Actor Oriented Transfer Methods for Mathematics and Science Integration

A Master’s Research Project Presented to

The Faculty of the Patton College of Education and Human Services

Ohio University

In Partial Fulfillment

of the Requirements for the Degree

Master of Education

by

Joshua Olson

August 1, 2015
This Master's Research Project has been approved
for the Department of Teacher Education

Ralph Martin, Ph.D.
Professor Emeritus
Department of Teacher Education

Frans Doppen, Ph.D.
Professor and Chair
Department of Teacher Education

[Check box] Checking this box indicates that the IRB Consent form is appended to this document.

[Check box] Checking this box indicates this document has been submitted and successfully cleared plagiarism check. Supporting documentation has been provided to the Department Chair and is appended to this document.
# Table of Contents

1. **Introduction**  
   Research Questions 3

2. **Literature Review**  
   Introduction 4  
   Calls for Integration 4  
   Defining Integration 5  
   Authenticity 6  
   Difficulties to Overcome 7  
   Transfer 8  
   Facilitating Classical Transfer 9  
   Actor-oriented Transfer Perspective 10  
   Previous Research 13  
   Conclusion 14

3. **Methods**  
   Participants 15  
   Concept Identification 16  
   Lesson Design 17  
   Preflection 18  
   Instruction 19  
   Reflection 19  
   Timeline 21

4. **Results**  
   Tide Graphing 22  
   Lesson Design 22  
   Preflection 23  
   Instruction 24  
   Student Work 26  
   Reflection 30  
   Jet Stream Calculations 32  
   Lesson Design 32  
   Preflection 33  
   Instruction 35  
   Student Work 36  
   Reflection 42  
   Research Questions Answered 43  
   Authenticity 43  
   Actor-Oriented Transfer 44
5. Discussion and Recommendations
   Authenticity 45
   Actor-Oriented Transfer Perspective 47
   Conclusion 49

References 50

Appendix A
   Example Coding of Student Work 54

Appendix B
   Graphing Tides 55

Appendix C
   Graphing Ties Analysis 57

Appendix D
   Jet Stream Calculations 59

Appendix E
   Jet Stream Calculations Analysis 63
Abstract

This study was completed in order to better equip science teachers with integrated mathematics lessons through the use of the Actor-Oriented Transfer Perspective. This perspective focuses not on whether students have achieved a correct answer, but rather, what connections they had made to the content of a problem. Use of this method might help to alleviate a common concern for science teachers, that the students will not get the mathematics. The study was designed to determine: whether or not mathematics could be integrated into science content in an authentic manner as well as how the use of the Actor-Oriented Transfer Perspective could impact this instruction. This was investigated by designing and implementing integrated lessons, making classroom observations, and analyzing student work. Student work was analyzed and categorized as conventional or unconventional and then used to plan future instruction. Actor-Oriented methods were indeed very useful for interpreting student connections. In each of the individual tasks studied there were students who arrived at an incorrect answer but showed positive connections to the mathematics and/or science content. It was difficult to use to use these positive connections without delaying future science instruction. This could be helped through the continued use of one or a few mathematical concepts within an entire year of science instruction. In this manner the connections students have made can be built upon continually, without a need to stop progress through science curriculum. In this manner students will be exposed to more authentic uses of both science and mathematics in the course of instruction.
Chapter 1

Introduction

Mathematics and science content are frequently cited as areas for possible content integration in secondary education. Previous research has tried to determine what integration means as well as the benefits and impedances of such integration. There are benefits of such integration, such as increased mathematics test scores, that can outweigh some of the difficulties associated with implementing integrated instruction (Schowls & Miller, 2012). Although there are many views about what integration of these content areas means, frequently integration refers to the incorporation of mathematical content into science lessons, units, or yearly curriculum. This integration is best accomplished by using mathematics within other content in an authentic manner that requires students to complete tasks that are reflective of real world procedures (Tran & Dougherty, 2014).

One of the difficulties educators experience when conducting an integrated lesson is the failure of students to use previous mathematics learning in a new context (Schowls & Miller, 2012). This use of previous learning is referred to as transfer of learning (Dixon & Brown, 2012). Classical transfer research has merely tried to determine if students could use previous knowledge in new situations. The actor-oriented transfer perspective (AOT) was created to determine what connections students were making between current and previous problems regardless of a correct or incorrect answer (Lobato, 2008). This AOT methodology presents a more useful measure for middle school teachers attempting to incorporate mathematical concepts into science content.
Purpose of Integration

The purpose of this Master's Research Project was to determine the efficacy of using AOT methods to inform instruction of science lessons with mathematics integration. Students received instruction in science lessons with a mathematical concept imbedded within the lesson. Their learning was assessed based on in-class observations and completed student work. These assessments were then used to inform and implement future instruction to maximize learning by capitalizing on the previous connections made by the students.

Research Questions

Given the difficulties associated with integrating the instruction of mathematics and science there lies an opportunity to improve the instruction at the middle school level. The purpose of this study was to help inform other teachers about how their practice can be influenced using the AOT perspective to integrate science and mathematics instruction by answering the following questions:

Can new or pre-service teachers authentically integrate mathematical concepts into science lessons?

What impact can the use of the actor-oriented transfer perspective make in the practice of new teachers?
Chapter 2

Review of Literature

Integration

**Calls for integration.** Integration of mathematical and science content is a frequently cited goal of researchers and educators in order to better reflect the demands of the real world (Judson, 2013; Lederman & Niess, 1998; Lee, Culpepper, Chauvat, Plankis, & Vowell, 2013; National Middle School Association, 2010; Schowls & Miller, 2012; Vasquez-Mireles, 2009; West, Vasquez-Mireles, & Coker, 2006). To further the development of educators interested in integration of science and mathematics content, university programs have been developed in both Arizona (Project Pathways) and Texas (Mix It Up) (Judson, 2013; Vasquez-Mireles, 2009). Incorporation of interdisciplinary coursework and problem solving are important tenets of *This We Believe*, the position paper of the National Middle School Association (2010). Dixon and Brown (2012) state that there is not enough real world problem solving at the secondary level. In this regard integrated content is useful because it can better represent real world situations where students will need to able to solve problems that are not contained within discrete content areas (Lee et al., 2013). Some research points to an increased understanding and retention of mathematics content for students who have been exposed to mathematics in science or integrated content (West et al., 2006). In the accountability era the benefit of increased mathematics scores on high stakes tests cannot be overstated as a reason to integrate (Schowls & Miller, 2012).

Integration of mathematics and science content is becoming increasingly important with the implementation of the Common Core State Standards for Mathematics (National Governors Association Center for Best Practices, 2010; Schowls & Miller, 2012). This integration is
consistent with the Common Core Standards (CCSS) for Mathematical Practice under the following content standards:

- Make sense of problems and persevere in solving them.
- Reason abstractly and quantitatively.
- Model with mathematics.
- Use appropriate tools strategically (National Governors Association Center for Best Practices, 2010).

The Next Generation Science Standards (NGSS) cites the importance of correlation between mathematics and science standards due to the quantitative nature of science (NGSS Lead States, 2013).

Frequently science teachers find that they are unsure how to proceed when students do not use or do not have the mathematical concepts necessary for achievement in science (Schowls & Miller, 2012). In order to alleviate this lack of content the NGSS are aligned with the CCSS in order to ensure that science content does not demand mathematical knowledge until after the mathematics has been taught.

**Defining integration.** What is meant by integration of mathematics and science is not always clear. Although many attempts have been made to integrate these two areas there is little agreement about what integration should or does entail (Lee et al., 2013). Lederman and Niess (1998) noted that sometimes integration means single classes that make no distinction between mathematics and science content. However, they add that inquiry and problem solving in mathematics and science follow different sets of guidelines making these processes fundamentally different. Lederman and Niess caution that fully combining mathematics and
science curriculum may result in a "hybrid version of inquiry that is both confused and chaotic" (p. 283).

Rather than representing a fully integrated course where the content areas are taught together, integration is often described or practiced in terms of using mathematical concepts within science curriculum or using science to illustrate or otherwise aid in mathematical instruction (Judson, 2013; Lee et al., 2013). This is the result of a number of reasons. Frequently pre-service teachers who have received instruction in integrated techniques receive teaching positions that are either solely in mathematics or science (Judson, 2013). This makes teaching a fully integrated curriculum impossible. It is also difficult for teachers who are not content experts in both mathematics and science to feel comfortable aligning curriculum in terms of an instructional unit much less an entire year. This situation could be somewhat alleviated if states were to publish a curriculum guide to illustrate where science and mathematics content intersect within a given state's standards. For this action research project math and science integration will refer to the incorporation of mathematical concepts into existing science curriculum.

**Authenticity.** Furthermore, the goal of this project will be not just to conduct integrated instruction but also to do so in an authentic way. Authentic instruction was defined by Roth & McGinn as requiring that learners complete activities that "engage in the everyday practices of a target community," (1998, p. 224). This requirement of authenticity requires that rather than identifying possible mathematical concepts that can be inserted into science lessons the instructors will need to find ways to use mathematics in an authentic setting. Tran & Dougherty identified the following characteristics that are considered desirable for authenticity: ensuring that students will have to analyze the problem for relevant information and not just implement an
algorithm, choosing problems that can/would occur in the world outside of school, and using problems that could be solved with more than one process (Tran & Dougherty, 2014). These situational experiences have become an important tenant of educational research (Frykholm & Glasson, 2005; Palm, 2008; Roth & Bowen, 1994).

Students fail to recognize a connection between the activities performed in schools and the requirements of those working in the relevant fields (Roth & Bowen, 1994). Roth and Bowen found that instruction should be guided by the situation in which the content could be applied. In some situations students who fail to recognize the realism of the situation give answers that are unrealistic (Palm, 2008). In order to provide more authentic tasks for students the educator should make sure that the question being asked is one that would be asked in a real world situation. Palm found that ensuring that questions were worded in this manner resulted in students responding with answers that were considered more realistic to the situation (Palm, 2008).

**Difficulties to overcome.** There are some issues that need to be overcome in order for mathematics and science content to be integrated. Many science teachers run into the problem of what to do when mathematical concepts necessary for a given lesson seem to be unknown (Schowls & Miller, 2012). Teachers also often find that students are unable to recognize that a skill they learned in a mathematics class is useful to solve problems in other areas (Dixon & Brown, 2012). Pre-service teachers are often optimistic about integrating mathematics and science but run into impedances when they get into the first years of their careers (Judson, 2013). Frequently these difficulties involve difficulties planning, shortages of time, and being required to work within the existing curriculum of a building or department. Educators also run into difficulty when trying to integrate because there is frequently a disconnect between what
students see in mathematics and science classrooms (Beauford, 2009). For example, graphs in science content often do not include the origin of a graph, which can lead to confusion for many students. In science the convention is to use the International System of Units (SI) while mathematics classes also use United States standard measurements in order to practice rate conversions.

In planning for a science lesson or unit with integrated mathematical topics it is beneficial for science teachers to diagnose deficiencies students have in mathematics so the requisite mathematical content can be scaffolded (Schowls & Miller, 2012). In order to diagnose these deficiencies Schowls and Miller advise that science educators go to mathematics instructors before teaching a lesson in order to gain insight into possible shortcomings of either individual or groups of students in order to plan for scaffolding of the mathematical content. Ensuring that instructors have at least some level of content expertise in both subjects could furthermore facilitate this process.

Transfer

Many teachers are apprehensive about using previously learned mathematics in a science classroom because they find that the students are unable to draw a connection between their present and prior learning (Dixon & Brown, 2012; Schowls & Miller, 2012). This process of using previous learning in a new or different situation is often referred to as transfer of learning.

**Defining transfer.** Transfer of learning refers to the ability of the students to use relevant skills or content from one area in another (Dixon & Brown, 2012). Although educators around the globe ask students to use their previous experiences in their new learning researchers have had difficulty showing transfer from previous experience to new situations (Lobato, 2012). The prevailing ideas about transfer constitute what is referred to here as the classical model of
transfer which requires students to correctly answer similar problems, but overlooks connections students make in the event of an incorrect answer (Lobato, 2008).

Transfer of knowledge is useful because it allows students to use previous knowledge in order to solve problems. Student transfer of mathematical concepts into science content alleviates the perceived lack of mathematical content knowledge that sometimes hampers integration (Schowls & Miller, 2012). For the purposes of this research project problem solving will refer to student ability to use methods or strategies from previous learning in order to complete a required task of an unknown type without having a specific algorithm provided (Fuchs et al., 2006; Sutton, 2003). Lack of transfer can occur because students do not make a connection between a concept, skill, or strategy they have learned in one arena and new problems in other venues (Dixon & Brown, 2012). In other instances students might remember the right concept or strategy but implement it in a manner that is not useful for the situation (Lobato, 2008). In order to transfer between content areas students need to build or envision a mental alignment between those areas (Siler & Willows, 2014).

Facilitating classical transfer. Distance of transfer refers to the similarity between prior learning and new learning (Fuchs et al., 2006). The researcher or observer in a given situation is responsible for determining the similarity of the task. In these instances students are only said to transfer knowledge if they perceive the connection that was drawn by the observer. In order to aid students in making these connections Fuchs et al. prescribe a dual approach of initial teaching of an idea or problem type and schema broadening, in which teachers facilitate a comparison of similar problems. In order for students to solve problems they need to build a mental representation, an abstract concept of the demands and information contained within a problem (Dixon & Brown, 2012; Sutton, 2003). Sutton (2003) states that in order to transfer learning
students need to build mental representations based on past experiences. This mental representation based on experience helps to support student understanding which in turn promotes better representation. Sutton described this as a cycle where better understanding creates better representations. In order to transfer students need to be able to recognize how new problems are related to problems that they have previously encountered.

Some research has been done to evaluate how the relative concreteness of instructional materials aids in representation resulting in transfer of mathematical knowledge (Blair & Schwartz, 2012; Kaminski & Sloutsky, 2012; Siler & Willows, 2014). Siler and Willows (2014) found that concrete materials helped with initial learning for middle grades students but these same students achieved mixed results when asked to transfer this learning. Kaminski and Sloutsky (2012) found that students could learn information from both concrete and abstract materials but that students incorporate material differently based on how abstract or concrete the source was. They found that concrete instantiations sometimes conveyed too much information that could be difficult for students to separate. Blair and Schwartz (2012) advocate for a combined approach using both abstract and concrete materials in order to enhance both learning and transfer. However, they caution that using abstract representations too early can keep students from recognizing a mathematical concept in a more concrete material.

**Actor-oriented transfer perspective.** AOT was pioneered by Lobato to correct the perceived lack of transfer in students that results due to the limitations inherent with the classical transfer approach (Lobato, 2006). Where classical transfer has looked to see if students were able to compute correct answers to similar problems, AOT intends to look at how students are making connections from previous learning to novel situations (Lobato, 2008, 2012). Transfer is viewed in AOT methods from the perspective of the actor rather than the observer as in the more
classical perspective. The goal of the classical transfer model was to determine whether students were able to transfer; in AOT methods the goal is to determine what students see as similar between previous and new situations. This difference can make AOT useful not just to researchers but also to classroom teachers who can alter their instruction to capitalize on what students did understand.

AOT differs from more classical perspectives of transfer in that it does not expect students to use a specific previously learned strategy in order for students to complete a given task (Lobato, 2008, 2012). In order to achieve this understanding AOT relies on qualitative investigative techniques in order to determine if students have understood previous learning and how students recognize the similarity of the previous learning in regard to a novel context. This differs from more classical approaches, which identify one method for method for solving a problem and then assuming that there wasn't any transfer if students cannot complete the problem. In the case of a correct answer classical transfer makes the assumption that the students used the method that the investigators had in mind. It should be noted however that the AOT model does not eschew the idea that transfer is based on the ability of students to make psychological connections between new and old learning.

The methods of a typical AOT can be difficult to incorporate into teaching and research because it is difficult to predict the connections, or lack thereof, that students might make in a transfer task. AOT needs ample instructional time as well as more conceptual approach than is seen in many classrooms (Lobato, 2012). Following instruction students will complete a task with probable connections to previous learning. While students are working observations are made and afterward researchers conduct interviews to further determine a given students line of reasoning. Data then needs to be analyzed to look for possible connections made by students.
While the goal of traditional research is to investigate how to obtain transfer AOT methods are intended to better understand how students generalize their learning and connect this learning to novel concepts. Lobato points out that as in classical transfer research the goal of AOT is still to help students improve mathematical abilities and accuracy. This goal is achieved by using information gleaned about what connections the students are making in order to inform future instruction.

The AOT perspective has two advantages over a more classical approach. One benefit is the opportunity to analyze student thinking in regard to problem solving. Lobato (2008) found that although students were not able to calculate the slope of a slide based on their prior experience with stairs, the students did recall that they needed the rise over the run. In the AOT this substantial gain is not overlooked, whereas in a classical perspective these students would have simply failed to understand slope. Lockwood (2011) found that she was able to determine particular aspects of problems that university combinatorics students were focusing on using AOT that would have been missed in classical transfer methods. This identification results in the second benefit of AOT, better shaping of future instruction. It is clear that students who already know that slope is a function of the ratio of rise and run already have a substantial piece of the knowledge that is needed in order to find the slope of the slide. Future instructional time is better used helping students identify the rise and run and not re-teaching what the slope means. This benefit might make AOT techniques useful to practicing teachers in order to guide future practice.

Students might benefit from this use of the AOT perspective in two different ways. There future instruction could be planned for in a manner that builds on the portions of a task that they had strong connections to. This will mitigate time wasted re-teaching concepts that the
students had already grasped. Students may also benefit from receiving some positive news about their efforts rather than the usual red marks. Students might receive this feedback individually in written or verbal form, or when necessary the whole class might benefit by seeing how different students approached a given problem.

**Previous research on mathematics/science transfer.** In a research study with undergraduate students Lockwood devised a system in order to categorize instances of AOT in combinatorics problems (2011). Although initially devised for a narrow situation, these categories could be applied to younger students using different kinds of mathematics. One of these categories is elaborated and unelaborated connections. Elaborated connections are those that have been explicitly demonstrated by students allowing the researcher to gain insight into the student's construction of meaning. This elaboration could be a written explanation of thinking or a verbal exchange prompted by a question from the teacher or researcher. Unelaborated connections are less useful because students have made a brief connection but there thought process has not been illuminated to the researcher. The second set of categories is conventional and unconventional AOT. In conventional transfer students see similarities between problems that the researcher sees as similar. Conventional transfer is closely aligned with classical transfer situations. Unconventional transfer occurs when students find similarities in problems where the observer does not see any similarity. An example of an unconventional transfer is a student who finds the answer to a problem about the mass of a liquid within a beaker by dividing by two when the mass of the beaker and liquid are equal. Lockwood found these unconventional transfer situations to be useful as a tool to identify how students perceive problems. Referent type connections are those where the students draw a connection to a particular problem, problem type, or a strategy (Lockwood, 2011). Lockwood described these
types as a progression noting that students begin with a particular problem "this is like the beaker problem", and then progressed to think in terms of types of problems "this is a takeaway problem", and subsequently to strategies for solving problems "I need to subtract for this kind of problem".

Some work has been done on transfer of mathematical knowledge for integration in science content, but not at the middle grades level or with AOT techniques. Hoban, Finlayson, and Nolan (2013) found that undergraduate chemistry students who were able to correctly answer a mathematical problem were better able to answer science questions using similar techniques. Furthermore, Hoban et al. found that students who were able to explain why they had answered a mathematics problem correctly were more likely to transfer this knowledge to the scientific context. This study was conducted with more classical transfer methods, which make it difficult to determine if students who were unsuccessful in the chemistry context were truly unable to transfer learning. An AOT approach would have allowed the authors to gather more insight into what connections these students were making. Fuchs et al. (2006) also conducted research on transfer of mathematics to real world situations but did not use AOT methods. They also advised that more research was needed on the topic.

**Conclusion**

Integrating mathematical concepts into science content can be difficult. Students often do not seem to transfer their skills in mathematics into science content for a number of reasons. AOT methods might be useful for in-service teachers to diagnose what connections the students do make and how to capitalize upon them. The purpose of this research project is to determine the efficacy of using actor-oriented transfer methods for lessons conducted in a middle school science classroom that incorporate mathematical content.
Chapter 3

Methods

Participants

This study was completed at a middle school in Southeastern Ohio in a seventh grade science classroom. Although, there were many sections of seventh grade science this study was conducted during the fourth and sixth period classes due to the broad spectrum of students within both class periods. These sections offered a grouping that represented a fair cross section of the students enrolled in this school. I chose not to use either of the first two sections of the day because this was the first time that I had taught these lessons and it was beneficial to have two opportunities to practice each lesson allowed for further refining the instruction before data was collected.

At this school science students were not tracked for science instruction resulting in a makeup of students across all ability levels. Each class had students identified as talented and gifted as well as students with individualized education plans. During the first grading term of the year student grades in both classes ranged from A+ to F. The average grade was a B- in the fourth period class and a C+ in sixth period. There were no significant behavior problems among students in either class that impacted the findings of this study.

Contrary to the grouping for science classes these students were tracked for mathematics instruction. The chosen science sections had students representing all levels of mathematics offered, ranging from honors algebra to special education pull out classes. This difference in mathematical ability was beneficial to this study because it allowed for observations to be made about students across a broad spectrum of mathematical mastery. Students in both class periods participated in the same lessons and activities. Some small changes were made in the instruction
in order to enrich or intervene based on connections that the students made in the preceding class periods.

**Concept Identification**

The first step in completing this study was to identify mathematical concepts that could be used within the seventh grade science curriculum with which to create high quality science lessons with authentic use of the mathematical concepts (see Figure 3.1). The mathematical concepts were chosen based on discussions with math instructors as well as an analysis of the CCMS to find concepts that students had already had some experience with. The goal was not to teach students new mathematical concepts, but to ask students to use concepts they were acquainted with in a different context and content area.

One key area that was identified was the use of graphs in order to represent and interpret data. The CCMS calls for the use of data interpreted and represented through graphs in grades two through five as well as using graphs to analyze the unit rates of equations in the seventh grade (National Governors Association Center for Best Practices, 2010). A better understanding of graphs for data representation has been identified as an area where improvement is necessary and possible (Clary & Wandersee, 2014).

Another identified area of need was using unit rates to complete multi-step problem solving. Recognizing and using unit rates from equations and written descriptions is a key concept within the seventh grade math standard (National Governors Association Center for Best Practices, 2010). The most important aspect of lesson design was choosing a scientific concept that could be augmented with mathematics. The emphasis was not placed on choosing a math concept to be taught in a science lesson, but finding a manner in which the science content
allowed for the use of mathematics in an authentic manner that would build on understanding in both content areas.

Figure 3.1
Lesson Design

Two lessons were devised, one that corresponded to graphing and another that relied heavily on the use of unit rates. The goal during the planning of each lesson and the accompanying materials was to ensure that the assessments would require an authentic application of mathematics within the science content as implied by Figure 3.1. This process began with an examination of the seventh grade science standards in order to identify content where mathematics would not be used in a contrived manner. Another important consideration was that the mathematical concepts not be too difficult. For example, a lesson about why the Moon orbits the Earth would align to the science standards. However a mathematical examination of gravity was far beyond the content most of my students are familiar with. To this end each mathematical concept was aligned with the CCSS.

The basic outline for each lesson was based on the following model and as much as possible completed in this manner. Lessons began with an introduction to the new scientific concept. This often began with the presentation of new vocabulary. This was done to either began and/or broaden student' schemas in order to mitigate the failure of students based on poor understanding of the science content. After initial instruction about the science content the
students were introduced to the manner in which mathematics would be useful for explaining or modeling the situation. Students were led through one or more examples and then asked to perform a given task individually.

Each student completed their work on an individual worksheet so as to facilitate the analysis of their work. The worksheets had differing levels of support imbedded depending upon the concept and what connections I thought students would make. In some instances the students had other resources to use as well including but not limited to: note sheets, vocabulary lists, calculators, rulers, colored pencils, and scratch paper.

Preflection

Pre-analysis of the lessons was integral to the final outcome of the study as illustrated by Figure 3.1. This took the form of a journal entry/preflection. Included in this writing was my rationale for the lesson and some thoughts about the connections the students might make. During the timeframe of this study I had a first period preparation. This was useful because it allowed for a fresh look at the materials/concepts of each lesson with a fresh perspective, which is to say not immediately after they were finished.

During this process an emphasis was placed on what the scientific goals and objectives were, as well as how mathematics fit into this goal. Included was an explanation for the methods chosen for each lesson. Also included in each reflection was order to prepare for the actual teaching of these lessons I had to prepare for some of the strategies to transfer or connections that I thought students might make between their previous learning and this new content. Finally, the preflection finished with a self-score from 1-5 about the authenticity of the mathematical requirement of the lesson. One represented little to no connection between the task
and the real world and Five represented a task that would be carried out in the everyday life of someone in a related field.

**Instruction**

Continuing with Figure 3.1, each lesson was taught a total of five times to 2nd, 3rd, 4th, 6th, and 8th periods although only the 4th and 6th period classes were used for data collections. Observations from second and third periods were used to inform the manner in which the fourth period class was taught. Some of these changes were merely in the manner in which new scientific concepts were introduced. In other cases changes were made in reaction to how the students were using mathematics. All of these changes were made on the fly as these periods are all in a row with only a three-minute passing time between them.

After the fourth period class each lesson was analyzed for possible areas of improvement during the teachers' lunch break. Sometimes this process took place as a collaboration with my mentor teacher. These discussions focused on what connections the students were making and how to engage in schema broadening and/or support transfer of mathematical knowledge. During this time I made a few notes about how the morning iterations had gone and how things in the afternoon classes could be done differently. These notes were included in the end of the day reflection. After lunch the amended lesson was taught to the sixth period class.

**Reflection & Student Work**

Again referring to Figure 3.1, at the end of each day a reflection was made about each lesson. This reflection was based on classroom observations as well as analysis of student work. Classroom observations included those conversations and interventions that had taken place in the class that would not show up in the physical work from the students. During the process of reflection the concept of authenticity was also revisited in order to determine if my perspective
on the realism of the lesson had changed. Although classroom observations were extremely useful in this process it was not possible to get a sense of how every student was doing on every problem. In order to get a better sense how each student was doing it was necessary to analyze individual student work.

In each lesson student work was placed into categories based on what connections the students had made. This system was based on Lockwood's (2011) system of elaborated/unelaborated and conventional/unconventional transfer. In order to dissect student performances a spreadsheet was created on which an analysis of individual student work was recorded. For example, if a student arrived at a correct answer and it was also possible to determine the method they used to achieve this answer that portion was coded 1. If a student arrived at what was a correct answer but it was not clear how they arrived at this answer this would be categorized as unelaborated and coded with a 2.

A unique set of codes and categories was created for each portion of a lesson due to the differing mathematical demands of individual tasks. The goal of this classification was to help me to determine my understanding of the connections made by the students, as well as to determine the practicality of using AOT methods on a cross section of students. An example spreadsheet is included in Appendix A.

I used the unconventional/conventional distinction to help to determine what connections the students were actually making. If students had completed a given problem in the manner that I had expected them to then their work was classified as conventional. For example, if a student had found the range between high tide and low tide by subtracting low from high that was classified as conventional. Work was classified as conventional if a student completed most of a problem as I expected but miscalculated or made an otherwise insignificant error at the end. If a
student had used a different method to find this information such as visually counting up from
the low tide to the high tide then this could be classified as unconventional. It was possible for
unconventional answers to arrive at either a correct or incorrect answer.

Finding and analyzing these unconventional transfers was an important goal for this
research project. Instances of unconventional transfer were also be further categorized and
assigned a code based on the strategies used by the students. As it is impossible to determine all
methods that a student might use to achieve a correct or incorrect answer the different codes
assigned to each strategy/method were assigned to

After analyzing student work it was necessary to react in some way. Sometimes this
reaction took place immediately with a verbal prompt or modeling a useful method. Other times
this reaction took the form of changing or redesigning a future lesson in order capitalize on the
connections the students had made in the previous lesson. The relevant data for "in the moment"
occurrences consisted of either reflections written after initial teaching, this took place either
during lunch or with the daily reflections after school. For the changes to following lessons the
data consisted of both these reflections as well as the new or amended lesson plans for
subsequent learning.

Timeline

The research process for each lesson (as seen in Figure 3.1) began approximately one
week prior to the instruction and student work was analyzed within two days of completion. It
was imperative to do this as quickly as possible in order to use relevant observations and
conversations from class in order to elucidate student thinking. Changes to instruction were
carried out in the coming weeks as allowed by the state testing schedule of the school district as
well as the order of science curriculum.
Chapter 4

Results

One of the goals of this project was to determine if AOT methods could be used to help support and inform future instruction. Accordingly the results are reported in chronological form. Each lesson is reported through all of the steps of the research project from lesson design through the reflection and student work.

Tide Graphing

The first integrated lesson occurred during a unit on the moon and tides. In the previous lessons students learned about the phases of the moon, the moon's orbit, and the effect of the sun and moon's gravity on Earth. After discussing the various positions of the moon the idea of tide was introduced. The students then learned about spring and neap tides. Each type of tide was identified by both the relative range (greater or less) and the position of the moon when each tide occurred.

In order to further develop this idea students fastened a periodic graph into a reference book they were completing that showed the rise and fall of tides over the course of a lunar cycle. Students then labeled where they thought spring tides, neap tides, full/new moons, and quarter moons were shown on the graph by the range of the tide during the course of a month. A class discussion of why students had chosen these particular locations helped to reinforce the concept.

Lesson design. This activity was designed so that the students could graph the highest and lowest daily tide for a specific area over the course of a week. In order to make the task as real as possible I selected real data from the National Oceanic and Atmospheric Administration (NOAA) for Kitty Hawk, North Carolina for the upcoming week (National Oceanic and
Atmospheric Administration, 2015). One of the reasons that real data was chosen was so that students would be able to see the tides line up with the upcoming phases of the moon.

Students received one of four different data sets at the bottom of a graph that was set up for them (see appendix B). The four graphs corresponded to the weeks that occurred around the next full, new, and quarter moons. A few numbers were altered slightly and/or rounded to the nearest quarter foot in order to simplify the process and to make the results as clear as possible. Students then used this graph in order to provide answers on an accompanying activity sheet (see appendix B). The answer sheet also included information to support/reinforce previous learning such as a reminder of what spring and neap tides are and how to find the range of tides.

**Preflection.** Based on my analysis of the standards as well as experience working with some of these students in a math content classroom I thought that the graphing portion would be fairly straightforward with students performing well. Considering the graph students had used in their Moon Books I thought they would readily understand the idea of illustrating how the tides change the height of sea level over a given time period. I further thought that most of my students would have little difficulty determining which portion of the graph showed a spring/neap tide by using the Moon Books as a reference.

I was concerned students would have some difficulty determining the range of tides even though an explanation of range was included on their answer sheet with an algorithm for finding the range. In order to support this idea I decided to project an example of a graph similar to the graph that students would be working on and modeled a procedure that could be used to determine the range. In order to find some of the ranges students needed to find the difference between positive and negative numbers. Based on the seventh grade mathematics curriculum in
this school, which included frequent use of subtracting negative numbers, I was hopeful that this wouldn't be a major impediment to student success on this task.

I rated the authenticity of this lesson as a four out of five for a number of reasons. The data the students would use was derived from actual predictions from NOAA and would correspond to the realistic days of the lunar cycle. Also, the graphs students produced are very similar to graphs used by NOAA to show tide heights although on a compressed time scale. This lesson was not rated a five as completely authentic because one who studies tides would not use a tide prediction to determine the location of the moon. In reality this process would go the other way around.

**Instruction.** This lesson took place during a shortened class period due to a two-hour delay for snowfall. I introduced the activity by asking students about what causes tides and the difference between tide heights. I then projected a copy of the graph that they would be completing and modeled how to complete the first two days their graphs. Students were then asked to begin using their data sets to complete their individual graphs. I directed the students to use the graphs to complete their answer sheets when they finished.

It immediately became clear that students had a difficult time with finding the location of numbers that were between whole numbers and halves. I moved around the room in order to support this concept by asking questions such as "Is 4.25 feet larger or smaller than 4 feet? Is it larger or smaller than 4.5 feet?" Students were easily able to answer these questions, so I then asked them to show me on the y-axis on their graphs where these heights were represented. Although they had difficulty converting the numbers to a graphic representation, this did not mean that the students failed to make connections about the numbers with decimals.
Many students also had difficulty translating numbers near and below zero onto their graphs. I think that students had difficulty with this because they are used to graphs that have a clearly marked line at $y = 0$. With this line lacking I saw a number of students graph positive data points in negative territory and vice versa. Over lunch I added a bold line at $y = 0$ and in the afternoon classes I used data with points that were both positive and negative during my introduction to the activity. This seemed to help clarify and fewer students in the afternoon classes had difficulties with positive and negative numbers near zero.

In the morning a minority of the students were confused about how to use the x-axis of the graph. These students most frequently graphed the high tide and low tide for each day using the same x-coordinate. They would then move over to the next day and graph high tide and low tide again. They were making a strong connection about the tides and particular days; however, they were not showing how the tide changed within the day. I explained to students who made this error that the high and low tide did not happen at the same time and that they should graph the next tide occurrence by moving over one half day. During lunch I made an adjustment to how I modeled the graphing procedure. I made a concerted effort to explain that each new tide should be located one half of a day to the right on the x-axis.

Having students produce graphs had the fortunate side effect of making it very easy to see what the students were thinking. It was extremely easy to visually analyze the graph and see if the students were performing as expected. When students had missed a connection it was possible to use their graph as a platform from which questions could be asked to help understand and/or clarify their thinking. For example, if a student had graphed a negative point as positive the range of the tide for that day appeared incongruous with those of the days adjoining it.
**Student work.** Student work completed during this shortened period showed a great
difference in the understanding that students had about this activity. Following is an analysis of
each task that 34 students completed. Tables of this data are included in Appendix C.

**Graphing.** The student graphs were completed in class and this analysis was performed
only after students had completed their graphs including instructional interventions. The graphs
showed five different categories of student thinking (see Appendix C- Table 1). Out of 34
students who completed this activity 22 students performed as expected. These were coded with
a one denoting a conventional graph.

More interestingly there were many other categories represented that showed the utility
of an AOT perspective. For example there were two students who inverted some of the numbers
across the \( y = 0 \) line of their graph. A conventional transfer perspective might have determined
that these students were simply unable complete this task. However, these students showed an
understanding of the passage of time by using the correct x-coordinate as well as using the
appropriate distances from the \( y = 0 \). There were also two students who graphed one or more
points off by a whole integer; these were coded 3. These students showed a general
understanding of the process that might have been overlooked by a traditional transfer
perspective.

There were three students who used the bottom of their graph paper as \( y = 0 \). These
students graphed points of low value (positive or negative) all near the bottom of the graph
showing a need for a broadened graphing schema. It was unclear if these students associated the
bottom of the graph with zero alone or if they may have also confused and/or ignored the
positive or negative values of their data points. The four students who either used the bottom of
their graph for \( y = 0 \) or inverted positive and negative values were all in the fourth period showing that the lunchtime adjustment helped students to produce a graph without these errors.

There were five students who had x-axis spacing that was different than what I had modeled and expected. These students showed a general understanding of how high and low the tides were, but seemed to be confused about what the x-axis was showing. They graphed both the high and low tides on the same x-coordinate resulting in vertical line between the two. They understood that the high and low tide happened on different days but did not show how the tide was changing within those given days. Interestingly, this method did show the range of tides on a given day very well, a useful result that was not overlooked.

**Question 1.** In the first question students were asked to label a point on their graphs that showed either a spring or a neap tide by identifying a day that showed a larger or smaller range. On this task there were five different categories of student work (see Appendix C- Table 2). 16 of 34 students identified the days that correlated with the correct tide and explained their answers by invoking the tidal range. Three more of my students identified the type of tide on the correct day but failed to explain their answers resulting in an answer classified as correct unelaborated.

Four students identified both types of tides within their graph for one week; these students correctly identified the tide and day that was intended within the data set. However they then also identified the opposite tide within that week as well. For example if a graph showed a neap tide these students labeled the day with the largest range as showing a spring tide. This answer showed a strong connection between range and the type of tide. Conversely, these students showed a poor understanding of the cause of these occurrences. An individual who grasped that spring and neap tides corresponded with new and quarter moons would not have identified these events happening in a three-day span.
In addition there were six students who did not complete this portion of the assignment and another five students whose answers were incorrect but without enough information to determine their thinking. These instances in which student thinking could not be used to determine a connection between were classified as unelaborated, answers of this sort were not useful for building upon with the AOT perspective.

**Question 2.** The second question asked students to identify the day that had the largest range of tides. They were further asked to explain their thinking in order to practice using evidence in their writing and also to help me understand the thinking involved in their selections. I had expected students to determine the largest range visually and did not require the students to identify the range numerically by any method. There were five different categories established for student work on this question (see Appendix C- Table 3).

There were a total of 22 students who correctly identified the day on their graph that showed the greatest range. Of these students 18 used the visual method I had expected. Surprisingly eight students used a calculation to find the range of the largest day. Although, I had not expected students to actually perform the calculation however this was also categorized as conventional. It was not clear if these students had performed the calculation because they thought it was required, or if they did not see a strong visual connection between the height of the lines on their graphs and range. Two more correctly identified the day but failed to explain their thinking so they were categorized as unelaborated.

Four students used a conventional visual approach to determine the day with the largest tide but due to inaccuracies in their graphs arrived at the wrong day. This situation was perfect for the AOT perspective. It would be unfortunate to assume that because these students did not get the right day that they did not understand what the range of tides looked like. However, a
quick analysis of the students' graphs showed a strong connection with the question. Had the students been using a more accurate graph they would have performed as expected. This analysis allowed me to provide better feedback to these students.

There were two students that used the conventional method of subtraction to find the range for each day but arrived at the wrong answer. Upon further analysis these students had trouble finding the largest range because they made errors when finding the difference between a positive and negative number. These students also showed an understanding of how to find the range but failed to correctly perform the calculation.

**Question 3.** The third question on this assignment asked for the range of the tide on the first day of each student's data set. Again, in order to help me understand student thinking students were required to show their work. Contrary to what I had wanted for the previous question I expected students to perform a calculation, subtracting the low tide from the high tide. This question resulted in seven different categories (see Appendix C- Table 4).

There were 25 students who set up a subtraction problem as expected and these answers were categorized as conventional. Although it wasn't exactly as I had expected, students who chose to use addition instead of subtracting a negative number were also considered to have used conventional methods. Of the 25 students classified as conventional 14 of them found the correct range for the first day. Another nine students had set themselves up to arrive at the right answer but did not have time to finish due to the snow shortened class length. One student set up a subtraction problem but arrived at an incorrect answer due to a clerical error, they simply transferred the wrong number from their graph/data set. Another student set the problem up correctly but arrived at an incorrect answer due to subtracting a positive number rather than the
negative from their data set. Even though there was a broad range of answers all of these students showed at least some positive understanding on this task.

There were also students who used unconventional strategies including one who arrived at a correct answer using a strategy of counting up by smaller units. This student began at the low tide and then counted the number of .25-foot increments on the graph. They then placed these quarter feet into groups of two to reach .5 feet and those into groups of 2 to reach whole feet. As this student arrived at a correct answer this did not require AOT methods for analysis. However, if this student had made an error using this method, a more conventional transfer perspective would have determined that the student did not understand either the mathematics or science content.

Another student chose to graphically represent the range of the graph by making a line of approximate length to the range on the graph on their answer sheet. This showed an unconventional idea of how to express their answer but a general understanding of what the range looks like. The other student approximated the range by using the closest whole numbers. Although this approximation does not show a correct answer it did show strong connections between the height of the tide at different points on the first day as well as showing use of a mathematical technique that is often encouraged in this school's mathematics curriculum.

**Reflection.** One of the most important observations made during the instruction of this lesson was the strong connection the students had to the word difference. When discussing how to find the range in class students seemed to be very confused. When I offered that they could find the difference between high and low tide the students proclaimed that we needed to subtract. One student even said "In math class difference means subtraction." This illustrated a perception
by students that mathematics and science have little in common, and that there might be a

different procedure to find the difference in science content.

One problem that became clear during student work analysis was that some of the

students had to find the range of a day in which a negative number represented the low tide.

Unsurprisingly, students who had these negative low tides had more difficulty finding the range

for that day. It would have been a better test if all students had completed a problem with either

a positive low tide or a negative low tide in order to determine how the students were doing

without having a difference in cognitive requirement of the problem.

It was difficult to decide how to respond to this lesson. Under normal circumstances it

would have been nice to follow up on this lesson with an intervention and enrichment lesson of

the concepts in order to help those who had difficulty and expand the connections made by the

more successful students. However, due to recent snow days it was clear that we needed to keep

moving in order to finish our required curriculum for the year. In part this decision was based on

the idea that taking time to reinforce the mathematical concepts would take away from time to

teach further science concepts.

Eventually the response that was arrived at was to teach multiple lessons in the coming

weeks where graphs and graphing played an integral role. For example, in the next unit about

the atmosphere students made a graph that charted temperature and atmospheric carbon over

time. This graph showed a periodic effect and students were able to build upon their experiences

in this lesson. This solution was useful because it allowed continued use and support of graphs

whilst allowing the science content to progress.

Although it was known all along that there was great variation in the mathematical

abilities of these students, this lesson further highlighted this discrepancy. Some students
finished very quickly while other students struggled. In order to help alleviate the struggle felt by some students as well as the time wasted by those who finished quickly it was determined that, when possible, future mathematics requirements would differentiated. This would mean more complex assignments for those who perform well on mathematics tasks rather than longer assignments in order to keep things as fair as plausible.

In my post assessment of this lesson I determined that the authenticity rating of 4 was still accurate. The use of real data was a way to show students that math is not simply a subject they need to study at school, but also a useful tool for understanding and explaining the world around them. Although, the methods used in this lesson were not those used by someone studying tides, this lesson asked students to use mathematics in a context that went far beyond what is typically seen in mathematics classrooms.

**Jet Stream Calculations**

The second lesson used within this study was based on the idea that the jet stream is an atmospheric current and that commercial airlines use these in order to arrive at destinations more quickly as well as to save fuel. This lesson followed previous discussions of oceanic currents and winds, which the students had learned are caused by differences in pressure.

**Lesson design.**

The goal of this lesson from a scientific perspective was to help students understand the importance of the jet streams to human air travel. Students would then use their knowledge about how wind acts as a force to work with or against airplanes in order to solve some mathematics problems. These problems involved all four of the operations and students would need to rely heavily on finding and manipulating unit rates. Each problem required the student
to understand how air currents would increase or decrease the groundspeed of an airplane. These problems are included in Appendix D.

Due to the differences in mathematical ability noticed in the previous lesson two different levels of mathematical difficulty were created for students to choose from. In order to incentivize students who were capable, the more difficult sheet was offered with one half point of extra credit for each problem students attempted. These two calculation sheets were referred to as regular credit and extra credit as seen in Appendix D.

The mathematics on each level was intended to become increasingly difficult as students moved from the first to the last problem. In some cases this was accomplished by designing problems with more steps. In other cases the problems themselves had a more difficult cognitive load, for example rather than using a problem where a student might add one that would prompt a student to divide.

Preflection.

I knew that students would have a difficult time with some portions on both options. Based on my own previous observations as well as discussions with other pre-service teachers it was apparent that multistep problems were a common area that could use improvement. However, each individual step in these problems was a mathematical concept that had previously been discussed in the mathematics classes of all of the students this year.

I expected students to understand that a tailwind would increase a plane's speed and a headwind would cause a decrease. It seemed that students would easily be able to determine these problems as requiring either addition or subtraction. This concept was paramount to all of the problems but was the sole focus of questions one and two on the regular credit sheet (see
Appendix D). The second question specifically set up a situation where I thought students might either envision a situation that necessitated addition or subtraction of a negative number.

Another important concept was to determine the speed of different airplanes. This skill was needed for many of the problems on both levels of work. I expected students to accomplish this by dividing the distance by the time often resulting in the recognizable mph. Students would have to use speed for varying purposes. I expected them to do well at this on problem three on the regular credit sheet, which also was the same as problem one on the extra credit sheet. I expected students to have more difficulty on problem five on the extra credit sheet which required students to find the difference in speed of planes moving in opposite directions but then determine that the wind was only accounting for half of the wind because it was acting on both planes.

During the preflection I decided that the difficulty of these problems might become a cause for concern to some of my students, in order to alleviate this, I decided to offer students a grade based on their participation. Students were awarded full credit with wrong or incomplete answers as long as they were working diligently during class time.

I rated this lesson a three for authenticity. I felt that the underlying idea was fairly realistic; certainly air traffic controllers and pilots consider air currents when plan and adjusting routes. This concept would also be useful in other areas. For example, truck drivers who drive on the interstates achieve much greater fuel economy when traveling with the prevailing winds. However, I also thought that most probably this was done by a computer and not on paper. That being said, this showed a more realistic contextual use of these mathematical skills than is typically seen.
Instruction.

In order to present the concept of a jet stream each student both wrote a definition and made a sketch on a prepared vocabulary sheet. We then discussed the implications that jet streams have on humans. In order to show the great impact that jet streams can have on weather we discussed the role the jet stream had in bringing the cold air experienced in this area the previous winter. Then after finishing with the effect these currents have on weather we transitioned to the focus of this lesson, showing how the jet streams impact flight.

I asked students if they had any ideas why these phenomena might be referred to as a jet stream and students rightly guessed that it had something to do with jet traffic. After projecting a map of the United States with a jet stream superimposed students were asked, "how could this affect air travel?" In both classes students were able to build on the previous discussion of ship travel and ocean currents to determine that it would be better to move with the current. This was heartening as it showed application of a previous lesson on new content.

I then led students through some example problems that utilized both adding and subtracting of wind speeds and unit rates. At this point I explained to students that they could choose either the regular or extra credit sheet and that their grade would not be adversely affected either way. In order to support computational needs students were allowed to use either their own calculators or those from a classroom set in the room.

Initially students had some confusion about the terms headwind and tailwind, namely remembering which was which. In order to help support this idea, I inserted a slide into my presentation that showed students which relative direction corresponded to each wind during my lunch break. This seemed to alleviate some of these questions but some students were still slightly confused during the afternoon. I had not considered this vocabulary as an important
piece of prerequisite knowledge; it was only through viewing their work and talking to students that I determined that they were not drawing this connection. Had they mistaken this and arrived at an incorrect answer AOT methods would have been extremely useful.

Not surprisingly some students did not make the connection between what they needed to do and their previous knowledge about unit rates. I frequently prompted students with a statement such as, "Well, how far did the plane go? How long did it take?" Overall the students worked very hard and asked for little help. I monitored student progress by moving around the room and tried to prompt students when I noticed a missed connection. At the end of the class period I asked students to turn in their work whether or not they had completed it.

**Student work.** Due to the number of different questions as well as the different mathematical skills needed to complete these problems there was a vast number of different connections and/or errors made by the students. The regular and extra credit student work was analyzed and is reported separately. Although two questions were identical between levels, it is interesting to see the differences in completed work between those who chose to tackle the extra credit questions and they have been reported separately. Following is an analysis of each question for the 23 students who completed the regular credit assignment and the 13 that completed the extra credit. This data is included in tables in Appendix E.

**Regular credit.**

*question 1.* Students had little difficulty determining the speed of a plane when a tail wind was added. They all used the expected method of adding the tailwind to the normal top speed of the plane. 22 out of 23 students accomplished this task accurately and the one other student simply made an error in computation (see Appendix E- table 1). This student's work again showed the utility of the AOT perspective. The problem had been set up correctly and the
student simply added the numbers incorrectly. If the teacher were to simply state, "the students can't even add" they would be overlooking an important connection that the students had made about the jet stream and plane acting together.

question 2. The second question was more difficult for many of my students. I had expected more students to recognize that the plane was moving in one direction and to represent the wind against it with a negative number, requiring them to subtract a negative. Three of my students indeed used this method (see Appendix E- Table 2). Six more recognized this problem as an addition problem. 14 students subtracted the wind speed from the speed the plane was moving. These 14 students showed an interesting result, because it seems as if the students recognized the headwind signified a need for subtraction. They just failed to recognize that by removing the wind they were taking away a force acting against the plane. They had made an important connection but overlooked a smaller part of the problem.

question 3. The third question required students to find the unit rate for two different airplanes. I expected a large number of students to do well on this problem due to the extensive practice on unit rates students receive in the seventh grade math curriculum. 14 students were classified as correct conventional because they completed this problem as expected. They found the speed of both planes by dividing miles by the number of hours (see Appendix E- Table 3). One more student arrived at the correct answer but did not show any work and another tried to find the unit rate but multiplied the number of miles by the number of hours rather than dividing. This student recognized that they needed to find the speed for each plane in order to answer the question but failed to use the correct operation. This was an important connection that would have been wasted if this had been simply marked wrong.
There were three students whose work on this problem was classified as unconventional. One of these students found the speed of one plane, but then multiplied that speed times the number of hours the other plane traveled. This shows a strong connection to the initial unit rate portion of the problem and confusion about what the question was asking. The two other students who used unconventional techniques showed work that showed no connections to the problem. I was unable to determine the methods used by three of the students and two more left this problem incomplete.

*question 4.* The fourth question proved to be very interesting. The students needed to determine which information was important and then multiply a unit rate by a number of hours. In order to solve the problem students needed to only find the effect tail wind had over the course of three hours. Many students had difficulty overlooking the normal top speed of the plane, which was extraneous to the problem. Only one student completed this problem in the manner that I expected and was categorized as correct conventional (see Appendix E- Table 4).

Four students added the speed of the plane together with the speed of the wind and multiplied this by three. This approach shows that students understood that they needed to multiply a speed times the number of hours, an important connection. This shows not so much a deficiency in math or science knowledge, but a problem with comprehension of the initial question.

There were 11 students who simply added the speed of the tailwind and plane together to determine how many miles per hour the plane would travel. Two students added the wind and plane together but then divided by the number of hours. This thinking shows the necessity to support multiplication and division as concepts. Although this is not strictly speaking the use of AOT methods, it was important to identify where the students. The last student whose methods
could be determined subtracted the wind speed form the speed of the plain as if there had been a headwind, showing either a misunderstanding or misreading of the type of wind.

*question 5.* This question was interesting because it showed great variability in what students understood about the question. It was clear that many students were confused by the situation described in the question. The students were expected to find out the difference in time of two identical planes that travel the same distance one with a tailwind and the other with no wind. Five students solved the problem as expected by dividing the distance by the actual speed of the plane and then finding the difference of those times (see Appendix E- Table 5). Another student answered the question correctly but showed no work. There was one student who used a novel approach of counting up by the speed to achieve the distance. They added 200 mph three times until they reached the appropriate distance. Unfortunately, they did not find the speed or number of hours for the second plane and this approach was categorized as incomplete conventional.

Three students showed few connections to this problem when the subtracted speed from distance and it was difficult to find many connections to build off from this method. Troublingly, three students mistook the distance that both planes traveled for the speed of the second plane. The work of these students showed some connections being made about both the mathematics and science content, again however, it seemed as if reading comprehension was the cause of the missed connections.

*Extra credit.* Overall, it seemed as if there were fewer opportunities for AOT to excel for those students who chose to do the extra credit sheet. There were more occurrences of answers that were characterized as correct and conventional. Although these outcomes are desirable,
when students achieve correct answers in the manner expected there is obviously not an
opportunity to build upon missed connections.

question 1. An example of these correct answers is illustrated by the first question. All
13 students provided answers that fell into the correct conventional category (see Appendix E-
Table 6). This was of interest because on the same question only 65% of regular credit students
got this answer correct.

question 2. The second question on the extra credit sheet was also a duplicate from the
regular credit option. Again students faired much better than their counterparts who chose to
complete the regular credit sheet. Five students were categorized as correct conventional with
two more getting the right answer without showing any work (see Appendix E- Table 7). Only
26% of students who opted for the regular sheet got this question correct. There was one student
who found the correct amount of time for both planes but miscalculated the difference between
the two. This was a chance to support this student by encouraging their thought process in
attacking the problem, without simply saying that they had gotten it wrong.

Again there were some students who were confused about what to do with distance and
speed. Two students subtracted speed from distance and two more simply misread the problem
and used the distance for the speed of the second plane. Unfortunately, neither of these thought
processes allowed an opportunity to build upon connections that the students had made. For both
regular and extra credit students this problem proved of little use for AOT methods. At least part
of the problem was the possibly confusing manner in which the question was written. When
students had a hard time understanding what was going on, they had little chance to succeed.

question 3. On the third problem on the extra credit sheet students needed to determine
how long it would take two planes to fly 3000 miles one with a tailwind and one without. They
then needed to determine how much longer the plane with no tailwind would take and convert that into a dollar amount using $700 per hour. The difficulty with this problem was not in any of the individual steps, but in the number of steps that were required. Seven students achieved the correct conventional categorization (see Appendix E- Table 8). One more did the question conventionally and simply did not read the question and could not deliver the correct answer.

One student multiplied the speed times the cost per hour. This was encouraging because they understood that they needed to multiply something by the cost per hour, they just did not find the number of hours extra that the plane took. The one student who added speed and distance together was less encouraging and it was difficult to find anything to build on with that thinking.

**question 4.** Converting one number from kph into mph in this problem proved to be unexpectedly difficult. I thought students would recognize that they needed to convert the speed of the wind and add that to the cruising speed of the plane. Four students were able to do so in the manner expected (see Appendix E- Table 9). Another student correctly completed this problem in an unconventional way by converting the initial speed of the plane to kph and then adding the wind before converting everything back into mph. Another student conventionally converted the tailwind into mph but miscalculated when adding them back together. Another example of a strong connection by a student that would be overlooked without careful analysis of their work.

Interestingly, three students applied the conversion factor to the plane even though it was already in mph. The good news was that they had done so correctly. AOT allowed for the determination that they understood how to convert units but simply misread the problem.
question 5. The final question was interesting and showed a lot of strong connections by students who did not arrive at the correct answer. They needed to find the speed of two planes moving opposite directions within the jet stream. The problem then required students to find the difference and half it because the wind was acting on both planes. Only three students were able to get this question right, all of them using the expected methods (see Appendix E- Table 10). Five students found the difference between the groundspeed of the planes but did not recognize that the wind was acting on both of them. Two more found the speed of each plane but then failed to complete the problem. Both of these instances of incorrect answers using conventional methods showed strong connections by the students that should not have been overlooked.

Reflection.

Students did indeed have a difficult time with many of these problems, which was not unexpected. However, my mentor teacher was amazed by the difficulty she saw some students experience. One of the impediments to student success seemed to be their understanding of the problem. This might have related to reading comprehension and/or to their conceptualization of the scenario. I found that frequently my feedback on student work involved highlighting portions of the question along with portions of their work where it was useful. I also frequently drew arrows in order to graphically represent the mathematics that students had used as well as the mathematics that I would have used.

If this lesson were going to be repeated I would ask students to not only show their work but to also sketch the direction of the planes and the winds. This could help them to understand the situation and help me to determine how they saw the problem.

In the post lesson analysis of authenticity I rated this lesson as a 4. My previous concerns about practitioners in the field not performing calculations such as this seemed to be a little
misguided. After further thought these are exactly the kinds of calculations and forces that are considered by engineers all the time. Previously they had seemed too simple to be truly authentic. After teaching the lesson it was clear that these concepts were appropriate for these students so the nature of the questions should not change the perceived authenticity of the lesson.

The most difficult portion for me came at the end of this process. It was not clear in what manner to proceed. The student work had brought to light many situations that needed an intervention as well as many concepts on which to build. The difficulty however was that students had seemed to grasp the scientific concept and it was hard to justify taking more time to scaffold the mathematical concepts used. Although, the lesson itself might have been a nice blend of science and mathematical knowledge, the student work seemed to tip the scale in the direction of a math heavy lesson. I elected to carefully respond to each students work in writing but we spent very little class time discussing the activity afterward except to reinforce the idea that the jet stream is an atmospheric current that affects air travel.

**Research Questions Answered**

This study helps to answer the research questions posed in chapter one. It is possible for pre-service teachers can generate lessons that authentically integrate mathematical concepts into science lessons. A great deal was also learned about the positive effects the actor-oriented transfer perspective can have on instruction.

**Authenticity.**

The lessons that were a part of this research project were initially rated three and four out of five for authenticity. These numbers reflect lessons that use mathematics within the science content in a meaningful way. After instruction both lessons were rated as four out of five. Although these lessons did not mirror the tasks that field practitioners might use to study the
same concepts they certainly did represent important prerequisite knowledge for those fields. Students used mathematics knowledge in order to help model events. In the case of tides real data was used to relate the alignment of the sun, Earth, and moon to actual event and in the jet stream lesson the numbers represented approximations of how air traffic is scheduled.

**Actor-Oriented Transfer.**

Actor Oriented Transfer methods proved to be very useful for determining how students perceived problems and what positive connections had been made. In every question in which students arrived at an incorrect answer there was at least one student who had used some of the correct mathematical concepts. It was possible to give these students feedback, especially on an individual basis that illustrated positive aspects of their work, while helping to broaden their understanding of how the mathematics and science were related.

In this study the information gathered was only minimally useful for developing future instruction. AOT methods had provided a great deal of insight into the thinking of the students that could have been useful for planning future instruction. However, it was difficult to plan future lessons that allowed continued development of the mathematical ideas while moving on to new scientific content.
Chapter 5
Discussion and Recommendations

This study was conducted in order to answer the following questions:

Can new or pre-service teachers authentically integrate mathematical concepts into science lessons?

What impact can the use of the actor-oriented transfer (AOT) perspective make in the practice of new teachers?

Authenticity is desirable because it has been shown to help students better to understand and arrive at realistic answers to contextual questions (Palm, 2008; Roth & Bowen, 1994). The actor-oriented transfer perspective is useful in helping teachers and researchers determine not just if a student is able to perform a given task as expected, but to determine what connections he/she had made within a given task (Lobato, 2008; Lockwood, 2011).

Authenticity

The lessons within this study were found to be mostly authentic although the tasks were not exactly those that would be used in the field by researchers studying the concepts addressed. The graphing tides lesson was made authentic through the use of real data from NOAA for a location that the students were familiar with. In this lesson students also interacted with the idea that the relative positions of the sun, moon, and Earth can be used to predict the range of tides. This idea would further help to support the idea that the time of day could be predicted for both high and low tides as well.

The jet stream calculations lesson initially appeared to be less authentic. The numbers were realistic and could have represented real air speeds but instead were chosen in order to make the questions result in nice round numbers. This lesson could have been made more
authentic by using actual air routes and the air speeds of airplanes in commercial fleets. In the
post assessment of this lesson however it moved from three to four in part because of the reality
of the situations. Planning routes to minimize travel time as well as fuel costs is a real practice
of the aviation industry but also of importance to sea and truck transport.

Although neither of these lessons was wholly authentic, they represent a step towards a
meaningful use of mathematics concepts. In both lessons students used scientific concepts and
mathematical skills that are essential to working in these fields. The major difficulty with
creating and using more authentic lessons is that those in the field often use mathematical
concepts and/or technology that are not cognitively appropriate for middle school students.

This difficulty does not mean that teachers should shun the goal of authenticity. Rather,
student activities should be designed to be as authentic as possible while maintaining cognitive
appropriateness for the students. This cognitive/authentic balance can be accomplished by
simplifying real tasks or investigating a smaller portion of these tasks.

Future research of this topic should include student surveys or interviews to ascertain
how students view these lessons and the affect that authenticity or the lack thereof has on their
motivation and retention. Interestingly, an unintended effect of this study was that a few
students began to see a larger connection between mathematics and science. On a year end
survey about the seventh grade science class five students responded to a question about what
they learned this year with a statement about how they learned that mathematics and science are
related. This view certainly reflects a meaningful connection that will serve these students well
in their future education as well as in future STEM careers.
AOT Perspective

Using AOT methods proved to be an excellent way to analyze student work and provide individual feedback. It was possible to categorize student responses using the system devised by Lockwood (2011), these categories helped to give a broad spectrum look at how students had performed. There were very few instances in which a student who arrived at an incorrect answer and had showed their work did not display some positive connections. These positive connections that students made did not go unnoticed and were used to give each student written feedback that showed how their thinking could be built upon in order to arrive at the correct answer. This could be useful to help to create a more positive climate for both the students as well as the teacher.

As also found by Lobato (2008), teachers using AOT methods do not have to simply think that students do not understand, instead, this perspective allows these teachers to focus on the positive outcomes that had occurred. In the same regard student motivation could be increased. Rather than students receiving feedback that reaffirms their self conceived notions of a mathematics deficit, they will see that although they might not have gotten "the answer" that they did indeed make some positive connections. It should be noted that this is not an entirely novel manner of analyzing student work; many teachers of mathematics have been giving students partial credit on assignments for years. These teachers have seen the utility in assessing students in a more nuanced manner than simply marking tasks as right or wrong.

Adopting an AOT perspective was extremely useful for analyzing student work in integrated mathematics and science lessons but did not prove to be as useful for informing future instruction. Ideally these lessons would have a follow up in which students would get to see a broad range of the connections their classmates made as well as a chance to use their work to
interact with similar problems. However, as noted by Judson (2013), it was difficult to justify taking time away from instruction of the material from the seventh grade science standards in order to engage in this schema broadening for mathematics content. For the AOT perspective to reach maximum utility it is necessary to build upon connections made by the students especially those whose work was categorized as unconventional.

Teachers who wish to integrate mathematics into science classrooms might better benefit from identifying specific concepts that they can support over the course of a unit or school year. These teachers might benefit from creating a bulletin board that supports a specific mathematical concept on which examples of student work could be posted. Teachers might also choose to group students either homogenously or heterogeneously based on the connections they made. These groups could help students to see the utility of their thinking as well as building using the ideas of other students. Students might benefit in future learning with a minimal amount of time being spent to reinforce mathematics.

In this study this continued use of a concept was accomplished somewhat effectively with the use of graphs. The difficulty experienced however was that different science topics required the use of different types of graphs. This sort of planning in which mathematics can be utilized within a unit rather than individual lessons can be difficult for pre-service and new teachers, but should become easier in future years as they become better acquainted with the time requirements of each unit as well as the mathematics abilities of their students.

Future research on the use of AOT methods should evaluate how students benefit from the use of the actor-oriented perspective over the course of longer integrated science units. The mathematical concepts would not need to be present in every lesson, but should ask students to use mathematics in a similar manner in each instance. This would perhaps allow students better
recognize the appropriate use of the mathematical concepts that they have been working on. It would be beneficial to use one mathematical concept in many different science lessons. Use of this strategy would allow the growth of the mathematical concept to be measured over the course of perhaps an entire year.

**Conclusion**

Integrating mathematics into middle school science instruction is indeed difficult. However, it is possible for teachers to design lessons that are grounded in concepts used in the practice of those working in various fields. The lessons might not be completely analogous to the everyday tasks of those practitioners, but it is possible for students to complete cognitively appropriate tasks that help to build a general understanding of the concept. Many science teachers are afraid to use mathematics because they feel like students might not be able to do the calculations or recognize the appropriate operations (Dixon & Brown, 2012; Schowls & Miller, 2012). Students do indeed have difficulty transferring knowledge between content areas. Through the use of AOT methods teachers can better focus on what connections students are making. Teachers who can plan and use specific mathematics concepts throughout the course of an entire year or longer instructional unit will be able to use the past positive connections made by students to broaden the students' schemata.
References


http://doi.org/10.1080/0020739X.2012.690895


Lobato, J. (2008). When students don’t apply the knowledge you think they have, rethink your assumptions about transfer. In M. P. Carlson & C. Rasmussen (Eds.), *Making the Connection: Research and Teaching in Undergraduate Mathematics Education.* Mathematical Association of America.


http://doi.org/10.1080/00461520.2012.693353


NGSS Lead States. (2013). Next generation science standards: For states, by states appendix L.


Appendix A

Example coding of student work.

<table>
<thead>
<tr>
<th>Code</th>
<th>Category</th>
<th>Student</th>
<th>Assigned Code</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Correct conventional</td>
<td>Jessica</td>
<td>2</td>
</tr>
<tr>
<td>2</td>
<td>Correct unconventional (converted initial speed to kph)</td>
<td>Franklin</td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Incorrect conventional (added incorrectly at the end)</td>
<td>Elizabeth</td>
<td>4</td>
</tr>
<tr>
<td>4</td>
<td>Incorrect conventional (converted speed and wind)</td>
<td>Reed</td>
<td>5</td>
</tr>
<tr>
<td>5</td>
<td>Incorrect unconventional (multiplied instead of dividing)</td>
<td>Melissa</td>
<td>1</td>
</tr>
<tr>
<td>6</td>
<td>Incomplete</td>
<td>Jed</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Julius</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Tommy</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fannie</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Esther</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Huxley</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Jolene</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wilson</td>
<td>4</td>
</tr>
</tbody>
</table>
Appendix B

Graphing Tides

Name:________________

<table>
<thead>
<tr>
<th>Day</th>
<th>High Tide</th>
<th>Low Tide</th>
<th>Day</th>
<th>High Tide</th>
<th>Low Tide</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3.0'</td>
<td>0.25'</td>
<td>5</td>
<td>3.75'</td>
<td>-0.5'</td>
</tr>
<tr>
<td>2</td>
<td>3.25'</td>
<td>0.0'</td>
<td>6</td>
<td>3.5'</td>
<td>-0.25'</td>
</tr>
<tr>
<td>3</td>
<td>3.5'</td>
<td>0.0'</td>
<td>7</td>
<td>3.0'</td>
<td>0.0'</td>
</tr>
<tr>
<td>4</td>
<td>3.25'</td>
<td>-.25'</td>
<td>8</td>
<td>3.25'</td>
<td>-.25'</td>
</tr>
</tbody>
</table>

Height Of Tide In Feet

Chart 1
Graphing Tides

Name: ________________________  Period: ______

1. Your graph shows either a neap tide or a spring tide, label the day that you think best shows this with either "neap" or "spring". Why do you think that this graph shows this type of tide? Explain your answer.

2. What day had the highest range of tides? Explain how you know this?

3. What was the range of the tides on the first day of your graph? (show your work)

Reference List:

- The range of tides can be found by finding the difference between high and low tides.

\[ \text{High Tide} - \text{Low Tide} = \text{Range of tides} \]

- Spring tides have a larger range
- Neap tides have a smaller range
Appendix C

Graphing Tides Analysis

**Table 1**: Analysis of student graphs from the Graphing Tides lesson.

<table>
<thead>
<tr>
<th>Category</th>
<th>Code</th>
<th>Number of Students out of 34</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graph as expected</td>
<td>1</td>
<td>22</td>
</tr>
<tr>
<td>Positive/Negative Inversion</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Points off by one integer</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Bottom of graph as zero</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>X axis spacing off</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

**Table 2**: Analysis of question 1: Your graph shows either a neap tide or a spring tide, label the day that you think best shows this with either "neap" or "spring". Why do you think that this graph shows this type of tide? Explain your answer.

<table>
<thead>
<tr>
<th>Category</th>
<th>Code</th>
<th>Number of Students out of 34</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct conventional</td>
<td>1</td>
<td>16</td>
</tr>
<tr>
<td>Correct unelaborated</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>Identified both types</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>No answer</td>
<td>4</td>
<td>6</td>
</tr>
<tr>
<td>Incorrect unelaborated</td>
<td>5</td>
<td>5</td>
</tr>
</tbody>
</table>

**Table 3**: Analysis of question 2: What day had the highest range of tides? Explain how you know this?

<table>
<thead>
<tr>
<th>Category</th>
<th>Code</th>
<th>Number of Students out of 34</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct conventional (visual)</td>
<td>1</td>
<td>18</td>
</tr>
<tr>
<td>Correct conventional (calculation)</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Correct unelaborated</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>Incorrect conventional (visual, graph incorrect)</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Incorrect conventional (subtracting a negative)</td>
<td>5</td>
<td>2</td>
</tr>
</tbody>
</table>
**Table 4:** Analysis of question 3: What was the range of the tides on the first day of your graph? (show your work)

<table>
<thead>
<tr>
<th>Category</th>
<th>Code</th>
<th>Number of Students out of 34</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct conventional</td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>Correct unconventional</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Incomplete conventional</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>Incorrect conventional (clerical error)</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>Incorrect conventional (subtracting a negative)</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Unconventional (drawing)</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>Unconventional (approximation)</td>
<td>7</td>
<td>2</td>
</tr>
<tr>
<td>No answer</td>
<td>8</td>
<td>5</td>
</tr>
</tbody>
</table>
Appendix D

Jet Stream Calculations Regular Credit

Name:______________________ Period:_____

To receive full credit you must show all of your work!

1. A plane that normally can fly 430 mph is flying with a 200 mph tailwind. How fast will the plane be moving?

2. A plane is moving 562 kph into a 138 kph headwind. How fast can the plane fly outside of the headwind?

3. A plane flies 1800 miles in 3 hours outside of the jet stream and it takes 2 hours within the jet stream. How many miles per hour faster is the plane flying in the jet stream?
4. How many km further can a plane that has a normal top speed of 550 kph go in three hours if it flies with a jet stream moving 230 kph?

5. Two planes can normally fly 200 miles per hour. One plane flies 600 miles with a 100 mph tailwind, another flies 600 miles with no wind. How much time will the plain with the tailwind save?
Jet Stream Calculations Extra Credit

Name:______________________          Period:_____  
______________________________________________________________________________

To receive full credit you must show all of your work!

1. A plane flies 1800 miles in 3 hours outside of the jet stream and it takes 2 hours within the jet stream. How many miles per hour faster is the plane flying in the jet stream?

2. Two planes can normally fly 200 miles per hour. One plane flies 600 miles with a 100 mph tailwind, another flies 600 miles with no wind. How much time will the plane with the tailwind save?

3. Two identical planes cost 700 dollars an hour to fly. They both have a cruising speed of 500 mph. Plane A flies 3000 miles from Los Angeles to New York with an average tailwind of 100 mph. Plane B has no tailwind. Which plane costs more to fly? How much more?
4. How many miles per hour will a plane with a cruising speed of 450 mph go with a 200 kph tailwind? 1 Mile = 1.6 kph.

5. Two identical planes fly in opposite directions for 900 miles. Plane A flies against the jet stream, plane B flies with the jet stream. Plane A gets there in 3 hours, plane B gets there in 2 hours. How fast is the jet stream moving?
Appendix E

Regular Credit Analysis

Table 1: Analysis of question 1: A plane that normally can fly 430 mph is flying with a 200 mph tailwind. How fast will the plane be moving?

<table>
<thead>
<tr>
<th>Category</th>
<th>Code</th>
<th>Number of Students out of 23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct conventional</td>
<td>1</td>
<td>22</td>
</tr>
<tr>
<td>Incorrect conventional</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>(computation error)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 2: Analysis of question 2: A plane is moving 562 kph into a 138 kph headwind. How fast can the plane fly outside of the headwind?

<table>
<thead>
<tr>
<th>Category</th>
<th>Code</th>
<th>Number of Students out of 23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct conventional</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Correct conventional (added)</td>
<td>2</td>
<td>6</td>
</tr>
<tr>
<td>Incorrect conventional</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>(subtracted a positive)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: Analysis of question 3: A plane flies 1800 miles in 3 hours outside of the jet stream and it takes 2 hours within the jet stream. How many miles per hour faster is the plane flying in the jet stream?

<table>
<thead>
<tr>
<th>Category</th>
<th>Code</th>
<th>Number of Students out of 23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct conventional</td>
<td>1</td>
<td>14</td>
</tr>
<tr>
<td>Correct unelaborated</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Incorrect conventional</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>(wrong operation)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incorrect unconventional</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>(mistook plane directions)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incorrect unconventional</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>(added hours to miles)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incorrect unconventional</td>
<td>6</td>
<td>1</td>
</tr>
<tr>
<td>(found speed of 1 plane)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incorrect unelaborated</td>
<td>7</td>
<td>1</td>
</tr>
<tr>
<td>Incomplete</td>
<td>8</td>
<td>3</td>
</tr>
</tbody>
</table>
Table 4: Analysis of question 4: How many km further can a plane that has a normal top speed of 550 kph go in three hours if it flies with a jet stream moving 230 kph?

<table>
<thead>
<tr>
<th>Category</th>
<th>Code</th>
<th>Number of Students out of 23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct conventional</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Incorrect conventional (added then multiplied)</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td>Incorrect unconventional (added)</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Incorrect unconventional (added then divided)</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>Incorrect unconventional (subtracted wind from plane speed)</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Incorrect unelaborated</td>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>Incomplete</td>
<td>7</td>
<td>2</td>
</tr>
</tbody>
</table>

Table 5: Analysis of question 5: Two planes can normally fly 200 miles per hour. One plane flies 600 miles with a 100 mph tailwind, another flies 600 miles with no wind. How much time will the plain with the tailwind save?

<table>
<thead>
<tr>
<th>Category</th>
<th>Code</th>
<th>Number of Students out of 23</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct conventional</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Correct unelaborated</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Incorrect unconventional (subtracted mph from distance)</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Incorrect unconventional (mistook distance for speed)</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Incomplete conventional (counted up by mph)</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>Unelaborated</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Incomplete unelaborated</td>
<td>7</td>
<td>4</td>
</tr>
</tbody>
</table>
Extra Credit Analysis

Table 6: Analysis of question 1: A plane flies 1800 miles in 3 hours outside of the jet stream and it takes 2 hours within the jet stream. How many miles per hour faster is the plane flying in the jet stream?

<table>
<thead>
<tr>
<th>Category</th>
<th>Code</th>
<th>Number of Students out of 13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct conventional</td>
<td>1</td>
<td>13</td>
</tr>
</tbody>
</table>

Table 7: Analysis of question 2: Two planes can normally fly 200 miles per hour. One plane flies 600 miles with a 100 mph tailwind, another flies 600 miles with no wind. How much time will the plane with the tailwind save?

<table>
<thead>
<tr>
<th>Category</th>
<th>Code</th>
<th>Number of Students out of 13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct conventional</td>
<td>1</td>
<td>5</td>
</tr>
<tr>
<td>Correct unelaborated</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Incorrect conventional</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>(subtraction error at end)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incorrect unconventional</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>(subtracted wind from plane speed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incorrect unconventional</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>(substituted distance for speed)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incorrect unelaborated</td>
<td>6</td>
<td>1</td>
</tr>
</tbody>
</table>
Table 8: Analysis of question 3: Two identical planes cost 700 dollars an hour to fly. They both have a cruising speed of 500 mph. Plane A flies 3000 miles from Los Angeles to New York with an average tailwind of 100 mph. Plane B has no tailwind. Which plane costs more to fly? How much more?

<table>
<thead>
<tr>
<th>Category</th>
<th>Code</th>
<th>Number of Students out of 13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct conventional</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>Incorrect conventional</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>(did not read the question)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incorrect unconventional</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>(added speed and distance)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incorrect unconventional</td>
<td>4</td>
<td>1</td>
</tr>
<tr>
<td>(multiplied speed times cost/hour)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incorrect unelaborated</td>
<td>5</td>
<td>2</td>
</tr>
<tr>
<td>Incomplete</td>
<td>6</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 9: Analysis of question 4: How many miles per hour will a plane with a cruising speed of 450 mph go with a 200 kph tailwind? 1 Mile = 1.6 kph.

<table>
<thead>
<tr>
<th>Category</th>
<th>Code</th>
<th>Number of Students out of 13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct conventional</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>Correct unconventional</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>(converted initial speed to kph)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incorrect conventional</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>(added incorrectly at the end)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incorrect conventional</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>(converted speed and wind)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incorrect unconventional</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>(multiplied instead of dividing)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Incomplete</td>
<td>6</td>
<td>2</td>
</tr>
</tbody>
</table>
Table 10: Analysis of question 5: Two identical planes fly in opposite directions for 900 miles. Plane A flies against the jet stream, plane B flies with the jet stream. Plane A gets there in 3 hours, plane B gets there in 2 hours. How fast is the jet stream moving?

<table>
<thead>
<tr>
<th>Category</th>
<th>Code</th>
<th>Number of Students out of 13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Correct conventional</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Incorrect conventional (found speed of each plane)</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Incorrect conventional (found the difference between planes)</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Incomplete</td>
<td>4</td>
<td>3</td>
</tr>
</tbody>
</table>
A determination has been made that the following research study is exempt from IRB review because it involves:

Category 1 - research conducted in established or commonly accepted educational settings, involving normal educational practices

Project Title: A Trial of Actor Oriented Research Methods For Use in an Integrated Mathematics and Sciences Lesson in the Middle School Classroom

Primary Investigator: Joshua Adam Olson

Co-Investigator(s): 

Advisor: Ralph Martin  
(if applicable)

Department: Teacher Education

Rebecca Cale, AAB, CIP  
Office of Research Compliance

Date: 2/6/15

The approval remains in effect provided the study is conducted exactly as described in your application for review. Any additions or modifications to the project must be approved (as an amendment) prior to implementation.
Plagiarism detect

online service to detect plagiarism in documents, text or websites

words in text
29376
sentences
2221

plagiarised from source: >1%
1. the difference between a positive and negative


plagiarised from source: >1%
1. paper of the National Middle School Association


plagiarised from source: >1%
1. paper of the National Middle School Association

http://www.mws.ca/33/about/leaders

plagiarised from source: >1%
1. paper of the National Middle School Association

http://ms-principal.msw.tonyelfy.a33.rij.at/
plagiarised from source: >1%
1. paper of the National Middle School Association

plagiarised from source: >1%
1. paper of the National Middle School Association

plagiarism detected
0%