IMPLEMENTING ACTIVE LEARNING

IN HIGH SCHOOL

PHYSICAL SCIENCE

by

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of the requirements for the degree

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION AND BACKGROUND

Implementing active learning has been the predominant goal and driver of instruction for almost the entirety of my fourteen years as a science teacher. I laboriously, and often fruitlessly, attempted "cookbook recipe" labs, project-based learning units, and inquiry through the direction of the Next Generation Science Standards (NGSS) engineering and science practices. Colleagues often refer to me as the lab person and it is no coincidence that active learning is my preferred instructional method. Twenty years ago, I graduated from a member of Ted Sizer's The Coalition of Essential Schools, Salem High School in Conyers, GA, which champions principles like "student as worker, teacher as coach", "learning to use one's mind well", and "personalization". Therefore, as an adolescent, I learned by *doing* (certainly not by reading, writing, or listening), which perhaps explains why I have always wanted to teach with active learning methods.

Active Learning

Active learning marries well with the contemporary NGSS and it is an exciting time to be a science teacher. However, implementing active learning is a difficult task, so much so that, during a recent school year, I found myself almost exclusively teaching through direct instruction. Notably and, perhaps consequently, my students' median national percentile on the Georgia Milestones Physical Science End of Course assessment dropped 34 points compared to the previous year's students. Direct instruction is a common name for passive learning, which involves students seated and subjected to a one-way delivery of information, usually from someone that has a much different experience, perspective, and way of communicating. This method sharply contrast active learning and my desired mode of instruction.

Active learning has been challenging to define, but people agree that students learn best by doing their own learning in an active way (Page, 1990). For research purposes, I simply defined active learning as students physically working in groups during exploration activities. Specifically, my active learning method is similar to a combination of the child-centered faction of the progressive movement from the early twentieth century and the cooperative movement from late twentieth century, which emphasizes student freedom and collaboration.

Overwhelming empirical evidence indicates that students actually learn more when they participate in active learning (Deslauriers et al., 2019; Freeman et al., 2014). In addition, people also agree that when students actively construct their own knowledge they, in turn, develop the ability to think critically and solve problems. Despite the obvious benefits of active learning, I have felt somewhat alone in my struggle and pursuit of trying to make it work. Simply, my colleagues were not interested in implementing active learning at the same level I was.

Focus Question

With the opportunity to do Action Research (AR), I earnestly implemented an active learning method with two high school physical science classes of predominantly ninth grade students. A critical part of this implementation was the use of the Cambridge Physics Outlet (CPO) curriculum, which involved the 5E model of instruction centered on top quality lab materials. I sought to learn how effective my active learning method was by using the CPO curriculum. The focus question for this study was how does active learning with the CPO curriculum in high school physical science impact student engagement?

Sub questions included the following:

1) How does active learning affect the students' cognitive engagement compared to passive learning?
2) What are the students' attitudes toward learning science and lab activities?
3) How does implementing active learning affect my role as a teacher?

In this paper, I further describe active learning and relevant literature regarding the concept, the methods used to answer the research questions, and evaluate my instructional method based upon the body of collected data. Lastly, I discuss potential factors that influence the effectiveness of implementing active learning and the impact is has on my teaching.

CONCEPTUAL FRAMEWORK

Introduction

A quick survey of literature illuminated the strengths of active learning and presented evidence for desirable outcomes, which provides valuable insight for this AR project. Impressively, Page (1990) provides a comprehensive review of the proponents and movements from a historical perspective, which recognized four common themes associated with active learning. This literature, amongst others in the 1990s, addressed the difficult task of defining active learning and began a reemergence of the active learning teaching model. Alongside well-founded theory, recent studies provided empirical evidence showing active learning increases actual learning when compared to passive learning (Deslauriers et al., 2019; Freeman et al., 2014). Lastly, Uskokovic (2017) passionately described stark criticism of active learning, which calls for a thoughtful, thorough, and authoritative presence in active learning classrooms. This article prompted serious reflection, which I discuss later in this paper.

Much of the design and analysis used to answer the AR questions derived from previous studies and pertinent literature. For data collection, Shumow et al. (2013) used the Experience Sampling Method (ESM) to gather students' self-perceived level of engagement during a two-week period by repeated surveying, which became a vital part of this AR. Additionally, Lovelace and Brickman (2013) argued that science educators use attitude surveys to inform the conclusions they make about the effectiveness of their instructional interventions. Lastly, Deslauriers (2019) compared active versus passive learning, which contributed to a research question that sought a comparison between active and passive learning methods. This conceptual framework reviews these sources of literature, which helped shape this AR and my discovery of active learning.

AR Direction

Intriguingly, and shortly after the turn of the twentieth century, multiple studies on lab investigations in the United States observed a glaring disconnection between labs and learning. The National Research Council's (2006) report on lab investigations in U.S. high school science indicated that most students participate in typical laboratory activities that are isolated from the flow of science instruction. This report also addressed the stagnant level of proficiency on the science portion of National Assessment of Educational Progress (NAEP) from 1969 to 1999. The NRC (2006) stated:

> Most people in this country lack the basic understanding of science that they need to make informed decisions about the many scientific issues affecting their lives. Neither this basic understanding – often referred to as scientific literacy – nor an appreciation for how science has shaped the society and culture is being cultivated during the high school years (p. 1).

In addition, prominent secondary science researchers Hofstein and Lunetta (2003) analyzed scholarship in science education since their critical review of the research on science laboratory in 1982. They ultimately concluded that our science classrooms has yet to realize the great potential for laboratory activities. Similar to the NRC report, they suggested solutions involving inquiry and students constructing their knowledge, which in turn seemed to usher in the age of science, technology, engineering, and mathematics (STEM) and NGSS. However, this push for science education reform appears to bear no fruit. For example, the two most recent NAEP science results (2009 and 2015) indicate insignificant growth and no more than 22% proficient. Compelling literature on active learning proposes that its models engage students in higher order thinking and supports the way all humans learn, which most likely offers a solution to our unsatisfactory "national report card" grade.

Page (1990) logically postulated that all learning is active, either through mental or physical action. In addition, she described that all proponents of active learning, which included but not limited to Dewey, Paiget, Rousseau, and Pestalozzi, shared four distinguishing themes (Page, 1990). These themes are important to recognize when attempting understanding what exactly active learning is and how to implement it.

First, each proponent to a degree rejected the traditional teaching model, which consists of lecture and rote memorization. They describe the traditional teaching model as boring, unimaginative, and even as far as being oppressive and inherently tyrannical.

Dewey, arguably the most prominent proponent for active learning, founded his own school in contrast to traditional education models. He said, "Having teachers deliver bodies of information made students docile, receptive and obedient and prevented them from learning how to solve problems" (Page, 1990, p. 20).

Second, each proponent applied an emphasis on the cognitive learning paradigm, which is aligns with constructivism and provides the theoretical underpinnings of active learning. In other words, students construct their own knowledge based on their experiences. "Dewey described the mind as a verb, as something to do rather than something to be filled like a sponge" (Page, 1990, p. 20). Furthermore, when interacting with the environment, Paiget theorized, the student assimilated their surroundings into existing cognitive structures and in turn altered these structures to accommodate their world (Page, 1990). He coined the term schema to represent a person's cognitive structures, which represents the extent of one's knowledge.

Third, each proponent expressed an emphasis on the essential relationship between school and society. Dewey saw the classroom as a "microcosm of a democratic society" (p. 20), which involved the teacher modeling democratic ideals and the students learning by experience the skills and attitudes necessary to maintain a democratic way of life (Page, 1990). Interestingly, and most applicable today, futurist argue that active learning is necessary for students to successfully navigate through the rapidly changing technology and society of our times.

Fourth, a shared positive belief in the worth and ability of the student. Pestalozzi believed that students are innately good and have the intellectual and physical powers to develop through activities and experiences on their own (Page, 1990). His teacher, Rousseau, believed that students deserved respect and that they are capable of self-direction and self-development, which was, and surprisingly, an unusual perspective during the middle of the eighteenth century. Dewey believed in the natural power of the student's attention and energy and contended that those attributes should be the basis of students' learning (Page, 1990). Contemporary proponents often put full faith into their students' capabilities and allow them to be involved in the choosing and planning of their educational experiences. As a teacher, I identify with these common themes, which drove my inquiry.

Along with this conceptual foundation, recent empirical evidence supports active learning in comparison to passive learning. First, Freeman et al. (2014) meta-analyzed 225 studies that reported data on exam scores or failure rate from undergraduate STEM courses under both traditional lecturing and active teaching. The results indicated a six percent improvement on exam scores in active learning sections and students in traditional lecturing were one and a half times more likely to fail. To my knowledge, this study is the largest and most comprehensive meta-analysis of comparing lecture and active learning studies published to date.

Secondly, Deslauriers et al. (2019) conducted a crossover experimental design involving 149 students randomly selected into two groups from fall and spring undergraduate physics courses. During instruction on static equilibrium, one group participated in active learning (treatment) while the other passive learning (control). Then, the following class each group kept the same instructor, but the original treatment group participated in passive learning and the original control group participated in active learning during instruction on the new topic of fluids. The researchers assessed both the students' feelings of learning and actual learning by a multiple-choice test. The results indicated that the students' perceived themselves learning more during passive learning; but in fact, they achieved higher test scores after participating active learning. This study provides more evidence in favor of active learning and confirms that research aiming to understand it is worthwhile.

Methodology

Primarily, this Action Research intended to develop instruments and methods that captured the students' perspective, which I considered highly important when evaluating the effectiveness of the intervention. Page (1990) suggested that researchers learn from the students in active learning programs. In addition, the students' subjective experience according to the motivational theory – Emergent Motivation Theory (EMT) explains how to foster students' engagement and learning. EMT posits that students will fully engage in activities and even make life-long commitments as a result of feeling consistent, positive affect while engaging in them (Csikszentmihalyi, 1990). Therefore, collecting data on student engagement (cognitive) and attitude would shed light on their subjective experience during my active learning method.

Shumow et al. (2013) conducted a study involving multiple perspectives on student outcomes in high school labs, which significantly contributed to the method of data collection in this research. Specifically, they used the ESM, which gathered data the students' perception by repeated surveying. During their study, the students reported on as many as 20 separate occasions and, in total, they collected approximately 1,300 responses with each student responding an average of nine times. They noted that ESM had a high degree of external and internal validity (Shumow et al., 2013).

Additionally, Lovelace and Brickman (2013) argued that science educators use attitudinal surveys to inform the conclusions they make about the effectiveness of their instructional interventions. The attitudinal survey used in this research was a modified version of the Colorado Learning Attitudes and Science Survey (CLASS), which includes questions about how students learn physical science and how physical science connects to their everyday lives (Madsen, 2019). The attitude data gathered by the modified CLASS is a reference for the students' general feelings toward learning science and provide insights about their subjective experiences

In summary, the literature reviewed during this AR provided valuable insights into active learning, its great prospect, and ideas toward how to conduct proper research. Furthermore, the literature contributed too much of the interpretations and resulting teaching implications discussed later in this report.

METHODOLOGY

Introduction

Dedicated to learning how to implement active learning and improve science literacy, I sought to understand how effective my active learning method was. Heavily influencing my teaching method was the Cambridge Physics Outlet (CPO) curriculum, which provided a solid platform for active learning. Research methods designed to compare active and passive learning in terms of students' cognitive engagement consisted of repeated surveying with Classroom Assessment Techniques (CATs), observational field notes, and student interviews. Methods seeking to understand the students' attitude toward learning science and labs used an attitudinal survey, CATs, and student interviews. Lastly, reflection notes, CATs, and interview data provided information for the discovery of my role when implementing active learning. Integrating data from each of these sources ensured triangulation and, ultimately, well-informed conclusions throughout the course of this AR.

Participants

Students from two mixed grade-level physical sciences classes in a suburban Atlanta, Georgia high school participated in this research (N=36). Demographically, 61% of the participants were female, 39% male, 86.4% Black, 6.8% Hispanic, 4.5% White, and 2.3% American Indian. Overall, 47% of the students at the school are from low-income families. Recent school changes in science sequencing placed ninth-grade students in physical science, but classes also included some tenth-grade students that have completed biology and eleventh-grade students completed biology and chemistry classes. The participants were 70.4% ninth-grade, 18.2% tenth-grade, and 11.4% eleventh-grade. Analysis of a sample of the participants eighth-grade End of Grade Physical Science Milestone indicates 72% are "beginning learners", 8% are "proficient learners", and 20% are "distinguished learners" (n=25). However, this research analyzed data as a whole, instead of individually, and received Institutional Review Board approval.

Treatment

Throughout the 2019-2020 school year, students participated in approximately 30 hands-on exploration activities, which allowed students to collaborate amongst their peers and investigate within an experiential context. Sixty percent of these explorations were Cambridge Physics Outlet (CPO) Science material, which included user-friendly lab equipment supported by comprehensive teacher and student guides. The CPO lab equipment is what sets this curriculum apart from others. Extensively used throughout this AR was the Car and Ramp (five investigations), simple machines (three investigations), Roller Coaster (two investigations), and Chemistry Models (seven investigations). In particular, the car and ramp materials is equipped with photogates and timer technology, which allowed the students to physically built a ramp, adjust sensors, and obtain accurate measurements. Besides the quality hands-on materials, CPO explorations have clear student guides with focus questions, background information, data tables, and questions. If there were a drawback to the student guides, it would be that they have a disproportionate amount of convergent questions compared to divergent questions.

At the beginning of the spring semester, a quasi-experimental study monitored students' cognitive engagement during a five-week period, which included seven explorations adopted from the Chemistry Models unit. This stage of the AR tested the null hypothesis that active learning has no effect on the students' cognitive engagement. The comparison groups occurred within each class and participated in both exploration activities and direct instruction. At the time of surveying, the recorded activity (lab or lecture) retrospectively determined these groups. We are calling them comparison groups because most of the variables in the study were uncontrolled.

During this study, part of the implementation was the use of the CPO curriculum's 5E model lesson plans. Barring the evaluate element of the 5E model, nearly all other suggested elements were implemented, which included engage, explore, explain, and elaborate elements. During each exploration, students used either atom model kits or periodic table tiles that allowed the physical manipulation of materials. The atom model kits give the students the capability to make atoms as large as technetium with labeled energy levels and orbitals. The periodic table tiles included each of 118 elements with color-coded groups and served as another sets of materials that promoted physical activity. In addition, students were encouraged to record CPO student guide responses into a science notebook. The student guide for each exploration was also congruent with the NGSS science and engineering practice of developing and using models.

During block periods of 90 minutes, a usual lesson included 10-20 minutes for engagement, 45-60 minutes doing an exploration activity, and then 10-20 minutes for explanation or summarization of the content. For example, the first lesson on atomic structure began with an illustrated Google slide highlighting alchemy and the attempt to turn lead into gold. The students responded and discussed the question, "How do you think a gold atom is different from a lead atom?" Then, groups of three to four students accessed the CPO investigation guide and obtained physical atom model kits. With the kits, students used color marbles as sub-atomic particles to build a model of Lithium-6 and responded to questions eliciting the relationship between information on Lithium's periodic table symbol and the model they made. As the teacher, I floated around the room offering assistance as needed. The investigation continued with the students making various assigned atoms ranging from beryllium to aluminum and, in particular, two carbon atoms of different masses. The students worked together to complete these task and answer subsequent questions from the investigation guide. At the conclusion of the exploration activity, direct instruction and attempts to generate discussion covered the concepts of an atom's identity, charge, and isotopes. During this time, I solicited for student questions, which mostly addressed questions from the investigation guide. In addition, the students randomly selected an element as the first step in an elaboration assignment to build an atom model project. Another example of a lesson, included students categorizing twenty random physical items, organizing periodic table tiles, and in small groups preparing a quick presentation on a periodic table group or classification. These examples depict the general implementation of the active learning method throughout this quasi-experimental study.

Data Collection

In the fall semester and piloting stage, data collected by CATs, attitudinal survey, observational field notes began the observation of my active learning method. Pre and post-initial CATs (ICAT; Appendix A) administered during the first two months of school, while inundating the students with lab investigations, provided data on the students' attitude towards the instructional method. The ICAT included a Likert-type item asking students to rank their attitude toward the CPO lab investigations between "hate it; not helpful" to "love it; very helpful" and an open-end portion elicited comments or ways to improve the learning experience. This instrument targeted the students' subjective experience and participant member checking helped to verify its reliability.

In October, the students completed the attitudinal survey (Appendix B), which included 15 Likert items asking the students' level of agreeance to statements concerning motivation, problem solving, and relevance. This survey, a modified version of CLASS, determines the level of students' attitude toward science compared to experts in STEM fields (Deslaruiers et al., 2019). Thus, as a vetted instrument used in traditional research it holds validity. As recommended by my professor, additional open-ended questions provided qualitative data describing the students' feelings toward learning science, which increased the AR's rigor.

Observational field notes collected on five separate occasions from mid-October to mid-November provided insights from a district science coordinator and peer facilitator, who both proved trustworthy and reliable, as their ratings of student engagement were honest and consistent with one another. These outside observers added diverse perspective, which helped increase the rigor of the AR. The field notes included data on what the class was doing, the level of student engagement, and the type of resistance. During the spring quasi-experimental study, I used the same observational protocol (Appendix C) to record what the students were doing during the time of surveying.

Data collected on the students' cognitive engagement, during the quasi-experimental study, came from a Likert-type item referred to as engagement CAT (ECAT; Appendix A), which asked the students to choose a level of agreeance for how completely they are concentrating on learning science. As a vital part of this AR, a colleague's review helped assure the validity of this instrument. On the ECAT, an additional open-ended question asked the students' to report what they were thinking about at that moment. Student facilitators assisted by setting a timer for surveying, which ensured a randomization. Engagement data collection occurred for five weeks on eight occasions, during January and February. In total, approximately 240 collected responses yielded data for this study, which included 125 responses during moments of active learning and 115 during passive learning. This method reflects the ESM described in traditional research literature, which cites analysis confirming its validity (Shumow at el., 2013).

In early March, semi-structured interviews (Appendix D) with three focus groups of two to three students provided additional insights about the instructional method. Interview questions about attitude toward learning science, perceived conceptual understanding, and relevance provided qualitative data from a sample of the participants. This participant debriefing increased reliability of the students' subjective experience and provided the opportunity for additional insight. Additionally, in mid-April a video chat with a master teacher provided an expert's perspective on implementing active learning, which increased the rigor of the AR.

After interviews, the preference CAT (PCAT; Appendix A) assessed the students' preferred instructional method. The PCAT asked students to select their preferred instructional method that helps them learn science. Options included lecture and notes, labs and activities, and mixture of both. The following table summarizes the instruments used to collect and polyangulate data in order for rigorous examination of each research question.

Table 1
Data Triangulation Matrix

Research Question	Data Source	Data Source	Data Source
Active learning's effect on cognitive engagement	ECAT	Field Notes	Interview
Attitude about learning science and labs	Attitudinal Survey	ICAT	Interview

My role when implementing active learning	Reflective Journal	PCAT	Interview

The research methodology for this project received an exemption by Montana State University's Institutional Review Board (Appendix E) and maintained compliance for working with human subjects throughout the course of the study.

DATA ANALYSIS

Cognitive Engagement

The results of the quasi-experimental study deduced that no matter the instructional method (active or passive), on average, the students ranked their level of agreeance to the statement "at the moment, I am fully concentrating on learning science" nearly the same (*N*=36; active mean = 3.76, passive mean = 3.72). Essentially, the results were identical.

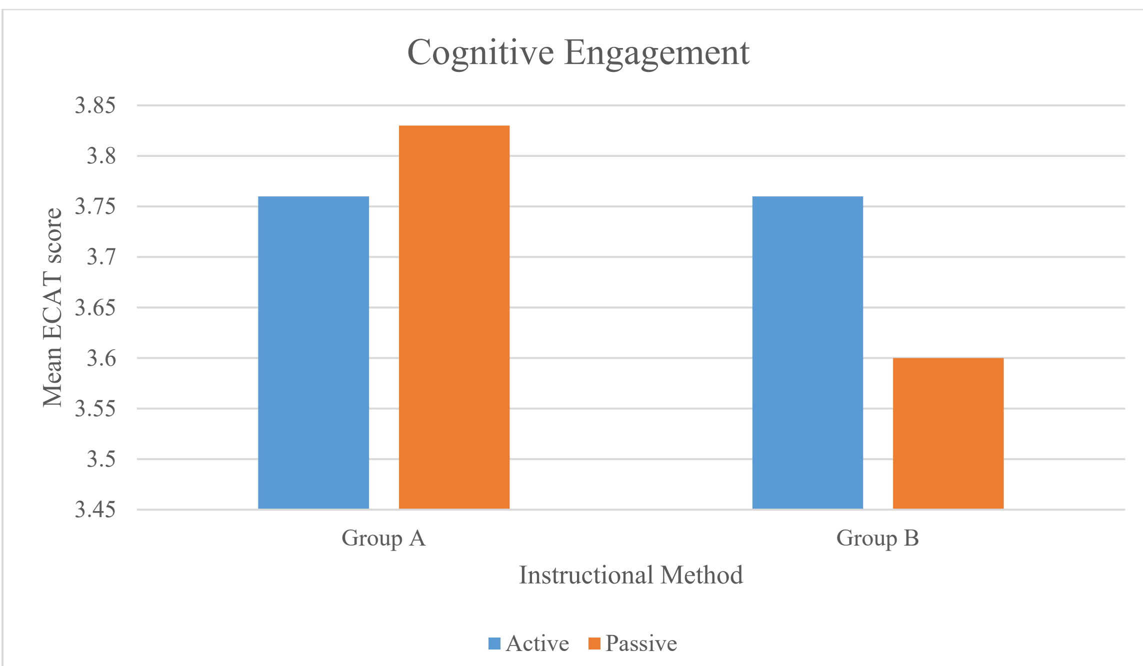

Figure 1. ECAT group average per instructional method (*N*=36)

Additional Chi squared analysis on disaggregated *engaged* (ECAT responses ≥ 4) and *not engaged* (ECAT responses ≤ 3) categories indicated no significant, if any, correlation between instructional method and cognitive engagement [x^2 (1, n = 240) = 0.15, p = .70]. Low statistical variance and standard deviation adds reliability to this data ($\sigma^2 = 0.76$; SD = 0.87). Additional median analysis, which is touted as resistant to outliners, showed active and passive were also identical (median = 4). This may be of interest, because of the skewed nature of the data (ECAT responses ≥ 4 = 154, ECAT responses ≤ 2 = 13). As expected, the mode also equaled four.

Factors that may account for such a similar result between active and passive methods might lie in the research design. Using the EMS data collection model may have been inappropriate. Steel and McLaren (2008) warned that sampling a population over time is to monitor changes and if the frequency of surveys were too high, than the sample would only register unimportant short-term movements of no practical interest. This appears to be an issue and weakens the research's validity. Another weakness, in hindsight, was that my experimental design lacked an adequate control. In other words, simply noting the instructional method at the time of surveying was most likely not enough to see any true outcomes of active and passive learning.

Overall, approximately two-thirds of the students reported being cognitively engaged in learning science (*N*=36). Possible explanations for this moderate level of engagement are most likely off-task behavior and lack of classroom practices that require mental activity. Preliminary observational field notes, gathered from outside observers, noted a low (< 50 percent) to mixed (50 – 90 percent) student engagement, particularly students' displaying passive resistance by "staring off" or not being "attentive". In addition, qualitative data gathered by the ECAT indicate the students' mind was frequently on other matters (i.e. food, sleep, social life). Interview data also indicates that off-task behavior and focus was a concern during the study. One student said, "Some group members were off task, which made the work frustrating." Most telling, the peer facilitator stated in his field notes, "Many students can be off and on. Sometimes willing to do the work without pressure, but usually requires it." This candid observation with afore mentioned data provides compelling evidence that the intervention did not optimize learning conditions.

Student Attitude

Student attitude data gathered by the attitudinal survey, ICATs, and interview instruments offered insight into student feelings toward learning science and lab activities. Results indicate most students reported that they use cognitive processes when problem solving and that they have a desire to learn. Nearly three out of four students selected that they agreed to items one, five, seven, and nine on the attitudinal survey, which addressed those attributes (figure 2).

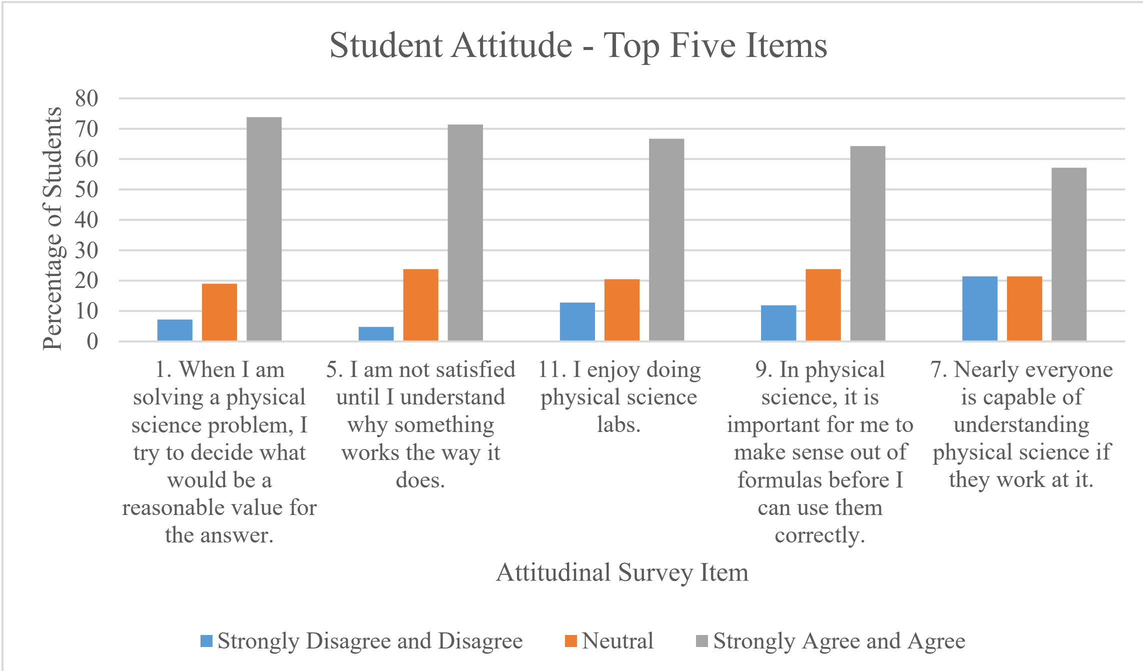

Figure 2. Percentage of students per top five attitudinal survey items (*N*=42*)*

Certainly, our human nature provides an explanation from these results, which are consistent with the active learning proponents' view on the worth and ability of the student. They argued that students deserve the freedom of discovery and that they have the capability of self-regulating their learning. This notion might explain why, out of all 15 items, problem solving skill and desire to learn was the highest scoring items. This fascinating result is contrary to probable grumblings heard around teacher lounges.

On the low scoring end of the attitudinal survey, the results indicate that many students do not see the relevance in science class. Less than one-fourth of the students agreed that they make connections from physical science to everyday life. On average, results from the relevance item cluster scored 15.5, which was the lowest compared to the problem solving (18.4) and motivation (17.2) (*N*=42*;* out of 25). Three of the bottom five scoring items, including items two, twelve, and fifteen corresponded with relevance in the classroom (figure 3).

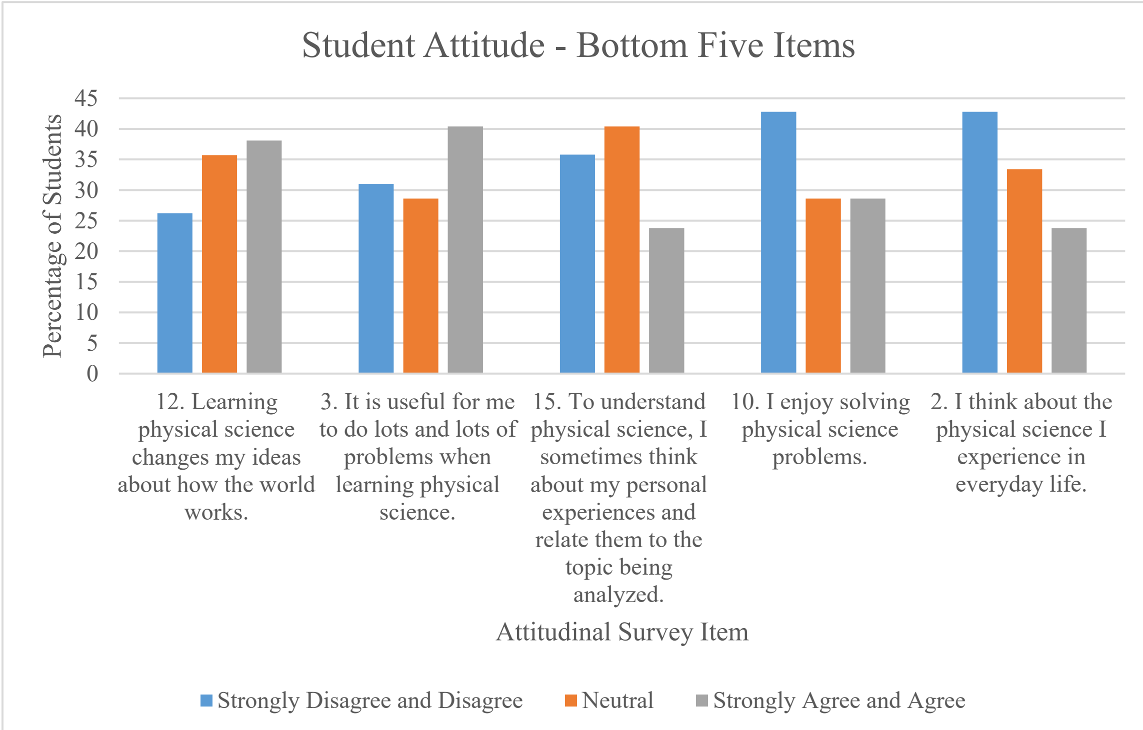

Figure 3. Percentage of students per bottom five attitudinal survey items (*N*=42)

One student's response to the written portion of item fifteen stated, "I just never thought of doing it like that". Possible explanations are that my active learning method, and furthermore, most students' previous educational experiences lacked reflective thinking and/or a teacher with the know how to clearly articulate the relevance of science lessons. Research has noted that the teachers ineffectively communication the purpose and/or connection of a lab to the real world (Shumow et al., 2008). In my classroom, the most likely cause is a systematic lack of mentally active and authentic activities. Research suggest that having students generate their own ideas about the relevance of a lesson promotes making connections to the real world (Hulleman & Harackiewicz, 2009).

Lastly, labs are a major vehicle for active learning so I sought to discover the students' attitudes toward them. The results indicate that the majority of the students enjoyed doing the labs, but were unaccustomed to using them as a main learning method. Attitudinal survey data revealed 66.7% of the students agreed to the statement "I enjoy doing physical science labs" (see figure 2). Some students noted that the labs were a refreshing break, from what I assumed was usual school to them, and that it helped their understanding. One student said, "The labs help because I am actually doing something other than a worksheet." Another said, "Sometimes I love the science we do to learn science, because it helps me understand it better than staring at a board writing notes." Also, interestingly several students expressed a satisfaction for the opportunity to be physically active. One student said, "I enjoy being able to move and get different results than other people." Another said, "I learn better when having the access to physical contact." These student insights elude to the need for physical engagement, which active learning recognizes and facilitates.

These positive results from the attitudinal survey are consistent with the trend captured by the ICAT during the piloting stage of the study, which targeted the students' attitude towards the initial lab investigations. The results from ICATs administered a month apart indicate a 22.4% increase in students "liking" or "loving" the lab investigations (*N=34*). In addition, qualitative results from the ICAT indicated a 60% reduction in students concern with instruction during this period, which involved twelve lab investigations in the first nine weeks of school. Clearly, this data reveals most of the students enjoyed doing the labs after they became accustom to them. This is supported by research that suggest when students experience the increased cognitive effort associated with active learning, they initially perceive their learning as poor (Deslauriers et al., 2019).

My Role

Having observed increased satisfaction in labs, yet modest levels of engagement I sought to assess the students' preferred instructional method. The results of the PCAT indicate that three out of four students prefer a mixture of both labs and lectures to help them learn science (*N*=34).

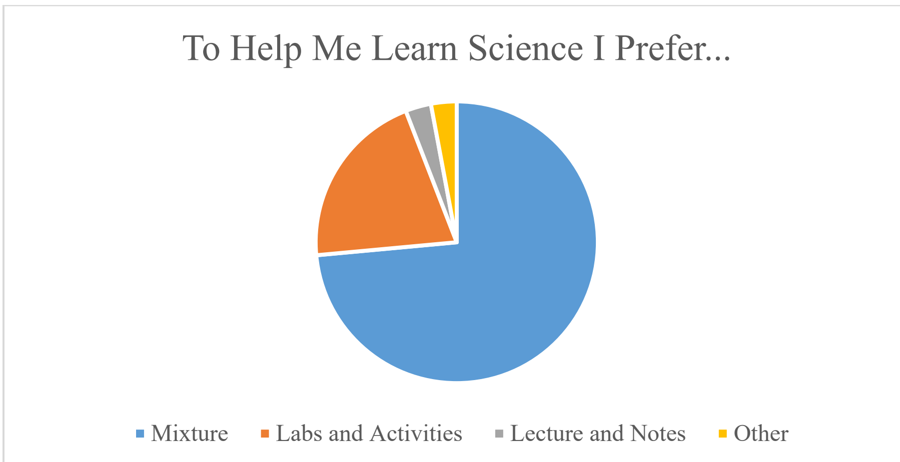

Figure 4. Student instructional preference (*N*=34)

In addition, interview data indicates this notion that providing a variety of method is preferred. One student said, "Maybe introduce a lab and the content for ten to fifteen minutes prior to doing a lab". However, upon reflection, I am not entirely convinced that I need to make direct instruction a bigger part of my instructional methods. Perhaps, Deslauriers at el. (2019) observation of students perceiving themselves to learning more during lecture also attributes to this PCAT result.

I believe that, and most importantly, my teaching methods needs to develop effective discussion and reflection practices. Page (1990) said, "Active learning models, involves the students being mentally and/or physically active" (p. 73). Furthermore, if a student sits and answers questions until they experience a discovery, than their action was mental and active learning still occurred. This concept set in motion a paradigm shift in mind, which influences my role as a teacher. Upon reflection, the method implemented effectively covered the physically active aspect of active learning, but woefully neglects mental action. Developing a clear, thoughtful, and structured way of incorporating discussion and reflection would most likely increase the students' mental activity, thus, their engagement and learning.

In addition, proponents of active learning, particularity Dewey warns that teacher must a) be aware of students behaviors, b) pay attention to and evaluate the students' work, and c) keep the process heading to a relevant and meaningful close (Page, 1990). I was fortunate enough to take an MSSE course from an instructor that was dedicated to accomplishing these three points of active learning. During a 45-minute video chat, the master teacher alluded to the idea of creating "extraordinary experiences" in the classroom, which struck me as an ultimate goal of teaching. Using their course as a model, I began to realize how my role as a teacher could make this goal a reality.

INTERPRETATION AND CONCLUSIONS

In response to how active learning through the CPO curriculum impacts student engagement, I found that students were moderately engaged and that improvements in my teaching method would most likely increase their engagement. For instance, striding toward using deliberate practices that overtly solicit mental activity and facilitating extraordinary experiences would help increase students' active engagement. Evidence from the ECAT and attitudinal survey, in particular, both showed two out of every three students reported that they are "fully concentrating" on learning science and that over time they enjoyed doing the labs. In addition, the observational field notes, interview data, and serious reflection discussed in the data analysis led me to the conclusion that as good as the CPO curriculum is at providing physical engagement; the teacher needs pedagogical knowledge on how students learn in order to optimize active learning. According to Wieman (2012), effective teaching must understand how students learn a particular STEM subject and the challenges and opportunities for facilitation of learning. When a teacher understands how students learn they can build classes that allow them to construct their own knowledge through experiences and deliberate practices, such as explorations, reflective thinking, and interactive discussion. The remainder of this section further outlines the reasoning behind why these changes in my teaching method should improve the moderate result observed in this study and discusses the findings from the studies sub-questions.

First, in response to how active and passive teaching methods affect cognitive engagement, I found that flaws in the research design inhibited an accurate comparison of the respective methods. The data indicated no difference between cognitive engagement and each method, but the research failed to control critical variables, in particular distinguished instructional method per topic and the teacher. This result is not consistent with the prevailing literature that overwhelmingly favors active learning methods. Experimental designs from prominent studies often use two separate classes with different teachers executing contrasting methods (active and passive) on similar content topics (Deslauriers at el., 2011 & 2019). However, this study used both active and passive methods intermittently in most classes and relied on which method the students happened to be participating in at the random time of surveying. Regardless, the study obtained meaningful results, but it failed to achieve a true comparison of active and passive learning.

Second, in response to what the students' attitude toward learning science and labs were, I found that the students enjoyed doing labs once they became accustom to the routine and that most of them did not see the relevance in learning science. The data revealed that two out of three students reported that they enjoying doing the physical science labs. Interestingly, the students also reported a 22.4% increase in satisfaction with the lab investigations when inundated with one point three labs per week during the first unit. This result is consistent with theory that students initially equate active learning with poor learning because of the increase cognitive demand or unfamiliarity (Deslauriers et al., 2019; Shumow et al., 2013). Thus, developing consistent routine and using consistent materials (i.e. descriptors and equipment) helped students become comfortable and benefit from doing the labs.

However, this method did not help the students see the relevance of science. Less than one out of four students reported that they made connections between physical science and everyday life. This result is consistent with studies that have identified relevance as an issue in the science classroom (Shumow et al., 2013; Hulleman & Harackiewicz, 2009). Therefore, identifying and evaluating strategies that promote real world connections could help motivate students and improve my active learning method.

Lastly, in response to my role as a teacher implementing active learning methods, I found that the students' mental activity should improve by using of deliberate practices and that providing students with extraordinary experience should be a primary goal.

Extensive discussion on how these two aspects affect my role as teacher and there implications for my teaching follows.

Mental Action

Upon reflection, my teaching method did not address or emphasized mental action, which is of course critical for learning. Dewey expressed it like this, “The notion that we have only to put physical objects before the senses in order to impress ideas upon the mind amounts almost to a superstition” (Page, 1990, p. 22). Admittedly, I had fallen into this trap of thinking that students will learn by merely providing them with hands-on activities.

Solutions for this mental action problem may include a) designated reflection time and questions, b) constant reciprocal discussion, and c) open-ended assessment. The proponents of active learning offer some wisdom on how to implement these practices. They stress the importance of the teacher providing appropriate levels of guidance, evaluation, and direction, which represents a basic rubric for me to check lessons against when implementing active learning. For example, throughout this study, my active learning method had adequate direction because of the CPO curriculum, but significantly, lacked adequate guidance and evaluation because of insufficient discussion and a reliance on district mandated selected response assessments.

Designated time for reflective thinking could occur in a multitude of ways. Dewey identified that suggesting, defining the problem, hypothesizing, reasoning and testing are involved in reflective thinking and is critical to learning (Page, 1990). I envision reflection occurring in five to ten-minute increments following various class activities, which include explorations, discussions, and/or explanations. In order to provide adequate direction clearly articulating the purpose and expectation for reflection time must be accessible to the students in writing. For example, the purpose of reflection is to help you learn from your experience and make connections to the things you already know. Moreover, the expectation is that students actively participate in sustained silent writing for any determined period of reflection. Guidance for reflection comes in the form of prompts, which may include what are some explanations for the phenomenon in question and/or from your prior experiences, what led you to this explanation. Evaluation of reflective thinking should look for deep thought and be generous with encouraging feedback.

Discussion may be the hallmark of effective active learning, which involves students freely voicing their thoughts. Tofade at el. (2013) writes, “Well-crafted questions lead to new insights, generate discussion, and promote the comprehensive exploration of subject matter” (p. 155). A teacher must provide direction for classroom discussion by explicitly establishing expectations and creating guiding questions. Fortunately, many curriculum resources, including the CPO material used in this AR, supply sufficient guiding questions. Then, the challenge becomes providing the guidance that ensures the communication is reciprocal, constant, not stifled but irrelevant ideas. The master teacher said, “Discussion is a matter of asking the right question, at the right time.” Furthermore, I envision a communication system that involves continual clarification, interpretation, and creation of information to gain a shared understanding. Lastly, evaluating discussion should focus at participation and thoughtfulness.

Open-ended assessments, including concept mapping and science notebooks, would allow students to visually organized and synthesize the information they are learning. In addition, concept maps are a valuable tool for teachers because they provide a unique opportunity to evaluate the students' level of understanding. For instance, the sophistication of a student's map provides information about how integrated their knowledge structures are. Science notebooks provide students with the authentic practice of recording the things they do, see, and think during explorations. Additionally, evaluating science notebooks provides teachers a way to support learning by offering feedback. Lastly, a teacher should provide clear detailed direction regarding the expectations and rubrics for both concept maps and science notebooks.

Surprisingly, two out of three students reported being cognitive engaged without any resemblance of these deliberate practices in my instructional method. Implementing reflective thinking, discussion, and open-end assessment when keeping the appropriate level of direction, guidance, and evaluation in mind would most likely increase the students' cognitive engagement and improve my active learning method. Beginning on the first day of school, detailing and cultivating these practices will be a priority.

Extraordinary Experiences

One does not forget an extraordinary experience and they can happen in the classroom. However, two out of three students agreeing that they enjoyed labs and even fewer drawing connections to the real world implications that the experiential quality of my active learning method should improve. Creating extraordinary experiences will also motivate students to put in the effort that is required for learning. This involves making the subject interesting, relevant, and inspiring (Wieman, 2012). Therefore, setting the professional goal to design classes full of extraordinary experiences will most likely increase student engagement.

At this moment, prior to doing and experiencing, I envision that the steps for achieving this audacious goal may include a) select a big idea b) read and compile activities and resources c) create or modify assignment descriptions and rubrics d) organize activities for student accessibility e) conduct class and guide f) evaluate student work and g) reflection. First, the teacher must determine what they want the students to learn and/or do, which most likely falls within the confines of a common content standard. For example, describe how scientist graphically represent motion.

Second, the teacher must deeply understand and create or gather a wide variety of activities that assist the students in learning the big idea. Setting a minimum requirement of activities for the students and accompanied them with further opportunities for inquiry and elaboration ensures differentiation and personalization. Activities may include discrepant events, explorations (recommend CPO), case studies, educational video and websites, field trips, interviewing an expert, etc. In this step, a teacher must ensure that the activities are appropriately challenging, relevant, and grants the locus of control to the student, which supports motivational and constructivist theory.

Third, after compiling activities a teacher must ensure that the students can clearly understand the purpose of them, how to complete them, and the assessment for them. Assignment descriptions and rubrics should accomplish these critical aspects and are necessary for adequate direction. Shumow at el. (2013) pointed out that when teachers do not express well-elaborated reasons and goals for doing labs it negatively influences students' engagement and their perceptions of learning. Consistent with this, considerable time and skill devoted to articulating written descriptors and rubrics will most likely positively influences students.

Fourth, the teacher embeds relevant activities and resources on a digital platform, which allow students to easily access and retrieve the information. The prospect for utilizing a digital platform is great. Pertinent teacher announces and class discussions can increase student engagement and facilitate effective and efficient communication systems.

Fifth, a teacher is prepared to captivate the students' minds and embodies the mantra –experience being together to learn. During class, a teacher enthusiastically sets the stage for discovery and becomes a coach focused on supporting students doing learning for themselves. Peer interaction and self-direction should be encouraged, but a teacher should not hold a permissive attitude toward behavior. In particular, Rousseau and Dewey stressed that student-centered activities did not mean that the student should or could do whatever they wanted. "That, Rousseau said, would create a monster" (Page, 1990, p. 11)

Sixth, a teacher should pay close attention to student learning by continual evaluation of their work. Constructive dialogue offering suggestions should clear up student misconceptions and/or gaps in understanding. Final student products should standup to a rubric and receive timely feedback.

Seventh, as active learning models implore students to reflect, a teacher's endeavor toward providing extraordinary experiences should do the same. Did the students clearly understand the activity? Did the activity excite and motivate the students? Was the class discussion constructive and productive? Did the students demonstrate understanding? Answers to these questions come from reflective thinking, which informs the practitioner and generates progress.

Uskokovic (2017) convincingly warned of the drawbacks associated with the under scrutinized methods and the blind faith of some contemporary active learning practitioners. He said,

> promotion of mediocrity through class 'democratization'; the suppression of solitary reflection and introspectiveness, along with the creative potentials associated therewith; the inhibition of extraordinariness through excessive teamwork; and the incompatibility with the dominant learning assessment strategies (p. 241).

Concerted effort to sanctify reflective thinking mitigates some of Uskokovic's concern, but from my interpretation, he essentially implies that active learning methods have stopped being about extraordinary experiences. Interestingly, he argues against the active learning proponent's rejection of traditional teaching models by proposing the embracement and poetization of lecturing. I wonder can lecturing enhance an active learning model. Perhaps, if the teacher has the attributes to make lecturing brief and vital to an extraordinary experience.

VALUE

The benefits of active learning have become clear to me during this project, which should have greater implications to science education in general. Besides the modest results discussed in this paper, I want to note that my classes out performed other physical science classes at Luella High School, which didn't involve active learning to the extent that I implemented. It is likely that student learning was enhance by my method, which is consistent with strong evidence supporting active learning in current research. Therefore, I argue that a unified implementation of active learning methods would certainly improve the state of science education across our nation.

Teaching Transformation

Action Research in itself is a testament to active learning. I know with almost full certainty that I learned more about my instructional method by doing AR, than I would have from any other form of education. This AR confirmed the importance of active learning and, ultimately, helped me find my identity as a teacher. I want nothing more than to help my students in constructing their own knowledge in an active way. Three years ago, in my application essay I wrote:

> Teaching a new generation of science students is becoming increasingly important. Students must engage in inquiry and develop reasoning skill to prepare them for successful lives and to solve the problems of the future. Earth is simply a better place with a science competent humanity. I am enthusiastic to do this work and earning a MSSE degree at MSU will greatly enhance my ability to do so.

Well, through the process of this Action Research, I learned what active learning is and is not, that it is a superior model for students, and gained a clearer understanding of its implementation. This experience has expanded my capacity and strengthened my will too effectively implement active learning.

Future Research

Having identified areas of improvement, specifically using deliberate practices to promote mental action and building a clear, coherent, and inspiring curriculum, resolving them is the next step. Then, these new strategies and structures become treatments for future research. Using CATs to monitor their effectiveness will shed more light on my continuously evolving active learning method. In the future, the process of observing, reflecting, and acting may look different in scale and focus from this AR, but certainly, it is the way to learn about and improve my teaching practice.

Having enjoyed read literature about active learning, I want to continue that aspect of research. Tofade's at el. (2013) article on best practices for effectively using questions, Campbell's (1995) book on John Dewey, and UBC & CU Science Education Initiatives (2014) course transformation guide are all on my reading list.

Lastly, having experienced such a difficult time trying to implement active learning throughout my teaching career, I wonder what could have made it easier and, thus, how to help others interested in active learning avoid the struggles I endured. How many of my colleagues would want to implement an active learning method?
What changes would they have to make? How does my school and district support active learning? Perhaps, these questions will also lead to future research.

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APPENDICES

APPENDIX A

CATs

ICAT

Rank your attitude toward the CPO lab investigations.

1	2	3	4	5
Hate it; Not Helpful	Dislike; Somewhat Helpful	Indifferent	Like; Helpful	Love it; Very Helpful

Comments or ways to improve your learning experience_________________________
____
____
____

ECAT

At this moment, I am fully concentrating on learning science.

1	2	3	4	5
Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree

Describe what you are thinking about at this moment____________________________
____
____
____

PCAT

To help me learn science I prefer…

___ lecture and notes

___ labs and activities

___ mixture of both

___ other

If other, please identify what you prefer______________________________________

APPENDIX B

ATTITUDINAL SURVEY

Introduction

Here are a number of statements that may or may not describe your beliefs about learning physical science. You are asked to rate each statement by circling a number between 1 and 5 where the numbers mean that following:

1 Strongly Disagree
2 Disagree
3 Neutral
4 Agree
5 Strongly Agree

Choose one of the above five choices that best expresses your feeling about the statement. If you don't understand a statement, leave it blank. If you understand, but have no strong opinion, choose 3.

Questions 2, 5, 7, 11, and 15 ask for an additional response.

Survey

1. When I am solving a physical science problem, I try to decide what would be a reasonable value for the answer.

Strongly Disagree	1 2 3 4 5	Strongly Agree

2. I think about the physical science I experience in everyday life.

Strongly Disagree	1 2 3 4 5	Strongly Agree

2b. Can you give an example from the above question?

____
____
____

3. It is useful for me to do lots and lots of problems when learning physical science.

Strongly Disagree	1 2 3 4 5	Strongly Agree

4. When I solve a physical science problem, I locate an equation that uses the variables given in the problem and plug in the values.

Strongly Disagree	1 2 3 4 5	Strongly Agree

5. I am not satisfied until I understand why something works the way it does.

Strongly Disagree	1 2 3 4 5	Strongly Agree

5b. Have you always felt this way?

____
____
____

6. If I get stuck on a physical science problem my first try, I usually try to figure out a different way that works.

Strongly Disagree	1 2 3 4 5	Strongly Agree

7. Nearly everyone is capable of understanding physical science if they work at it.

Strongly Disagree	1 2 3 4 5	Strongly Agree

7b. Please explain why you answered the way you did in the above question.

____
____
____

8. To understand physical science I discuss it with friends and other students.

Strongly Disagree	1 2 3 4 5	Strongly Agree

9. In physical science, it is important for me to make sense out of formulas before I can use them correctly.

Strongly Disagree	1 2 3 4 5	Strongly Agree

10. I enjoy solving physical science problems.

Strongly Disagree	1 2 3 4 5	Strongly Agree

11. I enjoy doing physical science labs.

Strongly Disagree	1 2 3 4 5	Strongly Agree

11b. Please explain why you answered the way you did in the above question.

____

12. Learning physical science changes my ideas about how the world works.

Strongly Disagree	1 2 3 4 5	Strongly Agree

13. Reasoning skills used to understand physical science can be helpful to me in my everyday life.

Strongly Disagree	1 2 3 4 5	Strongly Agree

14. I can usually figure out a way to solve physical science problems.

Strongly Disagree	1 2 3 4 5	Strongly Agree

15. To understand physical science, I sometimes think about my personal experiences and relate them to the topic being analyzed.

Strongly Disagree	1 2 3 4 5	Strongly Agree

15b. Can you give an example?

APPENDIX C

OBSERVATION PROTOCOL

Observer name________________________________

Date of observation____________________________

Time of observation___________________________

What is the class doing:

[ ] Exploratory activity
[ ] Direct instruction

Student engagement:

a. How would you characterize the *level of engagement* in the class (e.g., what percent of the class exhibits engaged posture, is directly engaged in task, invests high quality effort to the activity)

   [ ] High engagement: More than 90% of class is engaged
   [ ] Mixed engagement: 50% to 90% engaged
   [ ] Low engagement: More than half the class is off-task (i.e., on phone, chatting, etc.)

b. List the approximate percentage of the class that exhibits the each type of resistance:

	Approx percent	Describe
Open resistance (e.g., do not engage in the activity, engage in off-task work that is distracting to others)		
Partial compliance (e.g., complain that the task are too difficult, rush through the activity simply to finish the task)		
Passive, non-verbal resistance (e.g., act bored, grumble, roll eye)		
Other		

APPENDIX D

INTERVIEW QUESTIONS

1. What is your favorite thing to do at school?

Has it always been?

2. What is your attitude about learning science?

What experiences have you had in science did you like?

What did you dislike?

3. How well do you understand the science concepts taught?

Has labs helped your understanding?

Do you feel that you learn better from lecture and notes or the CPO labs activities?

What concerns do you have about that approach?

4. How could the science classroom connect to the real world or your everyday life?

APPENDIX E

IRB EXEMPTION

MONTANA STATE UNIVERSITY

INSTITUTIONAL REVIEW BOARD
For the Protection of Human Subjects
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MEMORANDUM

TO: Kurt Peters and Walter Woolbaugh

FROM: Mark Quinn *Mark Quinn cj*
Chair, Institutional Review Board for the Protection of Human Subjects

DATE: November 13, 2019

RE: *"The Impact a Lab-based Curriculum has on Student Engagement" [KP111319-EX]*

The above research, described in your submission of November 13, 2019, is exempt from the requirement of review by the Institutional Review Board in accordance with the Code of Federal regulations, Part 46, section 101. The specific paragraph which applies to your research is:

X	(b) (1)	Research conducted in established or commonly accepted educational settings, involving normal educational practices such as (i) research on regular and special education instructional strategies, or (ii) research on the effectiveness of or the comparison among instructional techniques, curricula, or classroom management methods.
X	(b) (2)	Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures or observation of public behavior, unless: (i) information obtained is recorded in such a manner that human subjects can be identified, directly or through identifiers linked to the subjects; and (ii) any disclosure of the human subjects' responses outside the research could reasonably place the subjects at risk of criminal or civil liability, or be damaging to the subjects' financial standing, employability, or reputation; and (iii) the information obtained is recorded by the investigator in such a manner that the identity of the human subjects can readily be ascertained, directly or through identifiers linked to the subjects, and an IRB conducts a limited IRB review to make the determination required by section 16.111(a)(7).
___	(b) (3)	Research involving the use of educational tests (cognitive, diagnostic, aptitude, achievement), survey procedures, interview procedures, or observation of public behavior that is not exempt under paragraph (b)(2) of this section, if: (i) the human subjects are elected or appointed public officials or candidates for public office; or (ii) federal statute(s) without exception that the confidentiality of the personally identifiable information will be maintained throughout the research and thereafter.
___	(b) (4)	Research involving the collection or study of existing data, documents, records, pathological specimens, or diagnostic specimens, if these sources are publicly available, or if the information is recorded by the investigator in such a manner that the subjects cannot be identified, directly or through identifiers linked to the subjects.
___	(b) (5)	Research and demonstration projects, which are conducted by or subject to the approval of department or agency heads, and which are designed to study, evaluate, or otherwise examine: (i) public benefit or service programs; (ii) procedures for obtaining benefits or services under those programs; (iii) possible changes in or alternatives to those programs or procedures; or (iv) possible changes in methods or levels of payment for benefits or services under those programs.
___	(b) (6)	Taste and food quality evaluation and consumer acceptance studies, (i) if wholesome foods without additives are consumed, or (ii) if a food is consumed that contains a food ingredient at or below the level and for a use found to be safe, or agricultural chemical or environmental contaminant at or below the level found to be safe, by the FDA, or approved by the EPA, or the Food Safety and Inspection Service of the USDA.

Although review by the Institutional Review Board is not required for the above research, the Committee will be glad to review it. If you wish a review and committee approval, please submit 3 copies of the usual application form and it will be processed by expedited review.