THE EFFECT OF INQUIRY-BASED LEARNING IN HIGH SCHOOL PHYSICS

by

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of the requirements for the degree

of

Master of Science

in

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DEDICATION

There are many people who have contributed to the successful completion of this action research project. First and foremost, I would like to thank my wife Emily, who has been so encouraging during this process. Without her love and support, there is no way that I would have been able to accomplish this. I want to thank my son Wyatt and daughter Ezrah for being patient with me during this time, as there were times during this process that they unfortunately missed out on time with their dad. Next, I would like to thank both the students and the administration at Westminster Christian Academy for being so supportive during this endeavor. The implementation of this action research was not always smooth, and the students were incredible. Also, as an educator it is great to be at a place where you know that administration has your back and encourages you to do what is best for the students. Finally, I want to thank those of you in the MSSE program at Montana State University that helped me accomplish every step of this journey. Specifically, I want to thank Dr. John Graves for all the courses that were so impactful to me as an educator and everything that he has done for me as my project advisor. Lastly, I want to thank Dr. Elinor Pulcini for her willingness to be my science reader, even though she was beginning her retirement.

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ABSTRACT

The purpose of this action research was to analyze the effect of inquiry-based learning in the high school physics classroom. Specifically, this research analyzed the impact of inquiry-based learning on student ability to scientific reasoning and concept mastery within the units of motion, force, energy, and momentum. The non-treatment group received instruction with a partially flipped classroom approach, with assigned pre-lecture videos and lectures focused on direct application of the content; whereas the treatment group learned through inquiry and following the experiments, were guided with questioning and further labs to fill in conceptual gaps in the content. Pre- and post-test results were analyzed to measure normalized gains in both scientific reasoning and conceptual understanding. Surveys and interviews were analyzed to measure student interest and attitude. The results of this study revealed that the non-treatment group achieved higher normalized gains in conceptual understanding in the areas of force, motion, energy, and momentum; whereas the treatment group achieved higher normalized gains in their ability to reason scientifically. While the theory-practice gap is a real inhibitor to inquiry-based learning in the physics classroom, students were able to connect course content with real-life scenarios, resulting in an overall positive experience for students.

CHAPTER ONE

INTRODUCTION AND BACKGROUND

Context of the Study

Westminster Christian Academy is a K3-12 private school, with a total enrollment of 743 students, in Huntsville, Alabama. Westminster Christian Academy has two separate campuses, a lower campus, where grades K3-5 are located and an upper campus, where grades 6 – 12 are located. Both campuses are located within an urban setting, as Huntsville is now the largest city in Alabama, experiencing almost a fifteen percent growth in the past 11 years. There are currently 496 students located at the upper campus, with an almost equal distribution between male (50.6%) and female (49.4%). Westminster Christian Academy has less than average diversity at 16.9% and only 6.4% of students are on tuition assistance. When it comes to learning plans, 16.7% students have individualized learning plans grades 6-12 (Knight, 2022).

For this research project, the focus was centered on two physics classes that are taught at the upper campus. In recent years, the number of physics students taking these courses has declined drastically, and therefore, the school hired and tasked me with turning the program back in the right direction. Although the school is not officially aligned with the Next Generation Science Standards (NGSS), it is on a trajectory to do so in the next few years, along with becoming STEM certified through Cognia (Accreditation & certification, 2022). Currently, the school is in its third year of its technological initiative, incorporating daily use of Chromebooks in classes. Previously, these physics courses were taught in traditional lecture formats with word problems and assessments that mirrored the word problems given during class lectures.

This is currently my eighth year of teaching physics, albeit the first at Westminster Christian Academy. Throughout the course of these eight years, different presentation styles have been utilized to optimize student performance, while also considering student attitudes in physics Students had been accustomed to the teacher introducing content and modeling the problem-solving process. Students then memorized the process and replicated it. In this traditional model, there is little room for the students to apply content to real-world scenarios and therefore there exists a disconnect between what they were learning and the perceived importance of the content.

When this disconnect exists in a class that is an elective, student interest wanes and enrollment drops. Therefore, to adequately address the waning enrollment in the physics courses at Westminster Christian Academy, an in-depth analysis is needed of not only student performance, but also in student attitudes and beliefs. While there was the initial student preference of traditional teaching methods, exposure to inquiry-based physics could rejuvenate interest in the physics program at Westminster.

The two physics courses that were used in this research project were the general physics course, which was available to students in grades 10-12, and the Advanced Placement algebra-based physics course (AP Physics 1), which was available to students in grades 11-12. Both courses met four times per week, for 55-minute periods. The general physics course used an inquiry-based learning environment with conceptual backfilling and the Advanced Placement (AP) Physics 1 course used a partially flipped classroom model. With each unit, conceptual proficiency was measured before and after instruction to measure student growth. Additionally, student attitudes and beliefs were measured at the conclusion of each semester.

Focus Question

My focus question was, What are the effects of inquiry-based learning in high school physics courses?

CHAPTER TWO

CONCEPTUAL FRAMEWORK

Balancing Prior Knowledge Levels

When it comes to learning the concepts of physics, how the content is delivered is fundamental in the lasting impression that the content has with the student. There are a multitude of ways in which physics is taught in the high school classroom. Most physics courses involve the traditional teacher-lecturer format, with assignments from the end-of-chapter content taken from textbooks. However, even though most courses are taught this way, one must question if it is the most effective way to educate the students. On average, students receiving traditional instruction master less than thirty percent of concepts that they did not already know before the course (Wieman & Perkins, 2005). Some educators use a flipped classroom model, believing that it may be more effective than the traditional model. A flipped classroom is one where students will complete some learning online prior to instruction in the classroom and prior to learning activities with their peers (Reidsema et al., 2017). Unfortunately, even under highly optimized conditions, the ability for students to learn and retain information from the flipped classroom format was not improved. Therefore, there has been a recent push for more inquiry-based learning in the science classroom since one of the primary goals in science education is for students to be more scientifically and technically literate to make informed decisions on those types of issues, which can be better achieved through inquiry-based learning (Wieman & Perkins, 2005). While there are many different technical definitions of what inquiry-based learning looks like, the working definition used for this research project is the nature of attempting to understand while you are exploring a question about the world (Wang et al., 2009). The questioning is initiated by the teacher as they allow students to observe a phenomenon, or thought-provoking event, related to unit. This is fundamental to the inquiry-based learning process because it sparks student interest and it leads to scientific investigations that are focused on the search for explanations regarding the phenomena that were observed (Moeed & Anderson, 2018).

When it comes to ensuring that certain content and concepts are addressed in an inquiry-based environment, there are essentially two possible times for this material to be delivered, which are prior to the inquiry investigation and after the investigation. If concepts are taught and applied prior to inquiry, students enter with what is referred to as prior knowledge. What effect does prior-knowledge play in the inquiry process? Students are usually unable to uncover currently accepted theories and therefore will practically be required to create their own theoretical entities (Wecker, 2013). Therefore, presenting ideas prior to inquiry activities provides students with the possibility of deriving predictions from theoretical ideas themselves, testing those predictions and because of that process, gaining a deeper understanding. In addition to these important learning processes, students are also able to structure their inquiries around theory-based experimentation and are therefore more likely to develop the exact relationships and concepts. Not only are students more likely to discover accurate relationships but they are also able to evaluate their conceptual understanding of the content as well as construct arguments through the process of self-reflection. This prior knowledge leading into inquiry investigations can greatly impact student learning (Yang et al., 2015).

Students with higher prior knowledge tend to possess more refined schema than those with lower prior knowledge and therefore, can devote more of their mental resources to higher-order thinking. Not only are these students with higher prior knowledge able to analyze higher order thinking, but also demonstrate the ability to integrate and correlate data presented in different formats (Ho et al., 2013). This is vital to student success because students must be able to analyze different types of data and make the connection to the underlying concepts in physics. In measuring overall performance, while students with low prior-knowledge may make the most gains academically, students who have more prior-knowledge will overall perform better in conceptual understanding (Wang et al., 2009). Expanding beyond the conceptual understanding, is the student's ability to participate in scientific argumentation. Students that possess more prior knowledge are more effective and successful when participating in this process (Yang et al., 2015). However, front-end loading of content is not always the best plan for student learning, as it can lead students to an almost unachievable standard in classroom laboratory experiments.

Addressing Theory-Practice Gap

If students enter an inquiry experience without prior-knowledge or learned concepts, they accumulate experiences to apply to learned concepts later (Wecker et al., 2013). When it comes to scientific inquiry, prior knowledge is not a barrier to growth or performance (Yang et al., 2015). Affirming this notion of having little prior knowledge entering an inquiry scenario, a study revealed an advantage for the presentation of concepts after an experimentation, rather than prior (Wecker et al., 2013). Perhaps one of the biggest problems with prior knowledge entering an inquiry experience is that students have learned something and expect to have that learning mirrored in a laboratory experiment. In the classroom setting, the results in the laboratory rarely end up mirroring the theoretical concepts. Therefore, by providing prior knowledge, one has created a theory-practice gap (Allen, 2010). By sustaining this theory-practice gap, the achievement of knowledge gains, engagement and retention of concepts can be inhibited (Mehalik et al., 2008). Finally, when this gap exists, students fail to see value in theoretical learning unless they were able to experience it for themselves (Allen, 2010).

Inquiry and Attitude of Learning

Optimizing the effectiveness of introducing physics concepts to students, while keeping the content relevant at the same time is not an easy task if it is in the traditional teacher-lecturer style. Unfortunately, simply switching to an inquiry-based environment is not an automatic fix. Even if students are embedded in an inquiry-based learning classroom, it does not matter how and when the concepts are introduced if the students are lacking a sense of satisfaction in the course (Wieman & Perkins, 2005). When students relate course topics to their daily experiences, a deeper connection is made, causing not only greater enjoyment in the material, but in retention as well (Bezen & Bayrak, 2020). Although it is proven that students can learn the content well in an inquiry-based physics course, if they have not been exposed to that type of learning environment, there can be extreme reactions in students’ attitudes toward learning. When this happens, there can be a large disconnect between learning and attitude, thus altering the amount of conceptual learning that can take place (Sadaghiani, 2008).

CHAPTER THREE

METHODOLOGY

Treatment

This research project sought to determine the effects of using inquiry-based instruction in the physics classroom. The research population was comprised of ten students at Westminster Christian Academy who were in two different physics courses. In the general physics course, which was the treatment group, the classifications of students were four seniors, one junior and one sophomore. Two of the six students were female, four were male and none of the students had any individual education plans. In the Advanced Placement Physics 1 course, the non-treatment group, the classifications of the students were two seniors and two juniors. One of the four students was female and there were three male students, also with no individual education plans present. Both groups covered the following units during this project: forces, energy, and momentum.

The treatment group was exposed to phenomena, which led to inquiry-based labs relating to the unit. After the students completed their inquiry labs and presented their results to the class, students were prompted with another experiment that targeted any concepts that were not addressed by the conclusions from first set of experiments. Following the completion and presentation of the second inquiry lab, clarifications were provided regarding any misconceptions, or any concepts not addressed in the labs. Upon completion of this conceptual backfilling, students were given written problems to work on as teams and then tasked with problem designs, in which students wrote their own physics problems regarding the content that was covered. At the conclusion of the unit, students were asked to come up with at least two different real-world scenarios in which this unit was applicable.

The non-treatment group was assigned conceptual videos to watch prior to class relating to the specific content that was going to be covered. An understanding check was conducted at random to encourage completion of the videos prior to the students' arrival at class. Students were additionally encouraged to ask any questions about content they did not fully understand from the videos leading up to class. When all questions were addressed, students applied the content through various means during the class periods. Students completed multiple choice questions, free response-problems both individually and as a group, as well as conducted lab experiments. Upon completion of these tasks, students completed problem designs, which were identical to the treatment group. Additionally, students were tasked with writing a laboratory design, in which they wrote an experimental procedure to complete a specific content-related task. Finally, like the treatment group, students were asked to come up with at least two different real-world scenarios in which the content from the unit was applicable. Due to the high stakes testing at the conclusion of the AP Physics 1 course, the potential gain from reversing the roles of treatment and non-treatment groups for this study failed to outweigh the potential risk of negatively impacting student ability to achieve college credit on the exam. The abrupt change in teaching method would increase the risk of students being inadequately prepared for the exam due to the time constraints on the course and the extended time required for learning through inquiry.

The research methodology for this project received an exemption by Montana State University's Institutional Review Board and compliance for working with human subjects was maintained (Appendix A).

Data Collection Instruments

Prior to the beginning of these units, students were given the Montana State University Formal Reasoning Test to establish a baseline of their scientific reasoning skills (Appendix B). On this standardized assessment, students were given twenty minutes to complete twenty multiple choice questions that focused on testing hypotheses, analyzing correlations, probability control of variables and scientific reasoning. The results of the Montana State University Formal Reasoning Test were not released to the students, as upon completion of the units covered for this research project, it was given a second time to analyze student growth in their ability to reason scientifically. The data collected was analyzed to determine normalized gains for both groups. These normalized gains are divided into low, medium, and high categories. Normalized gains that were less than 0.3 percent were considered low, 0.3 to 0.7 were recorded as medium and any gains greater than 0.7 were recorded as high (Hake, 1998).

As students in both the treatment and non-treatment groups began their study of forces, the Force and Motion Conceptual Evaluation was given as a pre/post conceptual understanding check (Appendix C). On this standardized assessment, students were given thirty-five minutes to complete forty-seven multiple choice questions that focused on forces, motion, and graphing. The results of both the pre and post unit evaluations were not released to the students. The data was collected and analyzed to determine normalized gains for both groups (Hake, 1998).

Following the completion of the post-unit Force and Motion Conceptual Evaluation, students began their study of energy and momentum. Students were given the Energy and Momentum Conceptual Survey as a pre/post conceptual understanding check (Appendix D). On this standardized assessment, students were given fifty minutes to complete twenty-five multiple choice questions that focused on energy and momentum. The results of both the pre and post unit evaluation were not released to the students. The data was collected and analyzed to determine normalized gains for both groups (Hake, 1998). These processes of quantitative data collection for both treatment and non-treatment groups resulted in two distinct flow paths for learning (Figure 1).

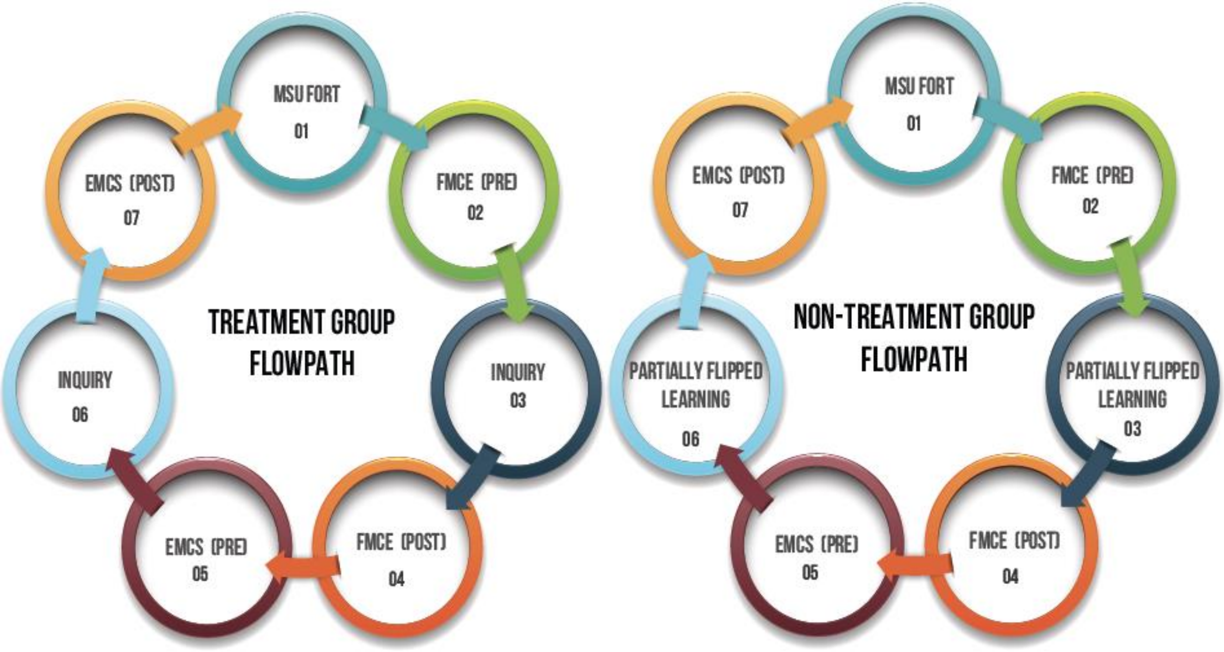

Figure 1. Learning flow paths for treatment and non-treatment groups.

Upon completion of the units, students in both the treatment and non-treatment groups were given the Student Attitude Survey (Appendix E). Using Google Forms to ensure anonymity, students were asked to answer nineteen questions regarding their beliefs and attitudes towards physics on a Likert-type scale with Strongly Agree (1), Agree (2), Disagree (3), and Strongly Disagree (4). This data was analyzed quantitatively in three categories: Attitudes, Relevance and Pedagogy. The data was collected and analyzed for means to determine overall student attitudes, perceptions, and beliefs in each of the three categories.

To conclude the research for the students in the treatment group, they were given the Inquiry Classroom Interview (Appendix F). This open-ended Google Form was given to students which addressed their beliefs about physics and the inquiry-based instructional method that was used in the course. Student responses were analyzed for emergent themes and were used to support other findings from this research project.

Alternatively, to conclude the research for the students in the non-treatment group, they were given the Partially Flipped Classroom Interview (Appendix G). This open-ended Google Form was used to address student beliefs about physics and the partially flipped instructional model that was used. Student responses were analyzed for emergent themes and were used to support other findings from this research project. A variety of data collection methods were enacted during this research process to help answer the question of how the inquiry-based learning environment impacts learning in high school physics courses (Table 1).

Table 1. Data Triangulation Matrix

Focus Question	Data Source		
What are the effects of inquiry-based learning in high school physics courses?	Montana State University Formal Reasoning Test Force and Motion Conceptual Evaluation Energy and Momentum Conceptual Survey	Student Attitude Survey Inquiry Classroom Interview Partially Flipped Classroom Interview	Problem Design Real-World Applications

CHAPTER FOUR

DATA ANALYSIS

Results

The results of the Force and Motion Conceptual Evaluation (FMCE) showed that the treatment group achieved a medium normalized gain of 0.35, and the non-treatment group also achieved a higher, but still considered a medium normalized gain of 0.66 (Hake, 1998). One of the students in the treatment group stated that, “forces were more difficult than motion because the video analysis software was impossible to get precise data, so we had to just pick a point and hope for the best.” One of the students in the non-treatment grouped stated that, “watching the videos ahead of time helped because we could focus on applying the content in class, rather than learning it in class and trying to apply it for homework.”

With the Energy and Momentum Conceptual Survey (EMCS), the treatment group achieved a low normalized gain of 0.21, whereas the non-treatment group achieved a medium normalized gain of 0.43 (Hake, 1998). One student in the treatment group stated that, “energy and momentum were easier than forces because the numbers from our data worked out a lot better and the percent error was a lot less, which was nice.”

In both units, the non-treatment group made higher normalized gains than the treatment group. However, when looking beyond concept mastery and focusing on the ability to reason scientifically through the analysis of the Montana State University Formal Reasoning Test (FORT), the treatment group was able to achieve a medium normalized gain of 0.34, whereas the non-treatment group was able to achieve a low normalized gain of 0.17 (Hake, 1998). One student from the treatment group stated that, “inquiry forced me think about what I wanted to accomplish, rather than just following the steps.” Additionally, one student from the non-treatment group stated that, “I wished we could have spent more time doing experiments where we could really apply the theoretical stuff we did in class” (Figure 2).

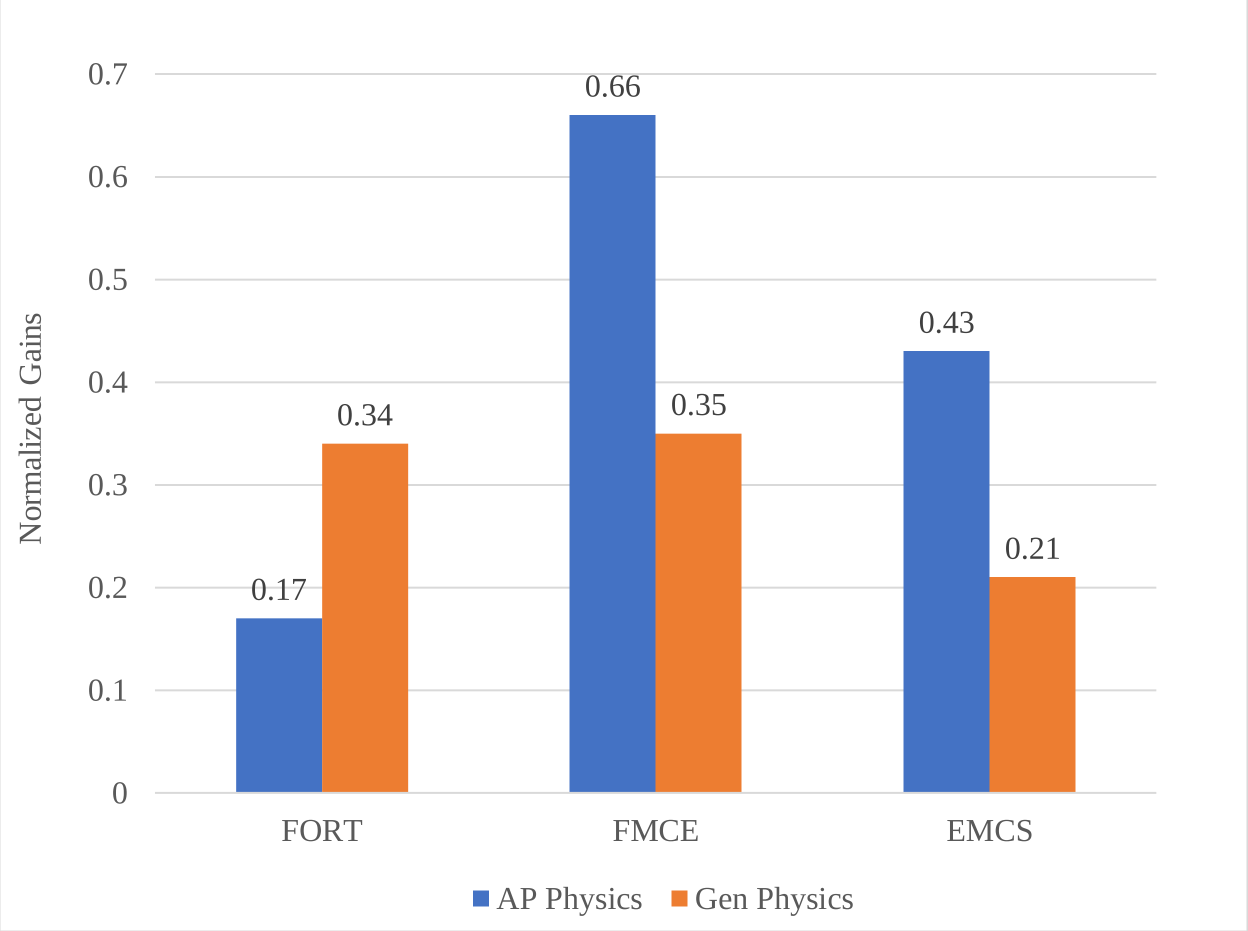

Figure 2. Normalized gains for concept mastery and scientific reasoning, (*N*=10). *Note.* FORT: Montana State University formal reasoning test. FMCE: Force and motion conceptual evaluation. EMCS: Energy and momentum conceptual survey.

In addition to pre and post-test data collected to measure normalized gains in conceptual understanding and scientific reasoning, student attitudes and beliefs were also analyzed. Prior to and after completing the units, students were asked to complete the Student Attitude Survey and the corresponding interview for their learning model. Some of the questions were not applicable to the pre-unit survey but were still included in the survey. While this survey included twenty-one questions, there are really four questions that best encapsulate the aim of this research, which is analyzing the impact of inquiry-based learning in the classroom. These questions focus on student's attitudes toward the class itself, the course content, and the perceived applicableness of the content beyond the walls of the classroom. While students had the option of selecting strongly disagree, slightly disagree, slightly agree, or strongly agree, with such a small sample size, the results were organized into either category of agreement or disagreement. Within the treatment group there were large advances made in student attitudes and beliefs with respect to physics during the inquiry-based process. Prior to treatment, two of the six students in the treatment group believed that physics helped them understand the world around them. After treatment, all the students in the treatment group believed that physics helped them understand the world around them. When asked if physics was an important class, two of the six students in the treatment group agreed prior to treatment, and five of the six students agreed following treatment. When asked if physics was interesting to them, three of the students in the treatment group agreed prior to treatment, and following treatment, five of the students from the treatment group agreed. Finally, when asked if they look forward to physics class, three of the students in the treatment group agreed prior to treatment and all students agreed following treatment. One student in the treatment group stated that, “I really enjoyed learning through all of the labs that we did and when he assigned the real-life application problems because it made me think about how everything fits in the real world” (Figure 3).

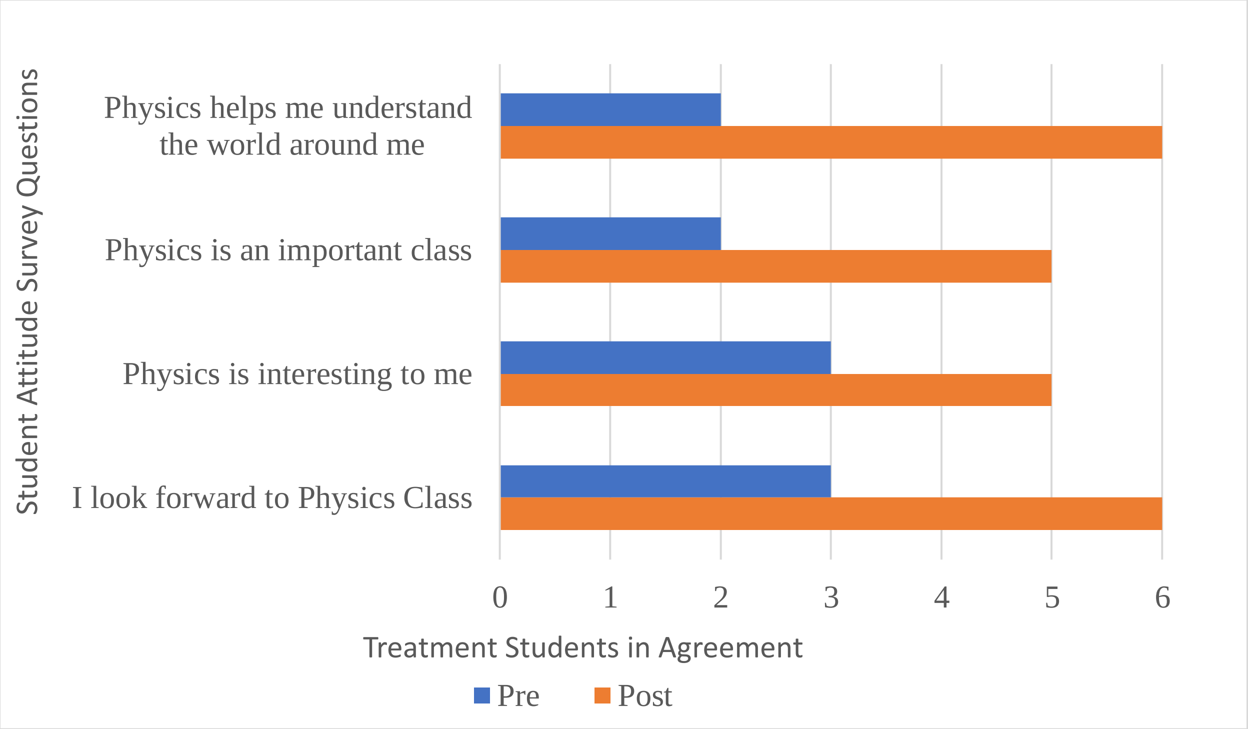

Figure 3. Treatment student-held attitudes and beliefs, (*n*=6).

Like the treatment group, gains were achieved in all four main target questions within the survey. Prior to this research, two of the four students in the non-treatment group agreed that physics helped them understand the world around them. After these units of study, three of students agreed. When asked if physics is an important class, the exact same results were achieved. When asked if physics was interesting to them, three of the four students agree prior to the units of study and afterward, all the students agreed. Finally, when asked if they look forward to physics class, three of the four students agreed prior to the units of study and afterward, all the students agreed. One student in the non-treatment group stated that, “he made the content a lot of fun and I enjoyed watching the videos prior to class because it made everything more efficient, and it was easy to do for homework” (Figure 4).

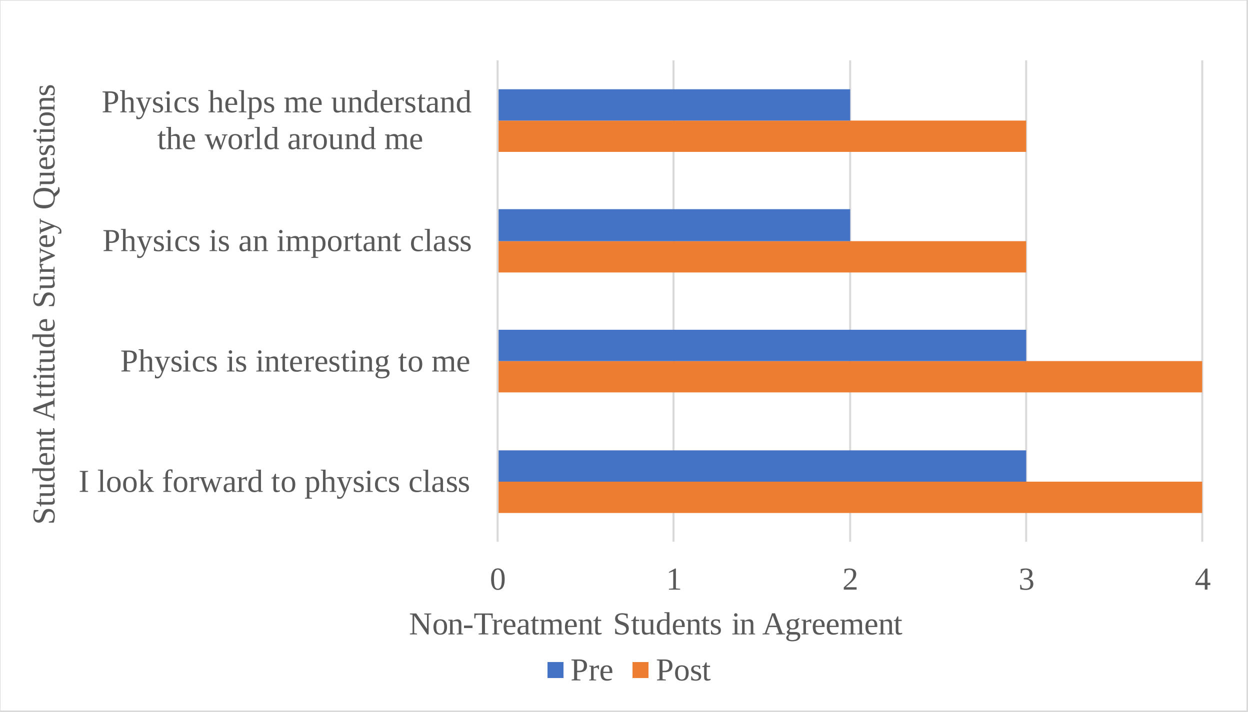

Figure 4. Non-treatment student-held attitudes and beliefs, (*n*=4).

CHAPTER FIVE

CLAIM, EVIDENCE, AND REASONING

Claims From the Study

The goal of this action research was to determine the effects of inquiry-based learning in the high school physics classroom. This research was conducted over the units of study of motion, forces, energy, and momentum and compared conceptual front-loading in a partially flipped classroom approach to that of inquiry-based learning with conceptual backfilling. The data that was collected from the pre- and post-assessments, surveys and interviews combine to showcase three distinct claims from this action research project:

1. Inquiry-based learning challenges students' scientific reasoning.
2. Inquiry-based learning allows students to connect content with real-world scenarios
3. Inquiry-based learning requires careful execution to minimize development of theory-practice gaps.

The first claim from this research was that although the inquiry-based learning approach was less effective at concept mastery than the partially flipped classroom approach, it was very effective with challenging the students' ability to reason scientifically. The medium normalized gains on the Montana State University Formal Reasoning Test for the treatment group (0.34) compared to the low normalized gains for the non-treatment group (0.17) speak to the critical thinking skills that are nurtured during inquiry-based learning. Too often science classes can become lecture-based, and it is a detriment to the students' ability to think critically and reason scientifically. At first, students were hesitant about inquiry-based learning as one student stated that, “we had never done inquiry-based learning before and at first I did not like it, but it really challenged me to think.” Another student stated that they “wished they would have had it before they had taken the ACT because that is what the ACT Science section covered.”

A second claim from this research was that the inquiry-based learning approach allowed students to see connections with real-life scenarios. This was evident through the student’s reflections in the survey, with 100% of students in the treatment group replying that it helped them understand the world around them, whereas only 75% of the students in the non-treatment group replied similarly. The interview responses also solidified this, as one student from the treatment group stated that they “enjoyed doing the labs first and then going back and either watching videos or working problems in class because it tied everything together and made sense.” Another student specifically commented on the application cards and how they thought “they were cool because in a lot of classes, they don’t ask you to do that as an assignment.” As if this was not compelling enough evidence on its own, a student from the non-treatment group responded that they “wished there were more labs because I feel like it helps us solidify what we are learning.”

The third and final claim from this research was that the theory-practice gap is unfortunately a very real inhibitor when it comes to learning physics through inquiry. The results of the normalized gains in the pre- and post-tests revealed that the non-treatment group achieved higher normalized gains in conceptual understanding in all units of study. This was initially surprising to me, but part of this was clarified by the students in the interview process. One student stated that they enjoyed the digital labs because there was not the error present in the physical labs. They went on to state that the “discrepancies in the data caused me to doubt myself and if I was doing what I was supposed to. I remembered some physics from physical science, and I knew things were not matching up.” Another student stated that it was “easier to work problems because we did not have to worry about error.” However, it was not all negative when it came to inquiry-based learning and discrepancies, as one student stated that it “was frustrating at times but made me more engaged, and I think I might have a better understanding of the concepts than I would without inquiry.”

Value of the Study and Consideration for Future Research

This action research project that revolved around the effects of inquiry-based learning in physics was enlightening for me as an educator and carries great value moving forward. If science educators can transition away from the traditional lecture-based format to a format that requires active critical thinking, collaboration, and connection with the content, student attitudes and beliefs revolving around that content are sure to improve. The results of the action research project validated the following inquiry-based process with an emphasis on real-world application that was utilized, and can therefore be used in future classes (Figure 5).

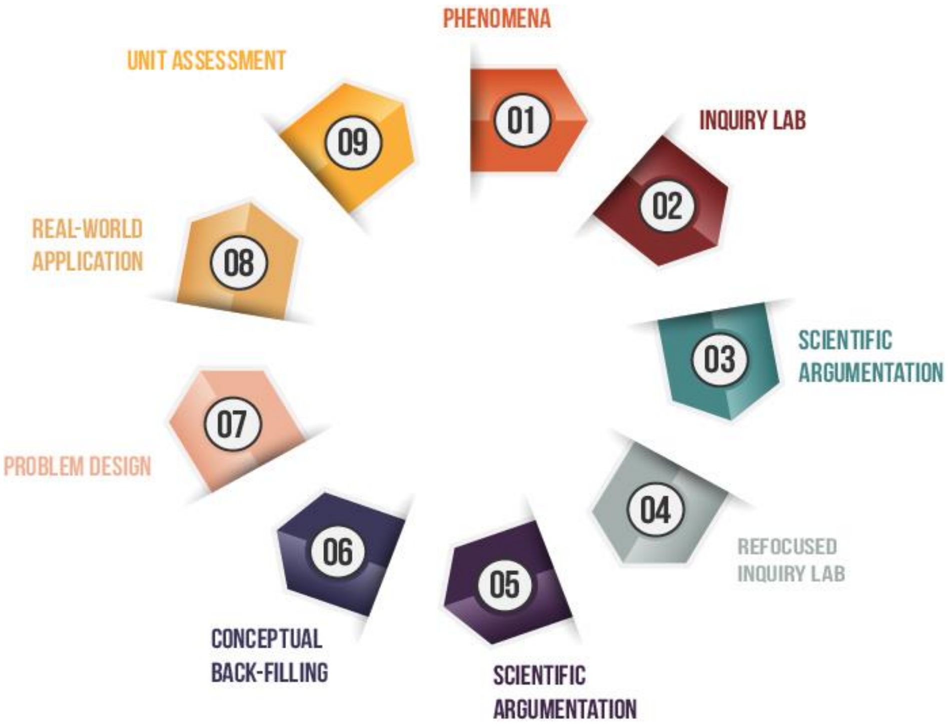

Figure 5. Inquiry-based learning flow path for real world application.

While the results were quite promising in some respects, there are others that need to be researched in more detail. With this being my first year at Westminster Christian Academy and attempting to breathe new life into the physics program, enrollment numbers were quite low. However, next year's enrollment numbers are double what they were this year. With a larger sample size, there is an opportunity to gather more data and eliminate some potential outliers that can skew the data in one direction.

Another aspect of this research that deems further consideration are the pre- and post-unit assessments. These assessments were first-year college course equivalent conceptual questions, sometimes combining multiple concepts, which the non-treatment course is specifically targeted at, as it is the College Board Advanced Placement Physics 1 Course. In addition, some of the language used in some of the questions was confusing to students. If the questions were reworded in a way that was less confusing and the concepts isolated from others, there could potentially be different outcomes.

The final aspect that demands further research is with respect to the available lab equipment. Currently, the lab equipment is very limited and because of that, the theory-practice gap was enhanced in the inquiry-based approach due to the inability to secure precise data. As more precision-focused equipment can be purchased, it will be interesting to see if the theory-practice gap can be bridged and the conceptual understandings increase at a higher rate in the inquiry-based classroom.

Impact of Action Research on the Author

This research project breathed new life into me as an educator. The administration at Westminster Christian Academy was incredibly supportive of me in my pursuit to better reach my students and to improve their classroom experience. Teaching physics through inquiry was intimidating initially, especially when this was the first time that the students had ever been in an inquiry-based classroom environment. However, after seeing the results of assessments, surveys, and interviews, it has been an incredibly rewarding experience. While there are topics in physics that are unable to be addressed in a high school physics laboratory setting with a limited budget, there are many that can. Moving forward, inquiry-based learning is going to be an integral part of the high school physics classroom experience at Westminster Christian Academy. Encouraging students to take charge of their own learning and helping them foster an authentic passion for the content that they are learning and how it applies to real-life scenarios is my goal as an educator. After completing this action research project, I now feel better equipped to accomplish that goal.

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APPENDICES

APPENDIX A

MONTANA STATE UNIVERSITY INSTITUTIONAL REVIEW BOARD EXEMPTION

Hello Feldbruegge, Adam,

Your protocol was reviewed by the IRB and has been approved.

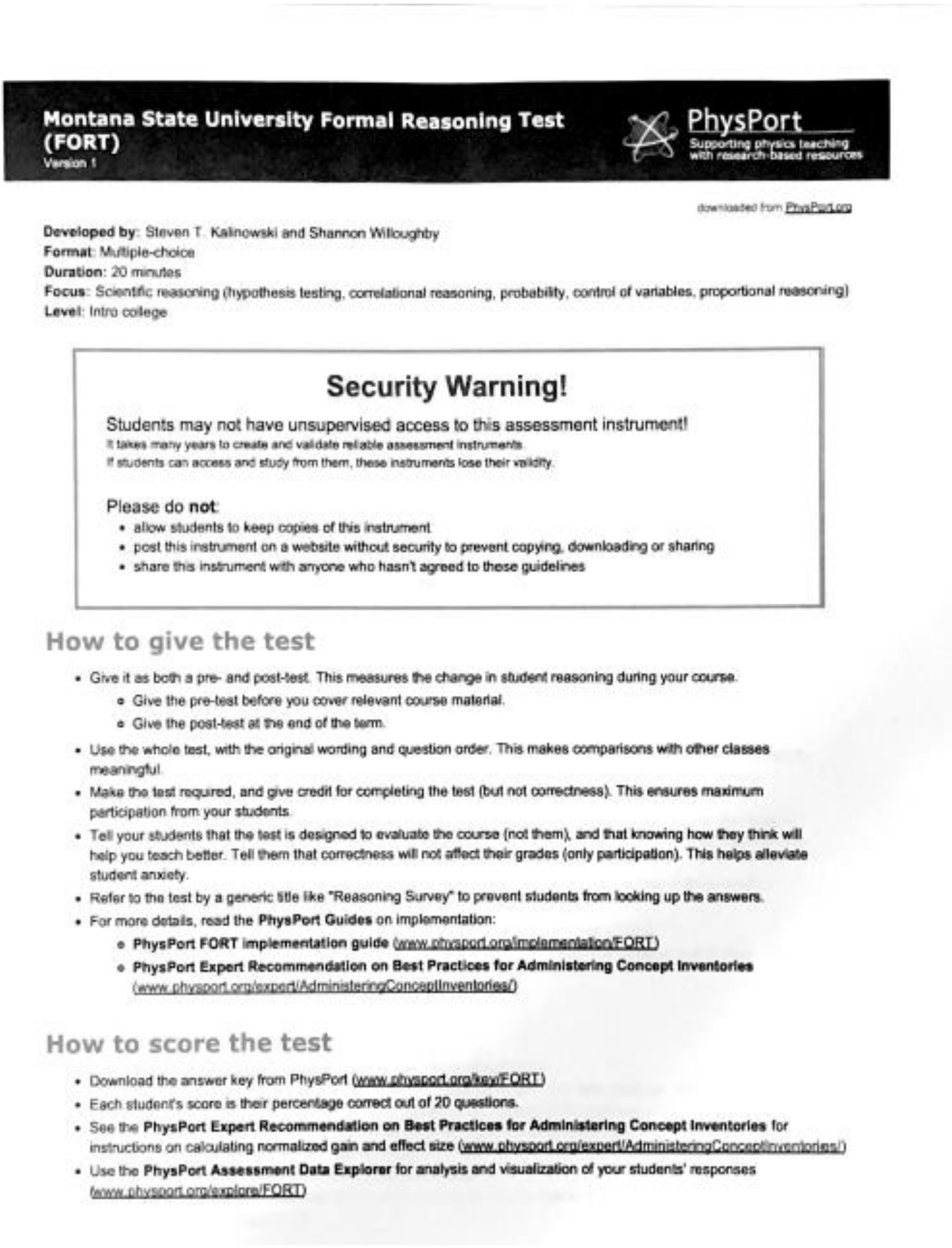
PI: Feldbruegge, Adam
Approval Date: 11/22/2022
Title: The Effect of Inquiry-Based Learning in High School Physics

Protocol #: 2022-441-EXEMPT
Review Type: Exempt Review
Expiration Date: 11/22/2027

Work described under this protocol may now commence. The PI is responsible for ensuring that the protocol accurately describes research practices being conducted.

APPENDIX B

MONTANA STATE UNIVERSITY FORMAL REASONING TEST



Montana State University Formal Reasoning Test (FORT)

Version 1

PhysPort
Supporting physics teaching with research-based resources

Developed by: Steven T. Kalinowski and Shannon Willoughby
Format: Multiple-choice
Duration: 20 minutes
Focus: Scientific reasoning (hypothesis testing, correlational reasoning, probability, control of variables, proportional reasoning)
Level: Intro college

Security Warning!

Students may not have unsupervised access to this assessment instrument!
It takes many years to create and validate reliable assessment instruments.
If students can access and study from them, these instruments lose their validity.

Please do **not**:

- allow students to keep copies of this instrument
- post this instrument on a website without security to prevent copying, downloading or sharing
- share this instrument with anyone who hasn't agreed to these guidelines

How to give the test

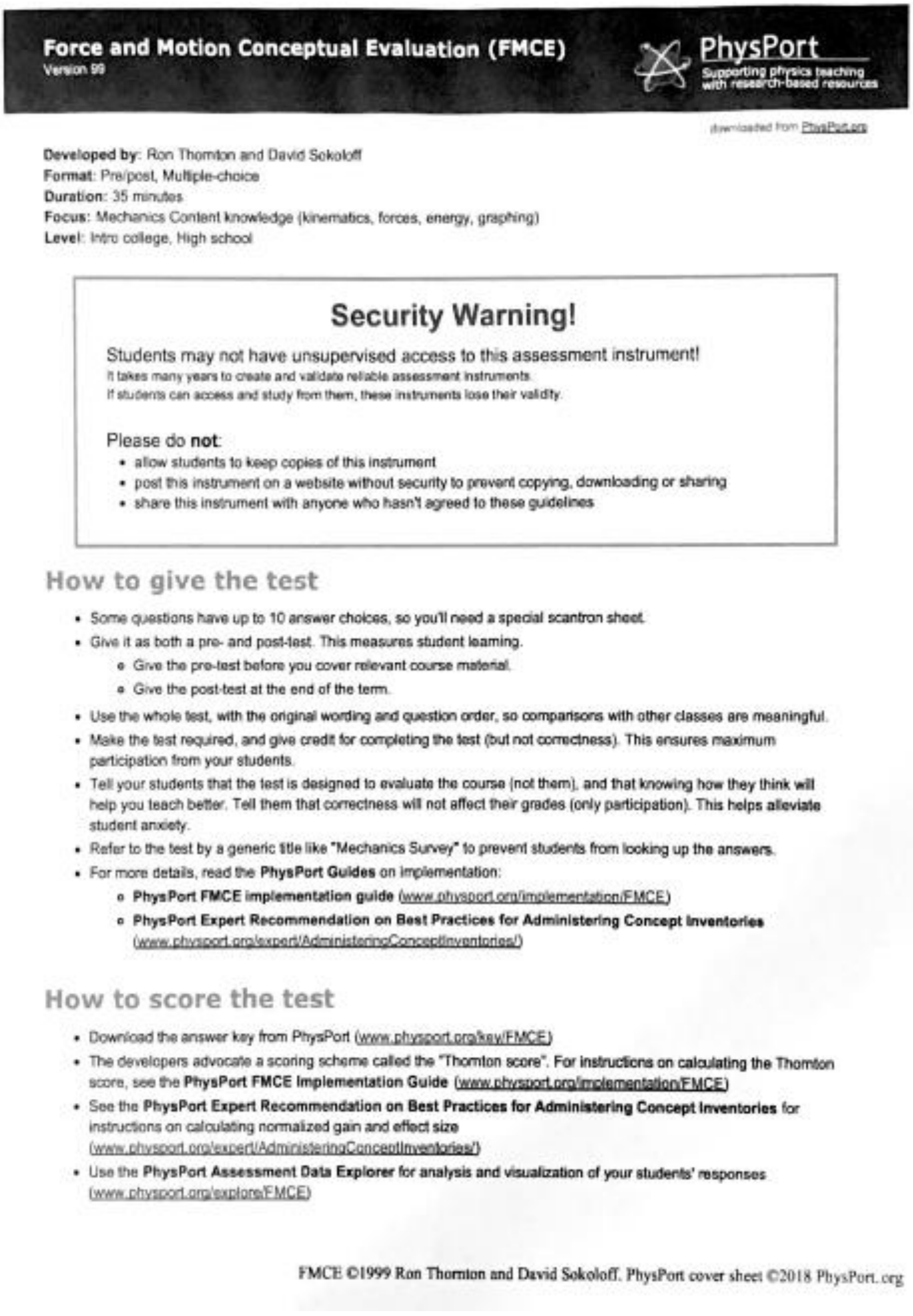
- Give it as both a pre- and post-test. This measures the change in student reasoning during your course.
  - Give the pre-test before you cover relevant course material.
  - Give the post-test at the end of the term.
- Use the whole test, with the original wording and question order. This makes comparisons with other classes meaningful.
- Make the test required, and give credit for completing the test (but not correctness). This ensures maximum participation from your students.
- Tell your students that the test is designed to evaluate the course (not them), and that knowing how they think will help you teach better. Tell them that correctness will not affect their grades (only participation). This helps alleviate student anxiety.
- Refer to the test by a generic title like "Reasoning Survey" to prevent students from looking up the answers.
- For more details, read the **PhysPort Guides** on implementation:
  - **PhysPort FORT implementation guide** (www.physport.org/implementation/FORT)
  - **PhysPort Expert Recommendation on Best Practices for Administering Concept Inventories** (www.physport.org/expert/AdministeringConceptInventories/)

How to score the test

- Download the answer key from PhysPort (www.physport.org/key/FORT)
- Each student's score is their percentage correct out of 20 questions.
- See the **PhysPort Expert Recommendation on Best Practices for Administering Concept Inventories** for instructions on calculating normalized gain and effect size (www.physport.org/expert/AdministeringConceptInventories/)
- Use the **PhysPort Assessment Data Explorer** for analysis and visualization of your students' responses (www.physport.org/explore/FORT)

APPENDIX C

FORCE AND MOTION CONCEPTUAL EVALUATION



Force and Motion Conceptual Evaluation (FMCE)

Version 99

PhysPort
Supporting physics teaching with research-based resources

Developed by: Ron Thornton and David Sokoloff
Format: Pre/post, Multiple-choice
Duration: 35 minutes
Focus: Mechanics Content knowledge (kinematics, forces, energy, graphing)
Level: Intro college, High school

Security Warning!

Students may not have unsupervised access to this assessment instrument!
It takes many years to create and validate reliable assessment instruments.
If students can access and study from them, these instruments lose their validity.

Please do **not**:

- allow students to keep copies of this instrument
- post this instrument on a website without security to prevent copying, downloading or sharing
- share this instrument with anyone who hasn't agreed to these guidelines

How to give the test

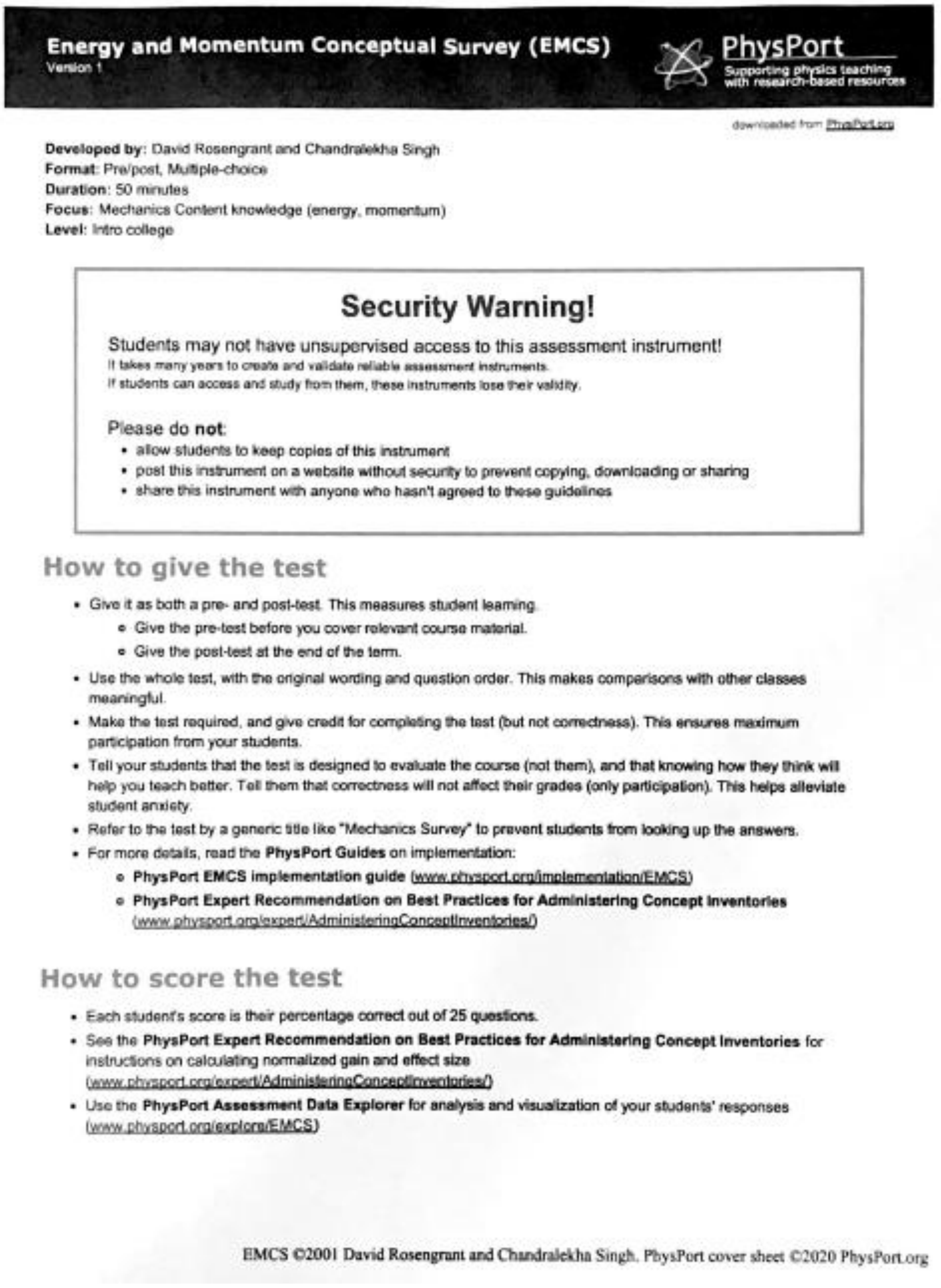
- Some questions have up to 10 answer choices, so you'll need a special scantron sheet.
- Give it as both a pre- and post-test. This measures student learning.
    - Give the pre-test before you cover relevant course material.
    - Give the post-test at the end of the term.
- Use the whole test, with the original wording and question order, so comparisons with other classes are meaningful.
- Make the test required, and give credit for completing the test (but not correctness). This ensures maximum participation from your students.
- Tell your students that the test is designed to evaluate the course (not them), and that knowing how they think will help you teach better. Tell them that correctness will not affect their grades (only participation). This helps alleviate student anxiety.
- Refer to the test by a generic title like "Mechanics Survey" to prevent students from looking up the answers.
- For more details, read the **PhysPort Guides** on implementation:
    - **PhysPort FMCE implementation guide** (www.physport.org/implementation/FMCE)
    - **PhysPort Expert Recommendation on Best Practices for Administering Concept Inventories** (www.physport.org/expert/AdministeringConceptInventories/)

How to score the test

- Download the answer key from PhysPort (www.physport.org/key/FMCE)
- The developers advocate a scoring scheme called the "Thornton score". For instructions on calculating the Thornton score, see the **PhysPort FMCE Implementation Guide** (www.physport.org/implementation/FMCE)
- See the **PhysPort Expert Recommendation on Best Practices for Administering Concept Inventories** for instructions on calculating normalized gain and effect size (www.physport.org/expert/AdministeringConceptInventories/)
- Use the **PhysPort Assessment Data Explorer** for analysis and visualization of your students' responses (www.physport.org/explore/FMCE)

APPENDIX D

ENERGY AND MOMENTUM CONCEPTUAL SURVEY



Energy and Momentum Conceptual Survey (EMCS)

Version 1

PhysPort
Supporting physics teaching with research-based resources

Developed by: David Rosengrant and Chandralekha Singh
Format: Pre/post, Multiple-choice
Duration: 50 minutes
Focus: Mechanics Content knowledge (energy, momentum)
Level: Intro college

Security Warning!

Students may not have unsupervised access to this assessment instrument!
It takes many years to create and validate reliable assessment instruments.
If students can access and study from them, these instruments lose their validity.

Please do **not**:

- allow students to keep copies of this instrument
- post this instrument on a website without security to prevent copying, downloading or sharing
- share this instrument with anyone who hasn't agreed to these guidelines

How to give the test

- Give it as both a pre- and post-test. This measures student learning.
  - Give the pre-test before you cover relevant course material.
  - Give the post-test at the end of the term.
- Use the whole test, with the original wording and question order. This makes comparisons with other classes meaningful.
- Make the test required, and give credit for completing the test (but not correctness). This ensures maximum participation from your students.
- Tell your students that the test is designed to evaluate the course (not them), and that knowing how they think will help you teach better. Tell them that correctness will not affect their grades (only participation). This helps alleviate student anxiety.
- Refer to the test by a generic title like "Mechanics Survey" to prevent students from looking up the answers.
- For more details, read the **PhysPort Guides** on implementation:
  - **PhysPort EMCS implementation guide** (www.physport.org/implementation/EMCS)
  - **PhysPort Expert Recommendation on Best Practices for Administering Concept Inventories** (www.physport.org/expert/AdministeringConceptInventories/)

How to score the test

- Each student's score is their percentage correct out of 25 questions.
- See the **PhysPort Expert Recommendation on Best Practices for Administering Concept Inventories** for instructions on calculating normalized gain and effect size (www.physport.org/expert/AdministeringConceptInventories/)
- Use the **PhysPort Assessment Data Explorer** for analysis and visualization of your students' responses (www.physport.org/explore/EMCS)

APPENDIX E

STUDENT ATTITUDE SURVEY

Student Attitude Survey

My name is Adam Feldbruegge, an educator at Westminster Christian Academy in Huntsville, Alabama. I am the lead primary investigator for research being conducted on behalf of Montana State University. If you have any questions about this process, please feel free to contact me at the following email address: adam.feldbruegge@wca-hsv.org. For any questions directed to the Montana State University Institutional Review Board, please feel free to contact them at the following email address: irb@montana.edu. Survey and questionnaires will be completed electronically with Google Forms to ensure anonymity and data collected from in-person formative assessments will not require participants names to be submitted.

Participation in this research is voluntary and you can choose to not answer any questions you do not want to answer and/or you can stop at any time. Participation or non-participation will not affect a student's grades or class standing in any way. Proceeding with the survey/interview/questionnaire indicates your consent to participate in this research.

1. Which grade are you in?
   Mark only one oval.
   10th
   11th
   12th

2. Which physics course are you taking?
   Mark only one oval.
   General Physics
   Advanced Placement Physics 1

3. I look forward to physics class
   Mark only one oval.
   Strongly Agree
   Slightly Agree
   Slightly Disagree
   Strongly Disagree

4. Physics class is exciting
   Mark only one oval.
   Strongly Agree
   Slightly Agree
   Slightly Disagree
   Strongly Disagree

5. Physics class is difficult
   Mark only one oval.
   Strongly Agree
   Slightly Agree
   Slightly Disagree
   Strongly Disagree

6. I understand what is discussed in class
   Mark only one oval.
   Strongly Agree
   Slightly Agree
   Slightly Disagree
   Strongly Disagree

7. I would like to have more experiments in class
   Mark only one oval.
   Strongly Agree
   Slightly Agree
   Slightly Disagree
   Strongly Disagree

8. I learn physics better when doing experiments
   Mark only one oval.
   Strongly Agree
   Slightly Agree
   Slightly Disagree
   Strongly Disagree

9. Physics is interesting to me
   Mark only one oval.
   Strongly Agree
   Slightly Agree
   Slightly Disagree
   Strongly Disagree

10. What I learn in class excites me
    Mark only one oval.
    Strongly Agree
    Slightly Agree
    Slightly Disagree
    Strongly Disagree

11. I am bored in class
    Mark only one oval.
    Strongly Agree
    Slightly Agree
    Slightly Disagree
    Strongly Disagree

12. I believe that physics is an important class to have
    Mark only one oval.
    Strongly Agree
    Slightly Agree
    Slightly Disagree
    Strongly Disagree

13. I believe that physics helps me understand the world around me.
    Mark only one oval.
    Strongly Agree
    Slightly Agree
    Slightly Disagree
    Strongly Disagree

14. I do not believe this class will be useful after I graduate high school.
    Mark only one oval.
    Strongly Agree
    Slightly Agree
    Slightly Disagree
    Strongly Disagree

15. I learn physics better if the teacher does not tell me everything.
    Mark only one oval.
    Strongly Agree
    Slightly Agree
    Slightly Disagree
    Strongly Disagree

16. If I get stuck on a physics problem, I try to think about it in a different way
    Mark only one oval.
    Strongly Agree
    Slightly Agree
    Slightly Disagree
    Strongly Disagree

17. Everyone is capable of understanding physics if they try.
    Mark only one oval.
    Strongly Agree
    Slightly Agree
    Slightly Disagree
    Strongly Disagree

18. There is more than one way to solve a problem correctly.
    Mark only one oval.
    Strongly Agree
    Slightly Agree
    Slightly Disagree
    Strongly Disagree

19. This class has changed how I thought about physics.
    Mark only one oval.
    Strongly Agree
    Slightly Agree
    Slightly Disagree
    Strongly Disagree

20. I enjoy physics more than I thought that I would.
Mark only one oval.
Strongly Agree
Slightly Agree
Slightly Disagree
Strongly Disagree

21. It is useful to do a lot of problems when learning physics.
Mark only one oval.
Strongly Agree
Slightly Agree
Slightly Disagree
Strongly Disagree

APPENDIX F

INQUIRY CLASSROOM INTERVIEW

Inquiry Class Interview

My name is Adam Feldbruegge, an educator at Westminster Christian Academy in Huntsville, Alabama. I am the lead primary investigator for research being conducted on behalf of Montana State University. If you have any questions about this process, please feel free to contact me at the following email address: adam.feldbruegge@wca-hsv.org. For any questions directed to the Montana State University Institutional Review Board, please feel free to contact them at the following email address: irb@montana.edu. Survey and questionnaires will be completed electronically with Google Forms to ensure anonymity and data collected from in-person formative assessments will not require participants names to be submitted.

Participation in this research is voluntary and you can choose to not answer any questions you do not want to answer and/or you can stop at any time. Participation or non-participation will not affect a student's grades or class standing in any way. Proceeding with the survey/interview/questionnaire indicates your consent to participate in this research.

1. Why did you choose to take a physics course?
2. Prior to this class, did you have any experience with physics?
3. How did using inquiry in physics make you feel?
4. How can the teacher better assist you with learning through inquiry?
5. Is there anything that you would change about how the course is taught?
6. What was your favorite part about the course? Explain why.
7. What was your least favorite part about the course? Explain why.

APPENDIX G

PARTIALLY FLIPPED CLASSROOM INTERVIEW

Partially Flipped Classroom Interview

My name is Adam Feldbruegge, an educator at Westminster Christian Academy in Huntsville, Alabama. I am the lead primary investigator for research being conducted on behalf of Montana State University. If you have any questions about this process, please feel free to contact me at the following email address: adam.feldbruegge@wca-hsv.org. For any questions directed to the Montana State University Institutional Review Board, please feel free to contact them at the following email address: irb@montana.edu. Survey and questionnaires will be completed electronically with Google Forms to ensure anonymity and data collected from in-person formative assessments will not require participants names to be submitted.

Participation in this research is voluntary and you can choose to not answer any questions you do not want to answer and/or you can stop at any time. Participation or non-participation will not affect a student's grades or class standing in any way. Proceeding with the survey/interview/questionnaire indicates your consent to participate in this research.

1. Why did you choose to take this course?
2. Prior to this class, did you have any experience with physics?
3. How did you feel about the flipped classroom approach? (Videos for homework)
4. What could the teacher do to help improve your learning in this course?
5. What was your favorite part about this course? Explain why.
6. What was your least favorite part about this course? Explain why.