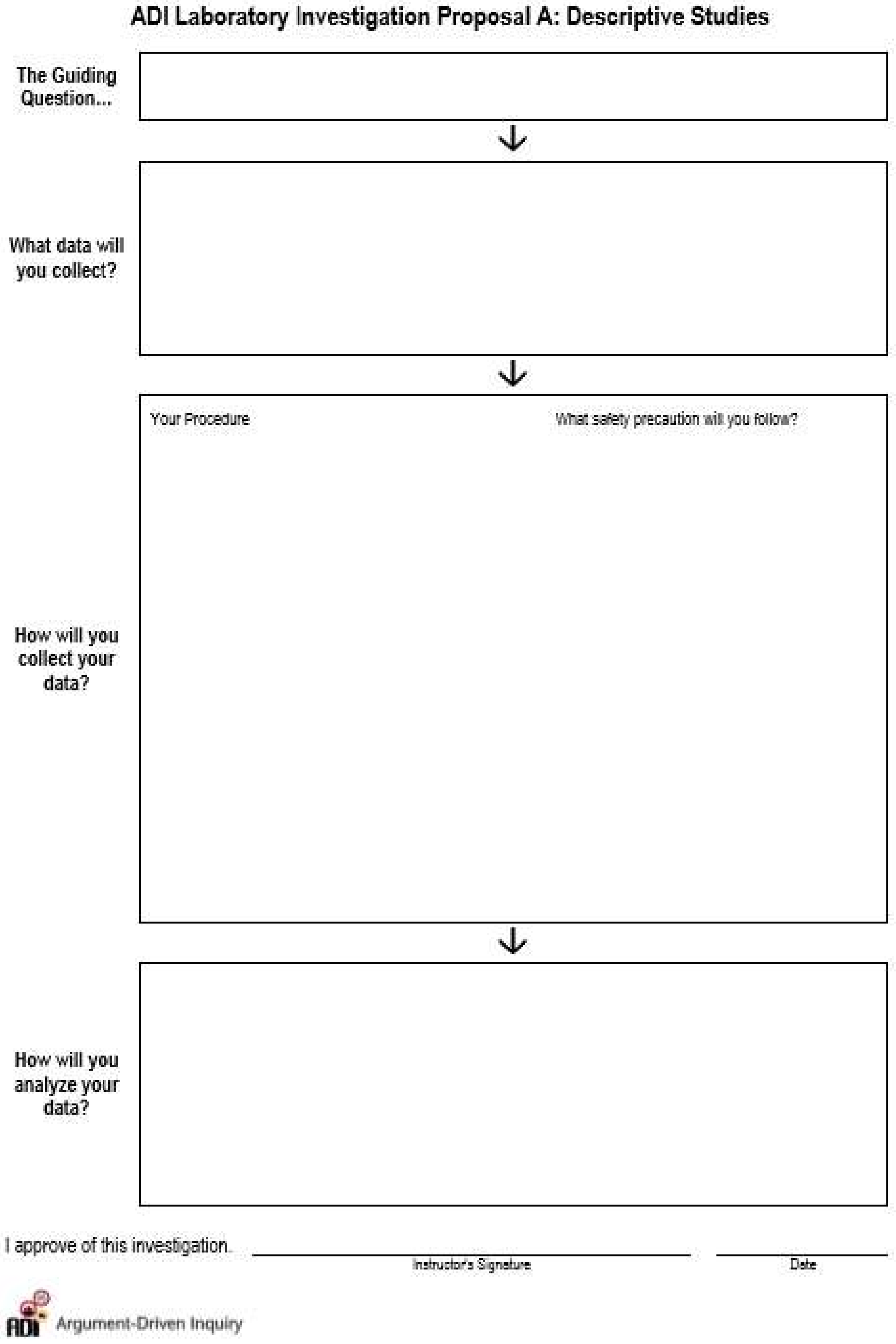
- How did your group collect the data? Why did you use that method?
- What did your group do to make sure the data you collected are reliable? What did you do to decrease measurement error?
- What did your group do to analyze the data? Did you check your calculations?
- Is that the only way to interpret the results of your group's analysis? How do you know that your interpretation of the analysis is appropriate?
- Why did your group decide to present your evidence in that manner?
- What other claims did your group discuss before deciding on that one? Why did you abandon those alternative ideas?
- How confident are you that your group's claim is valid? What could you do to increase your confidence?

Once the argumentation session is complete, you will have a chance to meet with your group and revise your original argument. Your group might need to gather more data or design a way to test one or more alternative claims as part of this process. Remember, your goal at this stage of the investigation is to develop the most valid or acceptable answer to the research question!

Once you have completed your research, you will need to prepare an *investigation report* that consists of three sections that provide answers to the following questions:

4. What question were you trying to answer and why?
5. What did you do during your investigation and why did you conduct your investigation in this way?
6. What is your argument?

Your report should answer these questions in two pages or less. The report must be typed, and any diagrams, figures, or tables should be embedded into the document. Be sure to write in a persuasive style; you are trying to convince others that your claim is acceptable or valid!



ADI Laboratory Investigation Proposal A: Descriptive Studies

The Guiding Question...

What data will you collect?

How will you collect your data?

Your Procedure

What safety precaution will you follow?

How will you analyze your data?

I approve of this investigation. ______________________ Instructor's Signature ________ Date

Argument-Driven Inquiry

ADI

Your Actual Data

↓

Your Analysis of the Data

↓

The Claim you will Make

Evidence-Based Writing in Science

Introduction

Deep learning in science requires students to gather, reason with, and communicate scientific information. These skills will also prepare students for college and career success. Because of the importance of these skills, the new Georgia Milestones Assessment System will require students to demonstrate their ability to comprehend, reason with, and respond to textual and graphical information through a combination of selected-, constructed-, and extended-response items. At the heart of these skills lies students' ability to make and evaluate claims based on various types of evidence and on their understanding of key ideas and concepts within various science disciplines. Teachers in all science classrooms can apply writing tasks designed around the ***Claim-Evidence-Reasoning (CER)*** framework as both learning and assessment tasks for students.

Q-CER Graphic Organizer

Use this graphic organizer to support student thinking within the CER framework and as a ***pre-writing*** organizer for extended-response items. After completing the graphic organizer, students should be ready to develop a clear, coherent, and complete written argument that draws on core science concepts and crosscutting ideas.

Question: (This is the question provided in the task.)	
Claim: (Often you can use part of the question to formulate your claim. In an extended response, this will be your topic or thesis sentence.)	**Evidence:** (This is data gathered from text or graphics that help you answer the question provided in the task. Choose a quote or other evidence that directly supports your claim. If you use a quote, then be sure to credit the quote properly.)
Reasoning: (This is the most important part of your answer. It provides your reader with the explanation for your claim, and it explains how your evidence supports your claim. This is also where you should draw on key ideas and concepts from the discipline to tie your evidence to your claim.) The evidence shows: I know (relevant disciplinary ideas – i.e., scientific facts and concepts that help answer the question): I can apply (relevant crosscutting concepts – i.e., big ideas that connect the concepts and evidence): Therefore, I can conclude that:	

Practice

Select a writing item from the OAS sample items that is most relevant to your subject area. Then use the Q-CER graphic organizer to analyze both an extended-response test item.

Question:

Claim:	**Evidence:**

Reasoning:

The evidence shows:

I know (relevant disciplinary ideas – i.e., scientific facts and concepts that help answer the question):

I can apply (relevant crosscutting concepts – i.e., big ideas that connect the concepts and evidence):

Therefore, I can conclude that:

Argumentation Session Notes for Presenters

Critiques of our claim…	Critiques of our evidence…
Critiques of our justification…	Ways to improve our argument…

Argumentation Session Notes for Reviewers

Claims made by other groups…	Examples of good evidence…

Examples of good justifications…	Questions to take back to my group…

ADI Investigation Report – Sentence Starters

We have been studying ______________________________ in class. At

the beginning of the investigation, we knew ______________________________

____

____

____

My goal for this investigation was to ______________________________

____

____

The guiding question was ______________________________

____

Method

In order to gather the data I needed to answer this question, I ______________________________

I then analyzed the data I collected by ______________________________

My claim is

The figure at right shows

This analysis indicates

When I analyzed the data I collected, I assumed

Appendix N: ADI LAB REPORT SCORING RUBRIC

	Aspect of the Essay	Point Value		
		0	**1**	**2**
Argument Struc	1.1 The author made the claim that s/he was trying to refute explicit to the reader. **The author should be refuting the expert's claim*	No	Somewhat	Yes
	1.2 The author provided several reasons for why the expert's claim is not accurate and/or acceptable. **If the student argues for the expert claim, then 1.1, 1.2, and 1.4 are automatically "No" and "None". 'Reasons' can be anything when scored at the structural level.*	None	Only One	≥ Two
	1.3 The author made the claim that s/he was advancing explicit to the reader. **The claim may be found anywhere in the essay*	No	Somewhat	Yes
	1.4 The author provided several reasons to support the validity or the acceptability of his or her claim. **When analyzing a reason statement, count it only one time, either as refuting the expert claim or supporting the author claim, not as both. Again, 'reasons' can be anything when scored at the structural level.*	None	Only One	≥ Two
Argument Con	2.1 The author provided reasons for why the expert's claim is not accurate that are empirical or analytical in nature. **If the student argues for the expert's claim, then this is automatically "No".*	No	Somewhat	Yes
	2.2 The author provided reasons in support of his or her claim that are empirical or analytical in nature. **Mark 'yes' if all the reasons provided by the author are either empirical (i.e., uses the data available) or analytical (e.g., points out a flaw in the expert's analysis) in nature. If one of the reasons does not meet these characteristics, then mark 'somewhat'. Mark 'no' if more than one reason does not meet the characteristics.*	No	Somewhat	Yes
	2.3 The author's interpretation of the data provided in the item was valid and relevant. **Mark 'no' if there are no relationships made between pieces of data and if they focus on data that is not relevant. Mark 'somewhat' if only one of these criteria is met. Mark 'yes' if all these criteria are met.*	No	Partially	Yes
	2.4 The author's overall argument was coherent and focused. **Mark 'no' if the author included a lot of extraneous information that was not needed to support or challenge the claim (i.e., it appeared that the author added information just to add information).*	No	Somewhat	Yes
	2.5 The author used scientific terms correctly and used rhetorical references that do not misrepresent NOS or NOSI **Mark 'yes' if the author used scientific terms (e.g., data, evidence, etc.) correctly and used rhetorical references that do not misrepresent the nature of science or the nature of scientific inquiry (e.g., these data suggest, etc.) throughout the essay. Mark 'mostly' if there are only 1 or 2 instances where the author misused a term such as evidence or claims that the evidence 'proves' that his or her claim is correct. Mark 'no' if there are more than two instances of misused terms or phrases in the essay or if there is are no scientific terms or rhetorical references used at all.*	No	Mostly	Yes

Writing Mechar	3.1 *Organization:* The order and arrangement of the paragraphs and sentences enhances the development of the main idea. *Mark ‘no’ if the essay seems to ‘jump around’ or the paragraphs are in an inappropriate order, paragraphs are too short or long, or if ideas are introduced within a paragraph where they should not have been.	No	Mostly	Yes
	3.2 *Word Choice:* The author uses the appropriate word at a given time (e.g., affect vs. effect, their vs. there, etc.).	No	Mostly	Yes
	3.3 *Voice:* The sentences are written in an active voice rather than a passive voice (e.g., the expert analyzed the data vs. the data was analyzed by the expert) and the author use a professional tone rather than a conversational tone.	No	Mostly	Yes
	3.4 *Grammar:* The author used complete sentences, proper subject-verb agreement, and a constant tense throughout the essay.	No	Mostly	Yes
	3.5 *Conventions:* The author used appropriate spelling, punctuation, and capitalization. *Mark ‘yes’ if there are only 1 or 2 errors, mark ‘mostly’ if there are more than two errors, and mark ‘no’ if there are so many errors that the ideas in the essay were obscured or you were forced to stop and re-read a section of the essay.	No	Mostly	Yes

Total Score: **/28**

Appendix O: ADI INVESTIGATION REPORT PEER REVIEW RUBRIC- HIGH SCHOOL VERSION

Report By: ______________________
ID Number

Author: Did the reviewers do a good job? 1 2 3 4 5
Rate the overall quality of the peer review

Reviewed By: ______________ ______________ ______________ ______________
ID Number ID Number ID Number ID Number

Section 1: Introduction and Guiding Question	Reviewer Rating			Instructor Score
1. Did the author provide enough ***background information***?	☐☐ No	☐☐ Partially	☐☐ Yes	0 1 2
2. Is the background information ***accurate***?	☐☐ No	☐☐ Partially	☐☐ Yes	0 1 2
3. Did the author ***describe the goal*** of the study?	☐☐ No	☐☐ Partially	☐☐ Yes	0 1 2
4. Did the author make the ***guiding question*** explicit and explain how the guiding question is related to the background information?	☐☐ No	☐☐ Partially	☐☐ Yes	0 1 2

Reviewers: If your group made any “No” or “Partially” marks in this section, please **explain how the author could improve** this part of his or her report.	**Author:** What revisions did you make in your report? Is there anything you decided to keep the same even though the reviewers suggested otherwise? Be sure to explain why.

Section 2: Method	Reviewer Rating			Instructor Score
1. Did the author describe ***the procedure*** he/she used to gather data and then explain why he/she used this procedure?	☐☐ No	☐☐ Partially	☐☐ Yes	0 1 2
2. Did the author explain ***what data*** were collected (or used) during the investigation and why they were collected (or used)?	☐☐ No	☐☐ Partially	☐☐ Yes	0 1 2
3. Did the author describe ***how he/she analyzed the data*** and explain why the analysis helped him/her answer the guiding question?	☐☐ No	☐☐ Partially	☐☐ Yes	0 1 2
4. Did the author use the ***correct term*** to describe his/her investigation (e.g., experiment, observations, interpretation of a data set)?	☐☐ No	☐☐ Partially	☐☐ Yes	0 1 2

Reviewers: If your group made any “No” or “Partially” marks in this section, please **explain how the author could improve** this part of his or her report.	**Author:** What revisions did you make in your report? Is there anything you decided to keep the same even though the reviewers suggested otherwise? Be sure to explain why.

The development of this peer review guide was supported by the Institute of Education Sciences, U.S. Department of Education, through Grant R305A100909 to the Florida State University

Section 3: The Argument	Reviewer Rating			Instructor Score
1. Did the author provide a ***claim*** that answers the guiding question?	☐ No	☐ Partially	☐ Yes	0 1 2
2. Did the author include ***high quality evidence*** in his/her argument? ☐ Were the data collected in an appropriate manner? ☐ Is the analysis of the data appropriate and free from errors? ☐ Is the author’s interpretation of the analysis (what it means) valid?	☐ No ☐ No ☐ No	☐ Partially ☐ Partially ☐ Partially	☐ Yes ☐ Yes ☐ Yes	0 1 2 0 1 2 0 1 2
3. Did the author ***present the evidence*** in an appropriate manner by***:*** ☐ using a correctly formatted and labeled graph (or table); ☐ including correct metric units (e.g., m/s, g, ml, etc.); and, ☐ referencing the graph or table in the body of the text?	☐ No ☐ No ☐ No	☐ Partially ☐ Partially ☐ Partially	☐ Yes ☐ Yes ☐ Yes	0 1 2 0 1 2 0 1 2
4. Is the claim ***consistent with the evidence***?	☐ No	☐ Partially	☐ Yes	0 1 2
5. Did the author include a ***justification of the evidence*** that: ☐ explains why the evidence is important (why it matters) and ☐ defends the inclusion of the evidence with a specific science concept or by discussing his/her underlying assumptions?	☐ No ☐ No	☐ Partially ☐ Partially	☐ Yes ☐ Yes	0 1 2 0 1 2
6. Is the ***justification of the evidence*** acceptable?	☐ No	☐ Partially	☐ Yes	0 1 2
7. Did the author discuss ***how well his/her claim agrees with the claims made by other groups*** and explain any disagreements?	☐ No	☐ Partially	☐ Yes	0 1 2
8. Did the author **use scientific terms correctly** (e.g., *hypothesis* vs. *prediction, data* vs. *evidence*) and **reference the evidence in an appropriate manner** (e.g., *supports* or *suggests* vs. *proves*)?	☐ No	☐ Partially	☐ Yes	0 1 2

Reviewers: If your group made any “No” or “Partially” marks in this section, please **explain how the author could improve** this part of his or her report.	**Author:** What revisions did you make in your report? Is there anything you decided to keep the same even though the reviewers suggested otherwise? Be sure to explain why.

Mechanics	Reviewer Rating			Instructor Score
1. ***Organization:*** Is each section easy to follow? Do paragraphs include multiple sentences? Do paragraphs begin with a topic sentence?	☐☐ No	☐☐ Partially	☐☐ Yes	0 1 2
2. ***Grammar:*** Are the sentences complete? Is there proper subject-verb agreement in each sentence? Are there run-on sentences?	☐☐ No	☐☐ Partially	☐☐ Yes	0 1 2
3. ***Conventions:*** Did the author use appropriate spelling, punctuation, paragraphing and capitalization?	☐☐ No	☐☐ Partially	☐☐ Yes	0 1 2
4. ***Word Choice:*** Did the author use the appropriate word (e.g., there vs. their, to vs. too, than vs. then, etc.)?	☐☐ No	☐☐ Partially	☐☐ Yes	0 1 2
Instructor Comments:				

Total: _/50

The development of this peer review guide was supported by the Institute of Education Sciences, U.S. Department of Education, through Grant R305A100909 to the Florida State University

Appendix P: VASI-INTER-RATER RELIABLITY EVIDENCE

Researcher's Inter-Rater Reliability

		item_1	item_2	item_3	item_4	item_5	item_6	item_7	item_8	item_9	item_11	item_12	Results
Student 1	Teacher 5	0	0	0	0	1	1	1	0	0	0	1	Naïve
Student 2	Teacher 5	1	0	1	1	1	1	1	1	1	1	1	Mixed
Student 3	Teacher 1	1	0	0	1	0	1	1	1	1	1	1	Mixed
Student 4	Teacher 2	1	0	1	1	0	0	1	1	0	0	1	Mixed
Student 5	Teacher 2	1	0	1	0	1	1	1	1	1	1	1	Mixed
Student 6	Teacher 3	0	1	1	1	1	1	1	0	1	1	1	Mixed
Student 7	Teacher 3	0	1	1	0	1	1	1	1	1	1	1	Mixed
Student 8	Teacher 3	0	1	0	0	0	1	0	0	1	0	1	Naïve

Chemistry Professor's Inter-Rater Reliability

		item_1	item_2	item_3	item_4	item_5	item_6	item_7	item_8	item_9	item_11	item_12	Results
Student 1	Teacher 5	0	0	0	0	1	1	1	0	0	0	1	Naïve
Student 2	Teacher 5	1	0	1	1	1	1	1	1	0	1	1	Mixed
Student 3	Teacher 1	0	0	0	1	0	0	1	1	1	1	1	Mixed
Student 4	Teacher 2	0	0	1	1	0	0	1	1	0	0	1	Mixed
Student 5	Teacher 2	1	0	1	0	1	1	1	1	1	1	1	Mixed
Student 6	Teacher 3	0	1	1	1	1	1	1	0	1	1	1	Mixed
Student 7	Teacher 3	0	1	1	0	1	1	1	1	1	1	1	Mixed
Student 8	Teacher 3	0	1	0	0	0	1	0	1	1	0	1	Naïve

Appendix Q: REVISED POMI CONTENT VALIDITY PART 1 AND PART 2

Table ____

Revised POMI Content Validity for Created Means-Focused Data (Part 1 and Part 2)
Revised POMI Interview Response (Revised POMI Survey Response)

Student Name	Teacher	Q5	Q8	Q14	Q16	Q19	Q22	Q23	Part 1 *	Part 2**
S1	Teacher 2	D (A)	SA(SA)	D(D)	A(A)	SA(D)	A(SD)	A(D)	B	X
S2	Teacher 4	A(A)	A(SA)	SA(A)	A(A)	A(D)	SA(D)	A(SD)	B	X
S3	Teacher 4	D(A)	A(A)	A(D)	D(SA)	D(D)	D(A)	D(A)	C	X
S4	Teacher 4	A(SA)	A(A)	D(A)	A(A)	D(A)	A(A)	A(A)	B	X
S5	Teacher 3	A(A)	A(SA)	SD(D)	A(D)	SA(A)	A(SD)	A(D)	B	X
S6	Teacher 3	A(A)	A(SA)	A(A)	A(A)	A(A)	A(A)	A(A)	A	X
S7	Teacher 3	A(D)	A(A)	D(SD)	SA(D)	A(D)	SD(A)	A(D)	C	X
S8	Teacher 1	A(A)	A(A)	D(A)	A(A)	D(D)	A(D)	A(D)	B	X
S9	Teacher 1	SA(D)	A(A)	SA(A)	A(A)	A(D)	A(D)	D(A)	B	Y(Q5)
S10	Teacher 5	A(SA)	A(A)	A(A)	A(SA)	A(SA)	SA(SA)	A(SA)	A	X
S11	Teacher 5	A(SA)	D(SA)	SD(SA)	SD(A)	D(D)	D(A)	D(A)	B	X(Q16)
S12	Teacher 5	A(SA)	SA(SA)	A(SA)	SA(SA)	SA(SA)	SA(SA)	A(A)	A	X(Q19)

Note. Q5, Q8, Q14, Q16, Q19, Q22, Q23 are means-focused motivation POMI items that were asked to students via online survey and via interview. POMI survey responses for each question were placed in parentheses and the responses to the left of parenthesis were POMI interview responses.

*In Part 1, three levels of coding existed to help understand any discrepancy between students POMI survey and POMI interview.

Part 1's column displayed the POMI's content validity based on how many times each student's interview and survey responses changed from any form of agreement to any form of disagreement (e.g. a change from strongly agree to disagree would be counted as 1, while a change from strongly agree to agree would not be counted. Level A ranged from 0-1; Level B; ranged from 2-4; Level C ranged from 5-7.

**Part 2 descriptions were coded level X, level Y, and level Z with each misunderstood question in parentheses. Level X describes a student that completely understood all the items by explaining the intent of each item accurately. Level Y describes a student that understood at least four out of seven items and the item is in parentheses next to the level. Level Z describes a student that understood three or less items out of seven and each misunderstood item is in parentheses next to the level.

Appendix R: POMI CONTENT VALIDITY PART 3

POMI Content Validity: Student Matching Scenarios for each Means-Focused Item (Part 3)

Student Name	Teacher	Number of Items Matched Incorrectly	Items Incorrectly Matched	Details for Incorrectly Matched Items
S1	Teacher 2	2	Q8 and Q19	Items Q8 and Q19 were flipped by student, which meant the student confused argumentation with lab results communication.
S2	Teacher 4	2	Q16 and Q23	Items Q16 and Q23 were flipped by student. Student confused problem investigation and asking questions to assist chemistry concept understanding during labs.
S3	Teacher 4	0	N/A	N/A
S4	Teacher 4	2	Q16 and Q23	Items Q16 and Q23 were flipped by student. Student confused problem investigation and asking questions to assist chemistry concept understanding during labs.
S5	Teacher 3	2	Q8 and Q23	Items Q8 and Q23 were flipped by student. Student confused searching for patterns in data with questions purposed to facilitate their own understanding.
S6	Teacher 3	2	Q16 and Q23	Items Q16 and Q23 were flipped by student. Student confused problem investigation and asking questions to assist chemistry concept understanding during labs.
S7	Teacher 3	0	N/A	N/A
S8	Teacher 1	2	Q8 and Q19	Items Q8 and Q19 were flipped by student, which meant the student confused argumentation with lab results communication.
S9	Teacher 1	2	Q19 and Q22	Items Q19 and Q22 were flipped by student, which meant the student confused evidence argumentation and the joy of learning via computer simulations.
S10	Teacher 5	4	Q5, Q8 Q19, and Q23	Student did not have an appropriate grasp on the understanding and utilization of a claim in a lab or how to

				effectively communicate their results after an experiment. Additionally, student could not differentiate between learning from computer simulations and asking questions during lab to gain a better understanding of chemistry concepts.
S11	Teacher 5	0	N/A	N/A
S12	Teacher 5	0	N/A	N/A

Appendix S: REVISED POMI CONTENT VALIDITY PART 4

Revised POMI Content Validity for Created Means-Focused Data (Part 4)

Student Name	Teacher	Order of Ranked Items (Range is first to last)	First Ranked and Last Ranked Items	Agreement in Interview with 1st and Last Ranked Item
S1	Teacher 2	Q5, Q8, Q19, Q14, Q16, Q23, Q22	First - Q5 Last - Q22	First - Q5 (D) Last - Q22(A)
S2	Teacher 4	Q22, Q14, Q5, Q16, Q23, Q8, Q19	First- Q22 Last - Q19	First- Q22(SA) Last - Q19(A)
S3	Teacher 4	Q23, Q16, Q22, Q8, Q14, Q19, Q5	First - Q23 Last - Q5	First - Q23 (D) Last - Q5 (D)
S4	Teacher 4	Q5, Q14, Q19, Q8, Q23, Q22, Q16	First - Q5 Last - Q16	First - Q5 (A) Last - Q16 (A)
S5	Teacher 3	Q5, Q8, Q19, Q14, Q16, Q23, Q22	First - Q5 Last - Q22	First - Q5 (A) Last - Q22(A)
S6	Teacher 3	Q16, Q23, Q14, Q5, Q22, Q19, Q8	First - Q16 Last - Q8	First - Q16 (A) Last - Q8 (A)
S7	Teacher 3	Q16, Q23, Q8, Q5, Q19, Q14, Q22	First - Q16 Last - Q22	First - Q16 (SA) Last - Q22 (SD)
S8	Teacher 1	Q8, Q23, Q22, Q14, Q16, Q5, Q19	First - Q8 Last - Q19	First - Q8 (A) Last - Q19 (D)
S9	Teacher 1	Q23, Q5, Q14, Q8, Q16, Q19, Q22	First - Q23 Last - Q22	First - Q23 (D) Last - Q22 (A)
S10	Teacher 5	Q16, Q22, Q8, Q23, Q5, Q19, Q14	First - Q16 Last - Q14	First - Q16 (A) Last - Q14 (A)
S11	Teacher 5	Q22, Q16, Q5, Q14, Q19, Q8, Q23	First - Q22 Last - Q23	First - Q22(D) Last - Q23(D)
S12	Teacher 5	Q16, Q22, Q5, Q19, Q23, Q8, Q14	First - Q16 Last - Q14	First - Q16 (SA) Last - Q14(A)

Note. Table focuses on Part 4 of interview that enabled students to rank all seven means-focused items by decreasing order of motivation toward learning chemistry.

Appendix T: VASI CONTENT VALIDITY

Table 4.3

VASI Content Validity Table

Student Name	Question #3 Interview Quotes	Question #3 Survey Quotes	Question #11 Interview Quotes	Question #11 Survey Quotes	Question #12 Interview Quotes	Question #12 Survey Quotes	Score for each question from VASI Survey	Score for each question from VASI Interview	Match Between Interview and VASI Score
S1	Yes, they can follow more than one method.	Yes, one method for finding the age of dinosaurs will be different for finding if social media causes anxiety in teenagers.	Reason 1 is weight distribution legs in the back of a species creates weighing down from top half the body Reason2 cartilage placement there is gaps in legs and arms to match the placement on body.	Placements of bones and ligaments line up, and you can put them back together later.	One way is looking at fossils you must look at the data with historic principles while other the hand if you are building a building you must look at geographical maps.	Evidence from facts of other experiments, data, and conclusions of their finding.	3. 1 11. 0 12. 1	3.1 11. 1 12. 1	2 out of 3
S2	Yes, if you are trying to size the noodle or you can use the water displacement are two different ways to get the same answer.	Yes, I think they can follow multiple ways.	Bigger bones are placed at its feet will make it have more power. If it is at the front than it will weigh the bottom half of the body down. Figure 2 stands on its legs it would break it would not be able to stand up. Bottom legs would be useless. There is more space for Figure 1 for its bones and the Figure 2 would be less mobile because the bones are tightly connected to its frame.	N/A	The data that they collect they use in their conclusion to answer the question or the result they are trying answer. Whether it is a scientific problem without the data they are not able to prove what they are researching about.	N/A	3. 1 11.0 12.0	3. 1 11.1 12.1	1 out of 3

S3	yes	No because there's a specific way that an experiment must be done. You must first collect some data and make a claim, then collect the materials needed for the experiment and conduct said experiment. Finally, you must put your data into a data table and restate your claim if it was right or wrong.	– Figure 1 had the best positioning it makes more sense because you wouldn't wont short legs and short longs. Tiny bones look like they would support the fossil property may not be able to function.	One reason would be that the animal's legs would have to be bigger to help support the body and that and animal will arm that big would not be beneficial to itself	The types of information use would be past bone lay outs to help justify the current bone and common sense one figure 1 looks more natural.	They use rational information and common sense.	3.0 11.1 12.0	3.0 11.1 12.0	3 out of 3
S4	yes	No, because there is only one method do to experiments and that is the scientific method.	Figure 1 looks natural because Figure 2 arms don't look correct or legs would not able to support the rest of the body. Figure 1 looks more obvious sorting of the bones.	Because it just looks righter that the second one. I mean gorillas kind of have the same structure as figure two, but it just looks so impractical for sorting and bone positioning compared to figure one.	Skeletons of creatures of that time period or evolution of the animal and place in a timeline based on the evolution of the creature and common sense of Figure 1 looking more natural than figure 2.	The good kind.	3. 0 11.1 12.0	3.0 11.1 12.1	2 out of 3
S5	Yes, seeing how much cereal is in the bag the person can use scale and another person can count	Yes, I believe that scientific investigations can follow more than one method because if one way doesn't work out then another way will.	The bones structure is parallel and how well the bones are together. Figure 2 they are slanted bones.	Figure 1 had the best sorting and positions of the bones because of the way the bones where placed and how they were found.	How old the bones are and where they were found and how damaged the bones are.	The type of information scientist uses to explain their conclusions is based on the evidence they found and what	3.1 11.1 12.1	3.1 11.1 12.1	3 out of 3

	it out and then divide to find the amount of cereal.					has a better understanding.			
S6	Yes, because you can have case study with only one subject or a correlation study where you can compare variables and they can both answer a question you have.	Yes, for example, in psychology multiple types of experiments can be done to collect data. Some are case studies, surveys, and naturalistic observations, all using the scientific method.	Because the main legs need to hold up all the body weight so they can be stronger. And they fit with the bottom half of the body for figure 1.	Because the legs on animal two are too weak to be used as legs, and figure one, the legs seem to hold the body weight of the dinosaur.	Research on the topic and background along with evidence from other comparative species.	Biological evidence and comparison of other animals or dinosaurs.	3.1 11.1 12.1	3.1 11.1 12.1	3 out of 3
S7	Yes, CER and Sci Method they differ because they approach the problem in different ways and use different steps to get to the result.	Yes, such as the prosses seen above in which an observation was first made and later tested, or in common claim evidence reasoning investigated investigations used by biologists.	The animal in figure 1 seems more able to survive and live and reproduce. The bones in figure 1 fit together better and are matched better than figure 2. Finally, the fact that the upper extremity bones are very thin in figure 1 and not good for walking on fours. Figure 2 upper extremity bones are thicker and better for walking on fours.	I think figure one is more prominent because it has a more symmetrical bone payout. Furthermore, figure two does not appear to be fit for any environment.	Scientist use logically thinking, sci inquiry, data, evidence and historical findings.	Evidence and Reasoning	3. 1 11. 1 12.1	3.1 11.1 12.1	3 out of 3

S8	Yes, if there is only one method then how can you get enough data to figure out what is right or wrong. If only do the same thing over and over and get same results is insanity. If you are trying to find out what a certain mineral is made of in terms of elements you could do that with an electronic microscope or by taking bits and pieces of it and testing reactivity of elements. Burn it or see reactivity to flame and see colors that it gives off and see if	Yes, scientific investigations can follow various methods. For example, experimenting on how chemicals react with water is a hands-on experiment, but observing the flight patterns of birds is more of an observation-oriented experiment.	They probably knew that the animal's muscles and ligaments would not have worked properly with the second positioning. They had scientific data to prove that was the case that the 1st figure is best.	It makes more sense because the weight distribution would be messed up in B.	They use data gathered by numerous experiments and test along with common sense logic and years of training and gaining knowledge and previous knowledge.	Scientific facts.	3. 1 11. 1 12. 0	3,1 11.1 12. 1	2 out of 3

	they match something.								
S9	No there is not more than one way to perform scientific investigation because you need to know about your subjects beforehand and record your data and draw your conclusions from said data.	Yes, they can follow more than one method because a student can observe birds and find an answer to a question or a student can conduct an experiment to get their answer.	The reason is because the figure 2 its clear that the bones cannot hold up the entire organism logically speaking.	Figure 2 put the legs where the arms are supposed to be and vice versa. The legs are bigger to support the weight of the dinosaur. Something small arms can't do.	Scientist used information that they had before of other dinosaurs that they had found and agreed on the form of and so they already have foundation to build upon in their mind.	How well the bones fit into the slots, how much muscle would be necessary to support the weight of the dinosaur, and past knowledge on dinosaurs.	3. 1 11. 1 12. 1	3. 0 11.1 12. 1	2 out of 3
S10	Yes, but I don't know how. Seems irrational that they only follow one method	I do not know.	Figure 1 has the bigger legs on the bottom to support the rest of body. Figure 2 the smaller legs at the bottom will work well for the dinosaur to walk on.	The leg position in figure 1 makes more sense in which the dinosaur would stand. Figure 2 would have immense trouble walking.	These two figures they use they use what is most reasonable on how the bone assortment should be.	The data and reasoning that makes the most sense?	3. 0 11.1 12.1	3. 0 11.1 12.1	3 out of 3
S11	Yes, I can't explain it. I feel that yes is true because I don't have specific reasoning.	Yes, because there are multiple ways to gather scientific information in different experiments that don't necessarily follow the same path. Scenario one is an	Logically because in the first one the way that lived and what they ate it makes more sense for them to support themselves on hind legs and use other arms to do other things. In	Most of the scientists agree that Figure 1 had the best sorting and positioning of the bones because the legs in figure 1 look more like legs and the	Scientists what they knew about dinosaurs to explain their reasoning.	Scientists use background information and knowledge to explain their conclusions.	3. 1 11. 1 12. 1	3. 1 11. 1 12. 1	3 out of 3

		example of an untraditional way to gather scientific information that was still effective. Many other experiments follow a specific step-by-step process of gathering information.	Figure 2 the hind legs are arms would not be that beneficial and the whole dinosaur would be more leveled and less tall.	legs in figure 2 look more like arms. Besides physical appearance, the bones look like they would fit better in figure 1.					
S12	No, following more than one method can lead to bias.	No, I believe there is only one way to conduct this experiment. With something so specific as beak and diet, the only two variables that can be administered and watched are beak and diet. Any other methods of testing might lead to inconclusive results	Longer hind legs provided an advantage to running or maneuverability .	The longer legs provided an advantage over other dinosaurs	Which structure was found more recently the amount of dinosaur bones recovered matching figure one?	They would need to include how one might have our lives the other or populations.	3.0 11.1 12.0	3.0 11.1 12.0	3 out of 3
S13	Yes, there are multiples ways to get solution to an answer.	Yes. There are many different thought processes that can lead u to solution.	Grab prey and hold close to eat. To attach prey close distance to them.	Helps pull pray closer	Fossils, to see what they might eat to see if that variable might affect other aspects such as arms.	Bones and meal plan over time	3. 1 11.0 12.1	3. 1 11. 0 12. 1	3 out of 3

Note. Table ___ displays the content validity of the Views About Scientific Inquiry instrument. Thirteen students were interviewed and quoted on their responses on the three most confusing questions to ensure students' comprehension of these questions.

Table _ starts with two columns for each question (3, 11, & 12), which displays interview quotes for that question and then survey quotes from the online VASI survey pertaining to each student.

In the next set of columns, all three question's VASI score was listed for each student; scores were 0 (naïve) or 1 (informed).
In the final column, VASI interview and survey scores were compared to evaluate precision for each student's responses, e.g. a student that scored 1 on each question for both VASI interview and survey match column would be: 3 out of 3.