THE EFFECTS OF DOCUMENTED PROBLEM SOLUTIONS ON PROBLEM
SOLVING SKILLS FOR INTRODUCTORY COLLEGE PHYSICS COURSES

by

John Henry Davis

A professional paper submitted in partial fulfillment
of the requirements for the degree

of

Master of Science

in

Science Education

MONTANA STATE UNIVERSITY
Bozeman, Montana

July 2014
STATEMENT OF PERMISSION TO USE

In presenting this professional paper in partial fulfillment of the requirements for a master’s degree at Montana State University, I agree that the MSSE Program shall make it available to borrowers under rules of the program.

John Henry Davis

July 2014
### TABLE OF CONTENTS

**INTRODUCTION AND BACKGROUND** .................................................................1

**CONCEPTUAL FRAMEWORK** .............................................................................4

**METHODOLOGY** ..............................................................................................7

**DATA AND ANALYSIS** ......................................................................................14

**INTERPRETATION AND CONCLUSION** ..........................................................27

**VALUE** ............................................................................................................30

**REFERENCES CITED** ........................................................................................39

**APPENDICES** ...................................................................................................37

- APPENDIX A: Western Carolina University IRB Approval ...............................38
- APPENDIX B: Student Confidence in Problem Solving Pre-Treatment Likert Survey ..................................................................................................................42
- APPENDIX C: Pre-Treatment Interview Questions .............................................46
- APPENDIX D: Documented Problem Solutions Student Directions ..................48
- APPENDIX E: Documented Problem Solution #1 .............................................50
- APPENDIX F: Documented Problem Solution #2 .............................................52
- APPENDIX G: Student Confidence in Problem Solving Post-Treatment Likert Survey .............................................................................................................54
- APPENDIX H: Post-Treatment Interview Questions ..........................................56
- APPENDIX I: Treatment vs. Non-Treatment .......................................................58
LIST OF TABLES

1. Data Triangulation Matrix .................................................................................13
LIST OF FIGURES

1. Survey Analysis .................................................................15
2. Pre vs. Post-Treatment Percent of Student Responses, Questions 1-3..............16
3. Pre vs. Post-Treatment Percent of Survey Responses, Questions 4-6,..............18
4. Student Sample Documented Problem Solution #1.....................................21
5. Student Sample Documented Problem Solution #2....................................23
6. Student Sample Documented Problem Solution #3.....................................26
ABSTRACT

My students struggle to solve physics word problems when the solution is not explicitly given to them. They can understand abstract concepts and repeat a problem that is solved correctly for them but cannot solve word problems that are new. The ability to solve problems should be a skill that a student acquires or improves at as a result of taking a college physics course. Over the past several years of teaching I have noticed that despite my best efforts, I have not observed any measurable improvement in my students’ abilities to solve physics problems. As a physics teacher, I needed to find some way to help my students become more comfortable and learn to enjoy solving physics problems. This capstone projects investigates the use of formative assessments on determining what changes can be implemented in teaching that might help students become more proficient at solving physics problems.
INTRODUCTION AND BACKGROUND

I teach at Western Carolina University, a four year, state school located in Cullowhee, North Carolina. Western Carolina is accredited by the Southern Association of Colleges and Schools Commission on Colleges to award associate degrees, diplomas and certificates.

I have taught several chemistry and physics courses at the high school and college level for over ten years. Currently, I teach introduction to chemistry, general chemistry, college physics and general physics. I am responsible for teaching the lecture and lab components for these courses, as well as grading and reporting grades. My students vary in their abilities and interests, as well as their educational and career goals. Some of my students are recently out of high school where they have taken a chemistry or physics course and are interested in eventually majoring in pre-nursing or pre-engineering. I also have older students who have worked for several years but were recently laid off and are attempting to start a new career, often in the medical field.

My approach to teaching a new chapter in a physics course begins with a lecture including a PowerPoint presentation to introduce new concepts and define new terms. Next, I often incorporate either an online virtual simulator or a physical demonstration to help students visualize the concepts being taught and how they are affected by various changes in several variables, while also leading questions to probe my students for understanding of the concepts and to clear up misconceptions that I have become aware of over the years. Then, I begin solving simple problems applying the concepts and gradually move on to solving some more complicated physics problems. Next, I move on to a laboratory investigation in which students collect data to verify some of the laws or
concepts they have learned in the lecture and to apply this knowledge to solve more complicated physics problems.

At the end of the lesson or unit, students are required to attempt to solve more involved physics word problems that require them to apply the concepts learned in the lesson. These problems also incorporate concepts from earlier topics into the new concepts we are learning. During this part of the lesson, I try to re-iterate some of the rules that we have all learned with regard to solving word problems. These rules include the following steps:

1. Write down what you know.
2. Write down what you are being asked to solve.
3. Draw a picture of the problem to help visualize the concepts.
4. Try to look through all the equations and think about the principles the class has been learning and attempt to find an appropriate equation or equations that can be used to solve for the unknown.
5. Be sure to rearrange all equations symbolically before using values.
6. When plugging in values, be sure to include appropriate units so that all necessary conversions are performed.
7. Check to make sure that your answer makes sense.

Regardless of the educational and/or career goals, most of my students are very motivated, complete homework, and study for exams regularly. My exams usually include a variety of conceptual, multiple choice questions that attempt to assess the extent to which my students have mastered the content and concepts that we have covered in the class. The exams also typically include more in-depth word problems to assess the extent
to which my students can apply the knowledge that they have acquired. This is the area in which my students often struggle. Over the years, it has become more evident that my students are not comfortable, or capable of solving physics problems independently. I frequently receive student feedback from course evaluations in which students express their frustration with solving word problems.

According to many of my students, when I introduced new topics, gave demonstrations and solved problems at the board, while guiding students through the solution, my students comprehended the material and felt confident about what they had learned in class. However, when students were given the task of using previously learned information to solve a new problem, they felt completely lost and incapable of completing the task.

I have become increasingly aware of this problem and began to ask myself why my students struggle to solving problems independently. Two possibilities seemed plausible: my students did not have the necessary mastery of the material that related to the problem, or my students have not acquired any useful systematic process for solving general problems, or physics problems specifically.

I researched various assessment techniques and ultimately decided to use a Classroom Assessment Technique (CAT) to learn more about why my students struggled with solving physics problems and how I could help them become more comfortable with this task. Classroom Assessment Techniques are formative assessment methods that are used to help teachers determine whether or not students understand the material, and to gauge the effectiveness of the teaching methods being used. The CAT most applicable to my area of interest was the Documented Problem Solutions (DPS). Documented
Problem Solutions as a formative assessment requires students to narrate the steps and thought processes taken while attempting to solve a problem.

This question grew into the focus question of this research. This capstone projects investigated the use of Documented Problem Solutions in order to answer the following questions:

1. Can the use of the Documented Problem Solutions CAT help physics students become better at solving word physics word problems?
2. Why do my students struggle to solve physics problems?
3. What activities and strategies can I employ to help students improve at solving physics word problems?

CONCEPTUAL FRAMEWORK

Assessment is a large, complex area in education. In the classroom, it is sometimes evident when students are unclear about concepts or material being taught. Although students may not verbally communicate their concerns, students will indicate their insecurities, in various ways, including their body language. The instructor can assess the student with careful inquiries to judge the student's understanding without promoting further insecurities. Such inquiries can be acquired by administering Classroom Assessment Techniques (CAT). CATs help teachers use feedback from students to monitor what, how much, and how well their students are learning (Angelo & Cross, 1993).

To ensure an optimal learning environment, it is important that students know that their teacher is invested in their learning. As a result, students are less resistant to the
course and more open to acquiring the knowledge necessary to be successful. The challenge that many teachers face, however, is how to assess students’ understanding so that it is clear to students that maintaining a student centered learning environment is of primary concern to the teacher, meaning that the acquisition of course material is first and foremost at the forefront of each lesson. According to Feldgen and Clua (2009), Classroom Assessment Techniques are useful in “monitor[ing] learning throughout the semester. [Teachers] get feedback from students on their learning and students get feedback on the results of the assessment and suggestions to improve learning” (n.p.). The authors acknowledge the difficulty that many students have showing and telling how they arrived at a solution to a problem. The authors stress the importance of assessing students using the Documented Problem Solutions technique so that students not only get the answer correct but also are able to narrate how they arrived at the correct answer. Such a technique demonstrates to students that simply arriving as a correct answer is not enough; it stresses the importance of the process to arrive at the correct answer. By understanding the process, students show their teachers whether they are successfully acquiring course content (Feldgen & Clua, 2009).

The ultimate goal of teachers should be to create a successful collaborative learning environment where students can grow and cultivate as learners. Implementing CATs is critical for such a collaboration to take place. Teachers are responsible for focusing on course objectives, and such objectives can be measured through students’ outcomes. A narrow area of assessment in education is through testing, but not all students test well. Therefore, CATs offer teachers the opportunity to assess whether
students can clearly master the concepts and apply them accordingly. Goldstein (2007) writes:

Documented Problem Solutions directs students to provide a step-by-step narrative of their solution to a problem. This CAT gives the instructor insight into students’ problem-solving strategies and the opportunity to point out specific ways students’ thinking may lead them in the wrong direction. It also compels students to reflect on their approach to understanding and solving problems. (p.79)

Documented Problem Solutions as a CAT also have an advantage in that students who lack the security of knowing course content can still benefit from the individualized feedback given by instructor comments, when the solution is returned. It is vital to provide students with detailed, timely feedback specific to each learner. Additionally, individualized feedback is important because it gives the students the opportunity to rectify any problems as they advance in the course. As a result, students know what to correct, and their acquisition of knowledge increases (Angelo, 1993).

Timely feedback allows students to make corrections early in the course, and CATs allow teachers the opportunity to see what weaknesses students might need to work on while completing future assignments. According to Harwood and Cohen (1999), “[f]or Classroom Assessment to be effective, it is essential that the [teacher] ‘close the feedback loop’ by discussing the result and suggested changes with students” (p. 700). It is important that teachers introduce, facilitate, and culminate course content into "teachable moments" to include course objectives and theories of importance. Also, teachers should continue to remind the students over the course of a semester of the
material that should be noted for future lessons. CATs used consistently over the duration of a course provide such aides in maintaining a student centered classroom. Additionally, great emphasis should be established on creating a personal relationship with students, not simply to facilitate a comfortable learning environment but also to convey to them that their teacher is genuinely interested in their academic progress and in their ultimate educational goals (Harwood, 1999). Wise (2004) notes “the use of CATs does not guarantee teaching excellence or student learning, but it can help create an environment that will facilitate student learning” (p.76)

METHODOLOGY

My capstone project used students from two of my introductory physics classes at Western Carolina University. There were a total of 113 students in both classes; 67 students were originally enrolled in the Class 1, and 66 students were enrolled in the Class 2. Before I could begin treatment, nine students withdrew from the Class 1, and eight students withdrew from Class 2. After I started the treatment, 23 students in Class 1 agreed to participate in the study, and 26 students from Class 2 agreed to participate in the study. All students, however, were required to participate in the completion of the DPS, as the assessment and problems being solved were still part of the course. Only students who agreed to participate in the study completed the pre-treatment and post-treatment surveys and the pre-treatment and post treatment interviews. None of the students were given extra credit for completing the DPS or for participating in the study. I also kept a journal with notes during all phases of the study, using only the data from students who agreed to participate in the study. The research methodology for this
project was approved by Western Carolina University’s Institutional Review Board in compliance for working with human subjects was maintained (Appendix A).

Both physics classes began by covering Unit 1 without the inclusion of the Documented Problems Solution CAT. Topics covered during Unit 1 included Introduction to Physics, One-Dimensional Kinematics, and Vectors. I taught the unit using the same format that I have used in recent years of teaching. I began with a PowerPoint lecture to introduce new terms and attempted to define and explain concepts based on previous knowledge that I believed my students had already possessed. I moved to using simulations and/or physical demonstrations to help students visualize concepts more concretely and asked leading questions to help clear up misconceptions. The next aspect of delivery of the lessons involved student centered experiments to give my students some practice and experience at testing and applying the concepts they were learning. The final step involved assigning more involved physics word problems for my students to work on, in which case I followed their efforts up by solving the word problems myself, while answering any questions that they had. No students participated in any activities related to DPS as this unit was covered.

After Unit 1 had been covered, both Class 1 and 2 took the Unit 1 exam. Part of the exam included a single, free-response, more involved physics word problem. I collected notes in my teaching journal in order to answer the questions; Why do students struggle to solve physics word problems? Can the use of the Documented Problem Solutions CAT help physics students become better at solving word physics word problems?
A few days after the students took the exam, the students who had agreed to participate in the study completed the Student Confidence In Physics Problem Solving Likert Pre-Treatment Survey (Appendix B). I created this instrument in order to gather information with regard to student’s self-perceptions about their ability to solve physics problems. In this scale, a score of 5 represented a student attitude of *Strongly Agree*, a 4 signified *Agree*, a 3 signified *Uncertain*, a 2 signified *Disagree*, and a 1 indicated *Strongly Disagree*. To analyze the data from the Student Confidence in Physics Problem Solving Likert Pre-Treatment Survey, I averaged the responses of all students.

Pre-Treatment interviews were conducted after the Unit 1 exam. The pre-treatment interview questions were written with the intention of answering the following research question: Why do my students struggle to solve physics problems? I chose interviewees based on their overall performance in the class. I separated the list of all students who had agreed to participate into three groups; students with an A average, students with a C average and students with a D or below average. I then randomly choose two students from each group to participate in student interviews (Appendix C).

Unit 2, involved Two-Dimensional Kinematics, Newton’s Laws, and Applications of Newton’s Laws. Only Class 1 received the treatment during Unit 2. Class 2 continued with Unit 2 without the inclusion of the DPS. The students in Class 1 were all given the Directions for Completing the DPS (Appendix D). This handout explained how to complete a DPS and also explained the justification for requiring students to complete the DPS. After the directions for completing the assessment were thoroughly explained and students were given a chance to complete a few practice assessments, the students were given more challenging physics word problems to solve during class lecture and during
the exam, during which time they wrote out a narrative explaining their process as they attempted to solve the problem.

During the treatment for Unit 2, Class 1, I required students to complete three DPS. One of the DPS involved projectile motion one involved Newton’s Second Law graphing problem, and the last involved Newton’s Second Law word problem. (Appendices E & F) All three DPS were presented as word problems in which the solutions were not explicitly shown as opposed to problems were variables were given, often known as “plug and chug” problems by physics teachers. After collecting and scanning the student DPS, I carefully studied them. My goal was to discover any trends that would reveal where in the problems students struggled.

As I found specific trends I would put some of the sample DPS on the overhead screen in order to share what I had learned with Class 1. Some samples would show students who had gotten stuck on the problem earlier on, some samples were of students who had progressed further in solving the problem, and some samples were of students who had solved the problem correctly and explained the steps that were taken clearly. During this time I was careful not to reveal any of the names of the students who had completed the DPS to the class.

During these Class 1 discussions, I shared with students the trends in their thought processes that seemed to be possible wrong turns and instances where I thought they were on track in solving the problems correctly. Additionally, I shared what I had learned from the DPS, particularly where I may have faltered in presenting the material, including concepts that I may not have explained clearly or thoroughly enough, in which case I would attempt to clarify the misconceptions and re-visit the concepts in whatever
manner I thought would increase student understanding. Finally, I would end the discussion by giving students a chance to ask questions regarding the concepts and steps involved in solving the problem. For each of the three DPS implemented during Unit 2 for Class 1, I kept detailed notes in my teaching journal. None of the students were given a grade for completing the three DPS but were given class participation credit for doing the work.

After covering Unit 2, both classes took an exam on Unit 2. During the exam I gave both classes a single more involved physics word problem to solve. I again collected detailed notes in my teaching journal in order to answer the question: Can the use of the Documented Problem Solutions CAT help physics students become better at solving word physics word problems?

Unit 3 involved Work and Energy, Linear Momentum and Collisions, and Simple Harmonic Motion. During Unit 3, both Class 1 and Class 2 received the treatment. I handed out the Directions for Completing the DPS to Class 2. I repeated the same treatment for both classes as was done in Unit 2 for Class 1. This treatment included three more DPS. One of the DPS involved work and energy, another involved momentum and collisions and the last problem combined concepts dealing with momentum and collisions and work and energy.

During Unit 3, for both classes, I carefully studied the DPS that were completed by students and recorded detailed notes in my teaching journal. The focus of my notes was to determine if the DPS being completed were resulting in any improvement in the students’ ability to solve problems and if the students were becoming more aware of their own systematic process for solving these problems. Based on the results of my own
observations after reviewing all of these notes, some general trends were revealed. The
trends that were revealed in my teaching journal helped me to answer the following
research questions: Can the use of the Documented Problem Solutions CAT help physics
students become better at solving word physics word problems? What activities and
strategies can I employ to help students improve at solving physics word problems?

In order to find out if the DPS strategy helped my students become better problem
solvers, I required all students in the class to complete another DPS as part of the Unit 3
exam. I reviewed the student work on this DPS and collected detailed notes in my
teaching journal. The notes in the teaching journal helped me answer the question: Can
the use of the Documented Problem Solutions CAT help physics students become better
at solving word physics word problems?

After finishing the Unit 3 exams, students who had agreed to participate in the
study completed the Student Confidence in Physics Problem Solving Post-Treatment
Likert Survey (Appendix G ). This Likert survey used the same format as the Pre-
Treatment Survey and attempted to gather information to students’ perceptions about the
extent to which they had improved at solving physics problems. The Likert Survey was
given to students to attempt to answer the question: Can the use of the Documented
Problem Solutions CAT help physics students become better at solving word physics
word problems?

My last data collection involved Post-Treatment student interviews with selected
students who participated in the study. The post-treatment interview questions were
written with the intention to answer all three research questions. The questions in the
post-treatment interviews were also designed to get more detailed data with regard to
why whether or not the students felt that the DPS helped them become more comfortable at solving physics word problems (Appendix H).

I selected interviewees for the post-treatment interviews based on my perception of their improvement on the responses to the DPS that were completed during the exams on all three units. I choose three students who I believed had shown improvement with regard to the quality of their DPS. I also choose three students who from my observations did not seem to show much improvement in the quality of their DPS after the treatment. All interviewees had previously agreed to participate in the study.

The instruments that were used during this study were designed so that I could gain the most in-depth perspective most pertinent to my research questions. Table 1 below outlines my triangulation matrix and describes how I planned to collect sufficient data to answer all of my research questions. The chronological order in which I implemented the treatment for Classes 1 and 2 can be seen in the Treatment vs. Non-Treatment. This order in which the treatment was organized was intended to help determine the extent to which the DPS treatment improved my students’ abilities to solve physics word problems (Appendix I).

Table 1  
Data Triangulation Matrix

<table>
<thead>
<tr>
<th>Research Questions</th>
<th>Pre-treatment Survey</th>
<th>Post-treatment Survey</th>
<th>Formative Assessment (DPS)</th>
<th>Teacher Journal</th>
<th>Pre-treatment Interviews</th>
<th>Post-treatment Interviews</th>
</tr>
</thead>
</table>

<table>
<thead>
<tr>
<th>Section</th>
<th>Yes</th>
<th>No</th>
<th>Amount</th>
<th>Grade</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Can the use of the Documented Problem Solutions CAT help physics</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>students become better at solving problems?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II. Why do students struggle to solve physics problems?</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>III. What activities and strategies can I employ to help students</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>become more capable and confident when solving physics problem?</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**DATA AND ANALYSIS**

There was an increase in the number of students with positive responses (agree or strongly agree) when the Student Confidence in Physics Problem Solving Likert Pre-Treatment Survey data was compared to the Student Confidence In Physics Problem Solving Likert Post-Treatment Survey ($N = 49$). The largest increase was for the question: I feel that I use a systematic method when solving physics problems. The average value for this question had an increase of 0.75 on the scale of 1-5 (strongly disagree to strongly agree). The smallest increase in confidence was reported for the question: The easiest part of solving a physics problem is finding the right equation. This question had an average value increase of only 0.14. There was a decrease in confidence for the question, The easiest part of solving a physics problem is doing the algebra required (Figure 1).
Figure 1. Survey Analysis, \((N = 49)\).
Note. 5=Strongly Agree, 4=Agree, 3=Indifferent, 2=Disagree, 1=Strongly Disagree.

When asked if students used a systematic method for solving problems pre-treatment, nearly 57% of students reported that they did not, and the other 43% of the students felt indifferently about the question (Figure 2). During the pre-treatment interview, one student said, “I cry, just kidding, I like to list the information that I know, what I need to know, and what is the goal of solving the problem.” Another student stated, “I feel that when solving most physics problems, that there is a method to solve them, even though it is sometimes hard to decide how to apply the method I know.” Another student stated “No. I do not feel as though I have any sort of method at all for solving physics problems, they frustrate me to no end.” Another student responded, “I learn physics by memorization.” The last student stated, “I don’t think from a scientific perspective so, often times it is more difficult to think logically.”
Figure 2. Pre vs. Post–Treatment Percent of Student Responses, Questions 1-3, \((N = 49)\).

On the Student Confidence in Physics Problem Solving Post-Treatment Survey, only 5% reported they did not have a systematic method, with 25% of the students agreeing, and the majority of students were indifferent to having a method (70%). When one student was asked about having a method for solving physics word problems, he stated, “I do feel like I have the right method down for solving physics problems, but the method I use does not always help me find the answer.”
When students were asked to respond to the statement: I feel confident my method for solving physics problems pre-treatment, 75% of the students disagreed. On the post-treatment survey, only 57% of the students disagreed to the same statement (Figure 2). When asked in the post-treatment interviews if they felt that they got better at solving physics problems as a result of completing and reviewing the DPS one student replied, “Yeah, they were really helpful, especially when I got to see an example of someone who got the problem right, because they explained how they solved the problem in a way that made sense to me.” Another student stated, “I liked that you would go over my solution sometimes in class, without anyone knowing it was mine and I didn’t have to ask you a question in front of the class.” Another student stated, “It was good to see that I was not the only one who didn’t understand the problems, and when you would go over the solutions, we got to talk about things that I didn’t know to ask about, but made sense.”

When asked if they felt that the easiest part of a physics problem is finding the right equation pretreatment, 94% of students either disagreed or strongly disagreed (Figure 3). The most difficult part of solving a physics word problem according many of the students in the pre-treatment interviews is the initial set up of the problem, in particular, trying to figure out which equation to use to try to solve the problem. One student said, “I struggle the most with setting up the physics problems. I can easier mess up plugging in all the information and then the problem will be wrong.” Another student stated that the concepts caused the most problems saying, “Remembering laws that tend to contradict what I personally would have believed reality for instance, law of gravity
where a heavier and lighter object released at the same time will hit the ground at the same time. Logic would tell me that the heavier object would hit the ground first.”

Another student stated, “I can re-do a problem once it is explained to me and understand it perfectly well, I just can’t get a problem started on my own, if it is new to me.”

![Pie charts showing pre and post treatment survey responses](image)

Figure 3. Pre vs. Post-Treatment Percent of Survey Responses, Questions 4-6, \(N = 49\)

When asked if the easiest part of solving a physics problem is doing the algebra pre-treatment, 88% of the students either agreed or were indifferent. When asked the
same question during the pre-treatment interview one student stated, “The easiest part of solving the physics problem is the actual math if I am given all the information and know the formula, I can do the math.” Another student responded, “Plugging in numbers after you know what the equation is.” After the treatment the percentage of students who still agreed or were indifferent to the same question only fell to 83%. When students were asked in the survey about how confident they felt they could jump back and forth between the math and the physics, the percentage of students that either disagreed or strongly disagreed fell from 73% before the treatment to only 45% after the treatment (Figure 3).

In the post-treatment interviews students were asked the question, What specific changes to the DPS activities do you think would be most effective at helping you improve at solving physics word problems? One student stated, “I wish we could get them graded by hand and given back instead of just going over some of them on the board.” Another student stated, “I would have preferred to work with someone on the solutions, so we could discuss and share our thoughts on how to solve the problem.” Another student answered the question by stating, “I enjoyed working on them, but it would have been more helpful to go over the correct solution while my own strategy was still fresh in my mind.”

The results of the student surveys and the interviews were helpful in determining if the implementation of the DPS helped students become better at solving physics word problems. However, they do not tell the whole story. As far as data collection was concerned, the analysis of the actual DPS that students completed and the notes made
during and after the discussions reviewing the DPS were more important in triangulating the data in order to answer all of the research questions.

Field notes were recorded for the eight DPS that students completed. For the two physics courses in which the DPS were implemented, there were over several hundred scanned copies of student solutions. The student who completed the DPS shown below solved the problem correctly. The student included enough comments on the description regarding how the problem was solved to show that the student understood the concepts. However, the student did not elaborate on the steps. This student was aware that the problem needed to be seen as two separate problems. There was an explanation given that the potential energy stored in the spring after it was compressed through a specific distance was equal to the kinetic energy of the bullet/block combination before reaching the spring, in order to solve for the velocity of the block/bullet before reaching the spring. The student also pointed out that the velocity of the bullet/block before reaching the spring was also the final velocity of the bullet/block after the collision between the bullet and the block. The student correctly pointed out that the conservation of momentum was used to solve for the initial velocity of the bullet before colliding with the block. The DPS however, is presented as an illustration of a DPS that does not describe the steps in enough detail for a productive class discussion.(Figure 4)
Documented Problem Solution:

This technique assesses your ability to conduct problem solving and your recall of the problem solving steps/framework that we have been working on in class. You will be asked to solve a problem and to think about how to approach a problem as you write down the solution steps.

PROCESS:

1. You will be provided with a problem situation/example. The situation/example should require a multi-step analysis.

2. You should draw a line down the center of a piece of paper. On the left side of the paper, you should attempt to solve the problem, showing all of your work. On the right side of the paper, you should write the steps or components of the problem-solving technique that your work reflects.

3. I will review the work to identify three that are good examples of correct answers with well-documented work and three examples of incorrect work, that show areas in need of improvement.

4. We will use these examples to spark class discussion.

\[ v = \frac{\Delta x}{\Delta t} \]

16) An 8 g bullet is shot into a 4.0 kg block, at rest on a frictionless horizontal surface. The bullet remains lodged in the block. The block moves into a spring and compresses it by 3.7 cm. The force constant of the spring is 2500 N/m. In the figure, the initial velocity of the bullet is closest to:

A) 440 m/s
B) 480 m/s
C) 500 m/s
D) 460 m/s
E) 520 m/s

<table>
<thead>
<tr>
<th>Solution</th>
<th>Steps Taken</th>
</tr>
</thead>
<tbody>
<tr>
<td>( m = 8 \text{ g} ) ( v_0 = \frac{\Delta x}{\Delta t} )</td>
<td>Listed down variables as I came to them</td>
</tr>
<tr>
<td>( m_{\text{block}} = 4 \text{ kg} ) ( v_0 = 0 )</td>
<td>Noticed problem to be two parts</td>
</tr>
<tr>
<td>( F_s = \frac{1}{2} k \Delta x^2 )</td>
<td>Bullet in Block ( \text{both at spring} )</td>
</tr>
<tr>
<td>( \Delta x = 3.7 \text{ cm} ) ( 0.037 \text{ m} )</td>
<td>wrote equations for spring and kinetic energy</td>
</tr>
<tr>
<td>( F_s = \frac{1}{2} k \Delta x^2 ) ( v = \frac{1}{2} \sqrt{k \Delta x^2} )</td>
<td>After calculating value for both ( \text{bullet and block} )</td>
</tr>
<tr>
<td>( 1/2 k \Delta x^2 = 5.8 \text{ m/s}^2 ) ( m_{\text{block}} v_0 ) ( (m_{\text{block}} + m_{\text{bullet}}) v_0 )</td>
<td>played number crunch with equations for momentum</td>
</tr>
<tr>
<td>( \Delta x = 3.7 \text{ cm} ) ( 3.7 \text{ cm} ) ( v_0 = 0 ) ( 0.037 \text{ m} ) ( 0.037 \text{ m} ) ( 1 ) ( m_{\text{bullet}} v_0 )</td>
<td>Had to look up equation for kinetic energy</td>
</tr>
</tbody>
</table>

Figure 4. Student Sample Documented Problem Solution #1.
As the students became more comfortable with completing the DPS, the quality of the DPS improved with regard to the detail given in the students’ description of how they solved or attempted to solve the problem. As no explicit grades were given for six out of eight of the DPS, some samples were not as descriptive. Students that had previously agreed to participate in the study were more thorough in describing how they attempted to solve the problem.

The DPS below shows a sample of a student’s DPS that was produced after the students became more comfortable with completing the DPS and more aware of the purpose of the activities. The problem that the student is attempting to solve is a very involved problem for an introductory physics student to solve, which requires several different concepts to be understood and several equations must be used to solve the problem. The student who completed this DPS solved the problem correctly and did an exemplary job explaining and elaborating on the steps that were taken to solve the problem. This solution is being shown to illustrate an example of a DPS that was effectively used in class discussions to show how to solve the problem correctly (Figure 5).
Figure 5. Student Sample Documented Problem Solution #2

The next DPS is one that was done by a different student, while attempting the same problem. That student did not solve the problem correctly. As previously stated, the problem was very involved, and the student came close to solving it correctly, completing many steps correctly and explaining the steps thoroughly showing strong understanding of the concepts and equations needed. The student correctly solved for the final velocity of the object as it leaves the ramp. The student used the work and energy theorem to solve for the final velocity of the object showing that the final kinetic energy
of the object was equal to the potential energy stored in the spring minus the gravitational energy or work done to get the object to the top of the incline and minus the work done against friction as the object slid to the top of the incline.

Yet, the student did make two crucial errors when attempting to solve for the horizontal displacement of the projectile. The first error that the student made was neglecting to separate the initial velocity of the object as it leaves the incline into the vertical and horizontal components and to analyze the motion of the projectile separately in each component. The value for the time the projectile spends in the air is the only the variable that is the same for both the horizontal and vertical motion of a projectile.

The second crucial error that the student makes is also evident from the DPS. The student explains on the right column that the final velocity of the projectile is assumed to be zero. A common misconception made by students in introductory physics classes when analyzing falling objects and projectiles is that when an object hits the ground and stops that the final velocity is equal to zero. As far as the motion is concerned, this is true, but with regard to solving the problem, the motion that must be analyzed in order to solve for the horizontal motion of the projectile must only incorporate the time the object was in the air. This motion does not include the moment the object touches the ground.

The notes that were made in the teaching journal and the discussion that followed this activity were engaging and helpful at mastering the concepts that were involved in this problem. It is important to note that these intricate details in the thought process of students when solving physics word problems would not have been discovered without the implementation of the DPS (Figure 6).
An object of mass 50 g is used to compress a spring with a spring constant of 50 N/m a distance of 30 cm. The object is then launched along the incline with an angle of 30° above the horizontal and which has a height of 1.3 m above the ground. The coefficient of static and kinetic friction between the object and the incline is 0.3. What horizontal distance beyond the incline will the object have upon being released?

$$m = 0.05 \text{ kg} \quad k = 50 \text{ N/m} \quad x = 0.3 \text{ m}$$
$$\theta = 30° \quad h = 1.3 \text{ m} \quad l = 2$$

$$m = 0.05(1.8) = 0.09 \text{ N}$$
$$d = \frac{1.3}{\cos 30°} = 2.25 \text{ m}$$

$$F_N = 4.9 \cos 30° = 4.24 \text{ N}$$
$$f_k = \mu_k F_N = 0.3(4.24) = 1.27 \text{ N}$$

$$t = \frac{kx^2 - mgx - f_kd}{\frac{1}{2} \alpha x^2}$$

$$v = \sqrt{\frac{2(0.05 \cdot 0.3^2)}{(0.05 \cdot 0.18 \cdot 0.3) - (0.12 \cdot 2.25)}}$$

$$v = \sqrt{7.28 \text{ m/s}^2}$$

$$v_f = 7.28 \text{ m/s}$$

$$v_f = 0 \quad d = -9.8 \quad a = -9.8 \quad t = 7.43 \text{ s}$$

$$v_f = at$$

$$d = v_f t = 0$$

$$d = 7.28 \text{ m} \cdot 7.43 = 5.42 \text{ m}$$

**Solution**

1. Write variables in correct units.
2. Draw diagram to find $F_N$.
3. Find normal force using weight and force body diagram.
4. Calculate $f_k$ from friction constant and normal force.
5. Using energy equations, find velocity.
6. Assuming acceleration is zero, velocity will be constant.
7. Final velocity will equal initial velocity of the box when it leaves the ramp.
8. Using the velocity as the box leaves the ramp and assuming $v_f = 0$, calculate how far in the air.
9. Use value $t$ to solve for distance traveled horizontally.
An object of mass 50 g is used to compress a spring with a spring constant of 50 N/m a distance of 30 cm. The object is then launched along the incline with an angle of 30° above the horizontal and which has a height of 1.3 m above the ground. The coefficient of static and kinetic friction between the object and the incline is 0.3. What horizontal distance beyond the incline will the object have upon being released?

![Diagram of the problem setup](image)

### Figure 6. Student Sample Documented Problem Solution #3

<table>
<thead>
<tr>
<th>Solution</th>
<th>Steps Taken</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>1. Write variables and units:</td>
</tr>
<tr>
<td></td>
<td>2. Draw diagram to find F_N</td>
</tr>
<tr>
<td></td>
<td>3. Find normal force using weight and force body diagram.</td>
</tr>
<tr>
<td></td>
<td>4. Calculate f_k from friction constant and normal force.</td>
</tr>
<tr>
<td></td>
<td>5. Using energy equations, find velocity.</td>
</tr>
<tr>
<td></td>
<td>6. Assuming acceleration is 0, velocity will be constant.</td>
</tr>
<tr>
<td></td>
<td>7. Final velocity will equal initial velocity of the box when it leaves the ramp.</td>
</tr>
<tr>
<td>m = 0.05kg</td>
<td></td>
</tr>
<tr>
<td>k = 50N/m</td>
<td></td>
</tr>
<tr>
<td>θ = 30°</td>
<td></td>
</tr>
<tr>
<td>h = 1.3m</td>
<td></td>
</tr>
<tr>
<td>l = 2</td>
<td></td>
</tr>
<tr>
<td>m = 0.05(1.8) = 0.94N</td>
<td>d = 6.25 = 22.5 m</td>
</tr>
<tr>
<td>F_N = 0.49 (cos 30° = 0.866) = 0.424N</td>
<td></td>
</tr>
<tr>
<td>F_k = μ_k F_N = 0.3(0.424) = 0.127N</td>
<td></td>
</tr>
<tr>
<td>( v = \sqrt{\frac{k x^2 - mgh - f_k d}{m}} )</td>
<td></td>
</tr>
<tr>
<td>v = 7.28m/s = v_k</td>
<td></td>
</tr>
<tr>
<td>v = 7.28m/s</td>
<td>V_k = 0</td>
</tr>
<tr>
<td>h = 1.3d = 2</td>
<td>t = 7.48s</td>
</tr>
<tr>
<td>V_k - v = at</td>
<td></td>
</tr>
<tr>
<td>-7.280 = -9.8t</td>
<td></td>
</tr>
<tr>
<td>d = v_1t + 0</td>
<td></td>
</tr>
<tr>
<td>d = 7.280(0.943) = 6.42 m</td>
<td></td>
</tr>
</tbody>
</table>

**Figure 6. Student Sample Documented Problem Solution #3**
The eight DPS could be separated into two distinct sets of assignments. The first four DPS for Unit 2, involved Two-Dimensional Kinematics, Newton’s Laws, and Applications of Newton’s Laws. The last four DPS involved Work and Energy, Linear Momentum and Collisions, and Simple Harmonic Motion. Unfortunately, not all of the problems assigned for the DPS were of equal difficulty, causing challenges in assessing the extent to which the students were improving at solving physics word problems.

**INTERPRETATION AND CONCLUSION**

The main focus of my research project asked the question: Can the use of the Documented Problem Solutions CAT help physics students become better at solving word physics word problems?

The student surveys support the conclusion that DPS help improve a student’s ability to solve physics word problems. According to the post-treatment student surveys, the students perception with regard to the extent to which they felt that they use a systematic method for solving physics problems and their confidence in the method used improved. As shown in Figure 4, 57% of the students in the pre-test survey answered negatively when asked if they had a systematic method for solving physics problems, 12% of the students answered very negatively. For the post-treatment survey, however, only 30% of the students answered negatively, and only 5% of students answered very negatively.

The implementation of the DPS also showed a surprising improvement in the degree of confidence students felt that they had in jumping back and forth between the math and the physics concepts. As shown in Figure 5, the percentage of negative
responses when asked if students felt that they could jump back and forth between the math and the physics dropped from 73% in the pre-treatment survey to 45% in the post-treatment survey. The time that students spent narrating their thought processes while also writing out a solution to the problem and performing the required algebraic steps needed to solve the problem could have positively contributed to the confidence level of the students.

Surveying students’ attitudes towards the treatment through individual interviews (pre and post-treatment) showed that there was a positive improvement in the way they viewed the effect the DPS implementation had on their problem solving skills. Most students stated in interviews that the DPS activities forced them to think about how they attempted to solve problems and that they benefitted from seeing and discussing the thought processes of their fellow students attempting to solve the same problems.

My research project was also designed to determine some of the reasons why students struggle to solve physics problems. This research question in some ways was the most difficult to answer, in part because the student DPS and interview answers pointed to many different reasons why students struggle to solve physics word problems. I will, however, present some of the major trends that were noticed when reviewing the student DPS. A copy of these trends can be found in Appendix S.

The most common trend that was observed as a result of the student interviews and the DPS completed by students with regard to the reason students struggle to solve word problems was that students just couldn’t figure out where to start. I as a teacher, can look at a problem dealing with two objects colliding with one another, and instantly
realize that the problem involves the conservation of momentum. As I read over the
students DPS, I realized that many students often used equations that describe kinematics
or work and energy. Some students who solved the problems correctly on DPS activities
started by categorizing a problem as a work and energy problem before moving on to
finding relevant equations to use.

Another common trend that was noticed by reviewing the DPS is that students
often stated that they thought that a specific equation should be used but they did not
know what all the variables in the equation stood for, or what the equation meant.

Another major trend that was observed from reviewing the student DPS was that
many students struggle to perform the algebraic steps necessary to solve the problem.
This observation contradicted the views that the students expressed in both the pre-
treatment survey and in the interviews. Specifically, students struggled to rearrange more
involved equations to solve for a variable, especially when the equations contained more
than three variables. Many students, whom could not rearrange the equation correctly,
would instead plug in values into the equation, often without units. The students would
then attempt to solve the equation by rearranging the values and doing the calculation
without showing the work. The students that were able to rearrange the equations
symbolically were far more likely to calculate the answer correctly.

The most important conclusion that can be made from this study, with regard to
the reason students struggle to solve physics word problems, is that the students often
simply do not have enough practice attempting to solve physics word problems on their
own, and instead rely too heavily on seeing problems solved, explained and repeated
what they observe. The DPS activities provide an effective method for getting students to practice solving physics word problems. The narrative that students must provide reinforces the idea that it is important to reflect on the thought process that is taken when solving a problem so that the student can improve how they think about problems and what steps have worked in the past.

A major flaw in the way I implemented the DPS in this research project was that I did not count the DPS assigned to students during regular class lecture time as a grade. I did not want to intimidate the students agreeing to participate in the study by allowing the DPS activities to affect their grades. This policy resulted in many students not putting forth as much effort into the DPS that were done during regular class lectures. I did notice students giving better feedback as the treatment continued, but the DPS that provided the most detailed narrative were from the exams, which were also the DPS that were being graded.

VALUE

As a result of this research project I was able to gain a much deeper understanding of why students struggle to solve physics problems. Perhaps more importantly, I have gained a deeper appreciation for the frustration and feeling of helplessness students who are taking an introductory physics feel when attempting to solve physics word problems. In the past, when grading a physics student’s work on a free-response word problem, I would see the progress made in terms of equations used and the algebraic steps completed. If the student gets the problem correct, then I would see the correct equations being used and the steps to solve the problem would be somewhat clear. For students
who did not get the correct answer, the student’s work would not give much information with regard to how well the students understood the physical concepts or the thought that the student put into the problem. Through the implementation of this research project, I now have an appreciation for the fact that when the student does not get the correct answer, they may still have considerable understanding about the problem, and they were sometimes very close to getting the solution.

I once heard a physics teacher compare the act of solving a physics problem to playing chess. Someone can explain the rules for chess to you in less than fifteen minutes. However, it takes much longer to become good at playing chess. For an experienced chess player, who has played several games of chess, over several years of playing, the moves that one learns become intuitive.

I have been solving physics problems for the topics that I teach in introductory level physics courses for several years. Through the development and implementation of this research project, I have come to the realization that I often have unrealistic expectations for my students. I am the person explaining the “rules” of solving physics problems. I do this each time I introduce and teach a specific unit or concept. I then often expecting my students to immediately be good “players,” without giving them adequate time to practice. As a result of the knowledge I have gained from this research project, I am determined to be more than the person explaining the “rules”, but a better teacher of how to play the game of physics. From my field notes that were recorded in my teaching journal, I have developed a plan to implement the DPS activities in a manner
that I think will be more helpful in improving my students confidence and ability to solve physics word problems.

One of the areas in which my students struggled in solving physics word problems involved how to get the problem started. In order to help students get the problem started, it might help to use class time to read several physics word problems and get students to try to categorize the problem. By categorize the problem, I mean for students to try to clarify which concepts covered in class relate to this problem best. Students could work in small groups to discuss why a problem deals with concepts that relate to work and energy, more than say momentum, kinematics, or Newton’s laws. During this type of activity, my plan is to delete the actual values for the information given, so that students are only responsible for giving a qualitative description of how and why they categorized the problem in the way they did.

Another trend that I observed from my field notes was that many students understood the problem conceptually, but could not pick out the correct equation to use, because they were not confident about what was involved in each equations. In order to help students to understand the equations more completely, it would benefit students to spend some time, periodically reviewing all the past and present equations that are at their disposal. I could separate the class into groups and assign each group an equation to review. The group could then present the equation to the rest of the class, describing what each symbol in the equation represents and what concept the equation relates to. After this activity, I could give a quiz to the entire class on all the equations that were reviewed.
A common obstacle that many students struggled with involved the algebraic steps needed to solve the more involved physics word problems. The most common problem involved students trying to plug in values into an equation after choosing the correct equation, and then attempting to rearrange values instead of variables to find the correct answer. Students need to have activities that focus only on rearranging several different equations symbolically instead of plugging in values. Worksheets could include several equations, where no values are given and students are required to solve for specific variables, showing their work. These activities could also be completed in small groups. This type of activity could also be followed up by a quiz where students have to rearrange several different equations symbolically to solve for specific symbols.

The most significant change that I will make to the implementation of the DPS in the next class that I teach, will be that I will assign more frequent DPS, and grade students on both the correctness of the work and on the details given on the narrative. As stated previously, the DPS that were not given a grade were of poorer quality in terms of the detail given in the narrative and on the apparent effort given by the student in attempting to solve the problem. The obstacle that I have faced in the past with regard to incorporating more formative assessment in class is that because of the limitations set on time, I worry that students are missing out on valuable lecture time when other activities are implemented. However, over the past few years, I have become more comfortable using video capture software to record lectures and problems being solved for students to watch. My goal for future physics classes is to make more of the lecture and problem
solving videos available for students to view as they work on homework, so that I can use more class time for formative assessment.

Another change that I have considered was to allow students to work on DPS in groups of two students and to hand out several different problems to the different groups and allow students to present their group’s DPS to the class. I could get one student to write down the narrative, showing how they attempted to solve the problem, and the other student would show the work. I could then scan both papers into one document and that document would be projected on the overhead screen for the class to ask questions during the presentation. My rationale is that because the narrative and the solution have to match one another, the students in the group would have to discuss the solution and therefore share their ideas. In my experience, when students know that they have to present their DPS to the class, they are usually motivated to solve the problem correctly.

An advantage of this DPS activity is that students are encouraged to share their thought processes with fellow students. Another advantage to working on DPS this way is that several different problems can be solved and explained to the class over two or three class periods. The other benefit of this activity would allow me to assign several problems so that the class could benefit from seeing several solutions in a few days. I am thinking that I could give one class period of about 50 minutes for the students to work on the DPS in their groups and two additional class periods for the students to present their solutions to the class.

One of the ideas that came to mind during the treatment was to require students to keep a portfolio of all their DPS so that they can review where they made mistakes in
previous problems and allow them to review those DPS while attempting new problems. The portfolio might be a resource that I can allow students to use during activities where DPS are assigned as grades, or to use during many of the previously described DPS activities.

The results of this research project have led me to understand the ways in which I need to change as a physics teacher, and further implications in the way I view the field of science education in general. I still believe that it is beneficial for students to experience many of the traditional activities involved in a physics course such as lectures, and laboratory experiments. However, I now have a deeper appreciation and I am more determined for my students to also have ample opportunity to get meaningful practice at solving physics problems independently. The practice that my students acquire will be meaningful because they will be required to reflect on the thought processes they use in attempting to solve the problems. Furthermore, they should benefit from the experience of the feedback from the instructor of the course and that of fellow classmates with regard to their thought process.

Formative Classroom Assessment is a topic that is often discussed among educators when we are focusing on the process of teaching. In the actual practice of teaching physics however, I have often postponed or omitted these formative assessment activities from my lesson plans. I have always viewed activities where I solve as many physics problems as possible in the time I have with students, as a more productive way to use the time I have with my students. I now feel confident that using Documented Problem Solutions during class will allow my students to get the exposure they need with
regard to solving physics word problems in a more effective manner, and I will continue
to benefit from learning why students struggle to solve physics word problems and how I
can help them become better at solving physics problems while learning the laws and
theories of physics.

I plan to continue to be aware of the extent to which my students struggle to solve
physics problems. I plan to use DPS in all future physics courses, to give my students the
practice they desperately need, but also it will provide me the feedback that I need in
order to effectively close the loop and help them improve each time they complete a DPS.
If I were to re-visit the analogy of the student learning to play chess, the DPS would be
like having an expert chess player watching all the moves you make, asking you about
your thought processes while you make the moves, elaborating on why some moves were
good and other moves were not, thus allowing you to get better at playing the game of
physics.
REFERENCES CITED


APPENDICES
APPENDIX A

WESTERN CAROLINA UNIVERSITY IRB APPROVAL
Western Carolina University
Institutional Review Board
c/o Office of Research Administration
109 Camp Building
Cullowhee NC 28723
irb@wcu.edu | 828-227-7212

IRB number: 2014-0177  Date of review: March 17, 2014

Investigators:  John Henry Davis

Project Title: The Effects of Documented Problem Solutions on Problem Solving Skills for Introductory College Physics Courses.

Your IRB protocol has been approved, effective with today's date, under the following category of expedited review, as authorized by 45 CFR 46.110 and 21 CFR 56.110:

☐ Clinical studies of drugs and medical devices (a) when an investigational new drug application (21 CFR Part 312) is not required or (b) medical devices for which (i) an investigational device exemption application (21 CFR Part 812) is not required; or (ii) the medical device is cleared/approved for marketing and the medical device is being used in accordance with its cleared/approved labeling

☐ Collection of blood samples by finger stick, heel stick, ear stick, or venipuncture

☐ Prospective collection of biological specimens for research purposes by noninvasive means

☐ Collection of data through noninvasive procedures (not involving general anesthesia or sedation) routinely employed in clinical practice, excluding procedures involving x-rays or microwaves

☐ Research involving materials (data, documents, records, or specimens) that have been collected, or will be collected solely for nonresearch purposes (such as medical treatment or diagnosis)

☐ Collection of data from voice, video, digital, or image recordings made for research purposes

☒ Research on individual or group characteristics or behavior (including, but not limited to, research on perception, cognition, motivation, identity, language, communication, cultural beliefs or practices, and social behavior) or research employing survey, interview, oral history, focus group, program evaluation, human factors evaluation, or quality assurance methodologies

☐ Continuing review of research previously approved by the convened IRB

Your protocol is approved for one year and may be renewed annually. If you wish to make changes to your protocol, including recruitment procedures, sampling, consent, interventions, data collection methods, and investigators, please use the amendment request located on the IRB website (http://www.wcu.edu/6801.asp) to submit your request in advance.
This approval does not cover research conducted prior to the approval date. Please remember that you are responsible for reporting adverse events or unanticipated risks to the IRB immediately.

IRB representative:

Date: 08/20/12
APPENDIX B

STUDENT CONFIDENCE IN PHYSICS PROBLEM SOLVING LIKERT PRE-TREATMENT SURVEY
STUDENT CONFIDENCE IN PHYSICS PROBLEM SOLVING LIKERT PRETREATMENT SURVEY

Participation in this research is voluntary and participation or nonparticipation will not affect a student’s grade or class standing in any way.

Choose a value of 1-5 for each of the five questions that follow.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Uncertain</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

1. I feel that I use a systematic method when solving physics problems.

2. I feel confident in my method for solving physics problems.

3. I usually have no difficulty visualizing the physics problem.

4. The easiest part of solving a physics problem is finding the right equation.

5. The easiest part of solving a physics problem is doing the algebra.

6. I can usually jump back and forth between the math and the physics.
APPENDIX C

PRE-TREATMENT INTERVIEW QUESTIONS
Pre-Treatment Interview Questions

1. In your opinion, do you solve physics word problems in a systematic way, in which you usually do things is a specific order?
2. Do you have confidence in the systematic method that you use?
3. Why do you think solving physics word problems is difficult?
4. What is the easiest aspect of solving a physics word problem in your opinion?
5. What is the hardest aspect of solving a physics word problem in your opinion?
6. Do you feel motivated to practice solving physics word problems on your own?
APPENDIX D

DOCUMENTED PROBLEM SOLUTIONS STUDENTS DIRECTIONS
Documented Problem Solutions Student Directions

Participation in this research is voluntary and participation or nonparticipation will not affect a student’s grade or class standing in any way.

OVERVIEW:

This technique assesses your ability to conduct problem solving and your recall of the problem solving steps/framework that we have been working on in class. You will be asked to solve a problem and to think about how to approach a problem as you write down the solution steps.

PROCESS:

1. You will be provided with a problem situation/example. The situation/example should require a multi-step analysis.

2. You should draw a line down the center of a piece of paper. On the left side of the paper, you should attempt to solve the problem, showing all of your work. On the right side of the paper, you should write the steps or components of the problem-solving technique that your work reflects.

3. I will review the work to identify three that are good examples of correct answers with well-documented work and three examples of incorrect work, that show areas in need of improvement.

4. We will use these examples to spark class discussion.
APPENDIX E

DOCUMENTED PROBLEM SOLUTION # 1
DPS # 1: A projectile is fired at time $t = 0.0$ s, from point 0 at the edge of a cliff, with initial velocity components of $v_{ox} = 30$ m/s and $v_{oy} = 300$ m/s. The projectile rises, then falls into the sea at point P. The time of flight of the projectile is 75.0 s.

In the figure, the horizontal distance $D$ is closest to

<table>
<thead>
<tr>
<th>Solution</th>
<th>Steps Taken</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX F

DOCUMENTED PROBLEM SOLUTION #2
DPS #2: Consider the following figure. Assume the strings and pulleys have negligible masses and the coefficient of kinetic friction between the 2.0 kg block and the table is 0.25. What is the acceleration of the 2.0 kg block?
APPENDIX G

POST-TREATMENT LIKERT SURVEY
STUDENT CONFIDENCE IN PHYSICS PROBLEM SOLVING

(Post-Treatment Likert Survey)

Participation in this research is voluntary and participation or nonparticipation will not affect a student’s grade or class standing in any way.

Use the Likert-Scale for questions 1 and 2. Choose a value of 1-5 for each of the five questions that follow.

<table>
<thead>
<tr>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Uncertain</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

1. I feel that I use a systematic method when solving physics problems.

2. I feel confident in my method for solving physics problems.

3. I usually have no difficulty visualizing the physics problem.

4. The easiest part of solving a physics problem is finding the right equation.

5. The easiest part of solving a physics problem is doing the algebra.

6. I can usually jump back and forth between the math and the physics.
APPENDIX H

POST-TREATMENT INTERVIEW QUESTIONS
Post-Treatment Interview Questions

1. In your opinion, do you use a systematic method for solving physics problems?
2. How comfortable are you with the method that you use to solve physics word problems?
3. In your opinion did you get better as solving physics word problems as a result of completing and reviewing the Documented Problem Solutions this semester?
4. Do you feel motivated to solve physics word problems on your own?
5. What specific changes to the DPS activities do you think would be most effective at helping you improve at solving physics word problems?
6. If you were to take this course again, would you recommend using class time to complete and review the Documented Problem Solutions?
APPENDIX I

TREATMENT VS. NON-TREATMENT
### Non-Treatment Units
- Teach lessons using PowerPoint slides, demonstrations, labs, problem solving activities.
- Collect observational data in teaching journal with regard to student problem solving weaknesses.

### Treatment Units
- Teach lessons using PowerPoint slides, demonstrations, labs, problem solving activities.
- Administer DPS student directions.
- Implement DPS during class lecture time.
- Review student DPS with class during lecture time.
- Take observational data from student DPS in teaching journal.
- Administer pre-treatment and post-treatment student surveys.
- Complete Pre-treatment and post-treatment interviews.

<table>
<thead>
<tr>
<th>Treatment Schedule Class One</th>
<th>Data Collection Techniques</th>
<th>Treatment (Y/N)</th>
<th>Dates</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chapters 1-3:</td>
<td>Observations of student problem solving abilities in teaching journal</td>
<td>N</td>
<td>1/13 - 2/21</td>
</tr>
<tr>
<td>1. Introduction to Physics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Kinematics</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Vectors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chapters 4-6:</td>
<td>Pre-treatment student surveys</td>
<td>Y</td>
<td>2/24 - 3/28</td>
</tr>
<tr>
<td>4. Two-Dimensional Motion</td>
<td>Pre-Treatment student interviews</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Newton’s Laws</td>
<td>Implementation of DPS.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Applications of Newton’s Laws</td>
<td>Observations of student problem solving abilities in teaching journal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chapters 7-9:</td>
<td>Implementation of DPS.</td>
<td>Y</td>
<td>4/1 - 5/2</td>
</tr>
<tr>
<td>7. Work and Energy</td>
<td>Observations of student problem solving abilities in teaching journal</td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Momentum and Collisions</td>
<td>Post-treatment student interviews</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9. Simple Harmonic Motion</td>
<td>Post-treatment student surveys.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Treatment Schedule Class Two

<table>
<thead>
<tr>
<th>Unit</th>
<th>Data Collection Techniques</th>
<th>Treatment (Y/N)</th>
<th>Dates</th>
</tr>
</thead>
</table>
| Chapters 1-3:  
1. Introduction to Physics  
2. Kinematics  
3. Vectors | • Observations of student problem solving abilities in teaching journal | N | 1/13 - 2/21 |
| Chapters 4-6:  
4. Two-Dimensional Motion  
5. Newton’s Laws  
6. Applications of Newton’s Laws | • Observations of student problem solving abilities in teaching journal | N | 2/24 - 3/28 |
| Chapters 7-9:  
7. Work and Energy  
8. Momentum and Collisions  
9. Simple Harmonic Motion | • Pre-treatment student surveys  
• Pre-Treatment student interviews  
• Implementation of DPS.  
• Observations of student problem solving abilities in teaching journal  
• Post-treatment student interviews  
• Post-treatment student surveys. | Y | 4/1 - 5/2 |