USING CONCEPT MAPPING TO ENHANCE HIGH SCHOOL PHYSICS INSTRUCTION

by

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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 others under the specified rules of the MSSE program.

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ABSTRACT

This study investigated the effects of using concept maps in the instruction of a high school physics class at a small classical Christian school. Eight students were the focus of the study on the level of understanding and long-term memory of physics concepts. The study also included student motivation, student engagement, as well as teacher attitude, motivation, preparation time and grading time. Students learned to identify concepts, hierarchically order concepts, and to relate the concepts to each other. The study was done comparing a two-week nontreatment unit on momentum to a two week treatment unit on periodic motion and a two-week treatment unit on waves. In the treatment units, concept mapping was used interactively and cooperatively with the students in the classroom to show concepts and the relationships between the concepts. Various instruments were used including targeted assessments, student concept interviews, student surveys, colleague observations, and teacher observations were used for assessing the effects of concept mapping. The results of the study were mixed. Data indicated that concept mapping had a positive effect on the student level of understanding, student engagement and on teacher attitude and motivation. For long-term memory of concepts, the treatment unit on periodic motion was better than the nontreatment unit on momentum, but the treatment unit on waves was worse than the nontreatment unit. The effect on student motivation was neutral. The preparation and grading time took longer for the treatment unit, but the preparation was better. I look forward to incorporating concept mapping into my teaching style.

INTRODUCTION AND BACKGROUND

These statements are what students use when they are asked to take a class in physics. For example, “WHAT?”, “You want me to take WHAT CLASS?”, “That class is only for brainiacs.”, “Why would I want or need to take that class?”, and “I will never use anything from that class in my life.” are comments that I have heard over the years. So how do I teach physics in a way that will overcome the biased attitudes and objections about physics? To help address this bias against physics, I looked for ways to help my students understand physics more effectively. In pursuit of this goal, my project was applying concept mapping in a physics classroom. Using concept mapping techniques should help students understand the principles of physics by logically displaying the concepts, showing how these concepts relate, and how these concepts apply to what they already know.

I have noticed that students and people in general, perceive physics as a difficult subject and generally irrelevant to their lives. I believe that knowledge of physics can enhance your life, make things easier to do and may even save your life. All of us use physics everyday whether we realize it or not. We are using physics, whether it is walking, driving a car or even flipping a light switch. As an example, while driving a car, physics is constantly used to estimate how fast to go and how to brace our body when we turn or slow down. Physics is used to drive safely on icy roads in the winter time. Knowledge of physics is part of defensive driving techniques (Defensive Driving, 2013).

To participate in today’s world, I believe that people need certain basics. Having a good basis in science is one of these basics that really help enhance a person’s life. To have a good basis in science, a student needs to have a good understanding in the breadth of the natural sciences which includes physics (Wisconsin's Model, 2013*)*. This project helped me see what effects using concept mapping can have in overcoming the prejudice against physics. One reason for doing the project was that I believed that concept mapping helps students understand concepts and relationships better. As a part of concept mapping during the capstone project, an effort was made to help the student see connections to their own lives like driving a car, using a computer or playing a musical instrument. A second reason for doing the project was to introduce my students to another way of understanding a subject so they can apply it to other classes and fields of study.

The focus question of my project is: what are the effects of concept mapping on the students' conceptual understanding of high school physics? To support this project, I have included the following subquestions: what are the effects of concept mapping on the students' long-term memory of physics concepts; what are the effects of concept mapping on the students' engagement and motivation in physics; what are the effects of concept mapping on my attitude and motivation as a teacher; and what are the effects of concept mapping on my preparation and grading time?

A concept map is a symbolic representation of information concepts and their relationship to each other. Concept mapping techniques are methods of teaching that have students form their own representative model of each concept and the relationship to each other. In general concept mapping consists of three core steps: 1. Identify the core concepts, 2. Arrange the concepts from general on the top progressively down to the most specific at the bottom and 3. Connect the concepts with how they relate to each other.

Further, concept mapping techniques connect these new concepts to concepts that the student already understands.

My study took place at Baldwin Christian School, near Baldwin, Wisconsin. Baldwin is a small rural community about a half hour from St. Paul, Minnesota. The school is a classical Christian school and is a member of the Association of Classical & Christian Schools. Eight out of the 20 high school students were involved in the study, which took place during their introductory physics class.

Any large project is dependent on many people. My MSSE Capstone Graduate Committee consists of Dr. Peggy Taylor, Montana State University Masters of Science in Science Education (MSSE) Program Director, as committee chair, Dr. Jewel Reuter, as MSSE Core and Capstone Advisor, and Dr. Gregory Francis as MSSE Program Reader. The major contributors to this project have been Dr. Jewel Reuter, my wife Susan Sumner and my physics students. Other contributors have been Bill Hickoks who is a retired middle school principal, Carolyn Martinson who is a teacher at Baldwin Christian School, Gregory Sumner who is an occupational therapist, and Mark Sampson who is software engineer.

CONCEPTUAL FRAMEWORK

The idea of this project is to measure the effects of applying concept mapping in a high school physics classroom. The literature indicated that concept mapping is an effective method to enhance learning, retention, and student engagement. In addition, concept mapping should be supportive of my attitude and motivation as a teacher. The effects of concept mapping on preparation time or grading time depends on how it is used.

In the 1960's and 1970's, David Ausubel was investigating and promoting ideational organizers to help enhance meaningful learning and retention of that learning. Ideational organizers were to make a connection between what the learner already knew and the new concept. In addition, they created a way to organize the concept (Ausubel, 1970). Concept mapping has its origins in the late 1970's and has developed since then. Instead of memorizing facts and ways to solve problems, concept mapping visually represents the relationships between concepts. Instead of learning isolated concepts, it is learning concepts and how they relate to each other (Novak, 1990). The basic idea is we learn better when we learn a concept in relationship to other ideas. Novak states that meaningful learning is "where the learner chooses conscientiously to integrate new knowledge to knowledge that the learner already possesses" (Novak, 2002, p. 549). When I first learned Newtonian physics, instead of memorizing all the formulas, I memorized the core formulas, how to use them and how to derive the other equations from these core equations. In essence, I was learning the relationships between the equations to be able to recreate the other equations. Concept mapping is a way to implement constructivist learning enabling students to create an individual structure of knowledge.

The literature indicates that concept mapping helps students understand physics better. Relating physics concepts to previously understood concepts can help overcome a reluctance to understand (Novak, 2002). Concept mapping has been found to have a positive effect on the level of the high school and first year undergraduate students learning of physics concepts (Pankratius, 1990), (Lindstrom & Sharma, 2011), and undergraduate students learning nanotechnology concepts (Tseng, Chang, Lou, Tan, & Chiu, 2012). Concept mapping has been applied to many subjects and has been studied in many ways (Daley et al., 2010). Concept mapping as a whole appears to have a very positive effect on learning, however, there is one negative in that it may allow a misconception to go unchallenged (Roth & Roychoudhury, 1993), but concept maps can also be used to identify and help correct misconceptions. A teacher needs to carefully review the student concept map to look for misconceptions.

Concept mapping has been shown to have a positive effect on long-term retention through more than 50 studies involving more 5000 students from fourth grade to undergraduate level, from the United States, Canada, Africa and Taiwan. These teachers teach science, statistics and humanities (Nesbit & Adesope, 2006). It has been shown to have a positive long-term effect one year later in a study on 62 veterinary students in a class on fluid and electrolyte disorders at Cornell (Edmundson & Smith, 1998). There are some mixed results as well with no long term effect in a study involving 149 fifth grade high-achieving science students (Gerstner & Bogner, 2009) although this study uses a variety of concept map structures and are not strictly hierarchical concept maps.

The second supporting subquestion concerns the effects of concept mapping on the students' engagement and motivation in physics. Concept mapping has been shown to have a positive effect on engagement and motivation in learning. It was suggested that concept mapping had a positive effect on understanding and retention due to increased engagement through more than 50 studies involving more 5000 students from fourth grade to undergraduate level, from the United States, Canada, Africa and Taiwan and dealing with science, statistics and humanities (Nesbit & Adesope, 2006).

My third subquestion concerns with the effects of concept mapping on my attitude and motivation as a teacher. A study involving high school 141 teachers of biology, chemistry, physics and mathematics showed positive effects on teacher attitude when they used concept mapping (Okebukola, 1992).

My last supporting subquestion is about the effects of concept mapping on my preparation and grading time. The amount of time concept mapping takes depends on how the teacher uses the concept maps (Zeilik, 2014).). It takes more time if the teacher creates concept maps and fill in the blank concept map forms than if the students create their own concept maps. Concept mapping displays a student's level of knowledge better than a standard paper and pencil test (Novak & Gowin, 1984). The method of assessing concept maps developed by Novak and Gowin (1984) has not greatly changed since that time (Allen, 2006). Assessing concept maps involves counting valid propositions between two concepts, counting valid heirarchial levels, counting valid cross-links and counting valid examples (Novak & Gowin, 1984). From my search of the literature, there was little on the amount of preparation time.

In summary, concept mapping is a very promising way to enhance students' ability to learn. The literature is rather clear that concept mapping is a very effective way to enhance understanding, retention, and motivation because concept mapping shows logical connections between each concept and connections between the concepts and what the student already knows.

METHODOLOGY

Project Treatment

My project was done over three units of study in physics. The first unit was a nontreatment unit followed by two units that were treatment units. This was done so a comparison could be made between nontreatment and treatment units. The nontreatment unit was on Momentum using my normal teaching style, which uses laboratory experiments, lecture/ discussion and problem solving, whereas the treatment units were on Periodic Motion and Waves. See Appendix A for lesson plans and what actually happened in each unit. See Appendix B for the experiments for each unit. After the nontreatment unit, there was an introduction to concept mapping in the unit on Periodic motion. Throughout the treatment units, concept mapping was used to connect concepts together during each unit and student worked in teams and individually to create concept maps. During lecture, question and discussion periods, the concept maps were expanded and modified as the discussion deepened. Later they used the concept maps they had created to answer review questions. The concept maps were handed in at the end of the unit for grading. These units were chosen because they are similar in complexity, but not as conceptually dependent on the preceding units as other units are.

My normal class structure covers a unit in two weeks with a two hour laboratory on both Mondays, a lecture/ discussion/ problem solving session on the first Wednesday and Thursday, a review session on the second Wednesday, and concluding with an exam on the second Thursday. During the project period, only treatment unit 2 progressed this way due to weather related disruptions.

The nontreatment unit started on a Wednesday and consisted of lecture/ discussion/ problem solving on Wednesday and Thursday, a laboratory on Monday, discussion and problem solving on Wednesday, a review session on Thursday, and ended with a mini review and exam on Monday. Treatment unit 1 had an introduction to concept mapping on the first Wednesday, walked through student concept maps on the second Wednesday, problem solving on Thursday, a laboratory on Monday, review with concept mapping on Wednesday, and finishing with an exam on Thursday. Despite numerous school closings due to weather, I feel the units were still fairly similar.

The intervention started with an introduction to concept mapping by building a couple of examples on the board. We finished with interactively and cooperatively building a concept map of simple periodic motion on the board. Students were assigned to write up a concept map on a topic of their own choosing. After the first session, concept maps were interactively and cooperatively built on the board during discussion and assignments were used to strengthen the concepts and their relationships. Normally, the students have to create a study guide outline of the unit, but this was changed to creating a concept map for the unit in the treatment units. Additionally, students were assigned to write up five questions about the unit which had to be related to the concepts and/or their relationship to each other.

Data Collection Instruments

My physics class consisted of eight students in Baldwin Christian School, a small classical Christian school just north of Baldwin, Wisconsin. Baldwin Christian School is a member of Association of Classical & Christian Schools with almost 70 students from kindergarten to 12^{th} grade. Twenty of the students are in the high school. Most of the classrooms are multiple-grade classrooms. Baldwin is a small town of about 4,000 people. There are many dairy farms and some light industry in the area. The median income per family for Baldwin was $58,405 in 2010 (US Census, 2010). The parents, a mixture of middle class professional and tradesmen, are very devoted to their children and are sacrificing to send their students to the school. All of students are either rural or small town residents although they are only 30 minutes from a major metropolitan city. Most students live nearby, but some commute as far as 30 miles. There are four 12^{th}-grade males, one 12^{th}-grade female, one 11^{th}-grade female, and two 11^{th}-grade males. The five seniors had physical science class as ninth graders, but all of the students have taken biology and chemistry, except for a transfer student. There is a wide spread of mathematics skill and level in the class. Three are taking calculus, two are taking precalculus, two are taking Algebra II after completing geometry last year, and the final student, having competed geometry and algebra II, is not taking any mathematics this year. All of the students are Caucasian in this class. In general, all of the students were hard-working, respectful, and full of energy and fun.

To help answer my questions and produce more valid results a variety of instruments were used. For each of my questions, three different instruments were used producing quantitative and qualitative data from multiple perspectives. The data were generated by the students, the instructor, the parents and an outside observer. This method of collecting data is called triangulation. The three sources of data help to either reinforce each other to strengthen a conclusion or question a conclusion from only one source. By this way, using triangulation helps produce stronger conclusions. Table1 is a triangulation matrix of the focus question and subquestions.

Table 1
Triangulation Matrix

Focus Question	Data Source 1	Data Source 2	Data Source 3
Students understanding of high school physics	Pre and postunit student capstone project targeted assessments	Pre and postunit student concept interviews	Pre and posttreatment student surveys on their perception of understanding
Long-term memory of concepts	Postunit and delayed unit capstone project targeted assessments	Postunit and delayed unit student concept interviews	Postunit and delayed unit student surveys on their perception of understanding
Student engagement and motivation	Teacher field observations	Pre and posttreatment student nonconcept interviews	Pre and posttreatment student surveys, postunit parent surveys.
Teacher attitude and motivation	Colleague classroom observations with prompts	Teacher weekly reflection journaling with prompts	Pre and posttreatment teacher surveys
Teacher preparation and grading time	Teacher log	Teacher weekly reflection journaling with prompts	Pre and posttreatment teacher surveys

Overall, a variety of assessments was used in assessing these questions. A targeted assessment, see Appendix C, was used pre, post, and delayed two weeks for each unit. This was initially taken during the first day of the nontreatment unit. After that, the assessment was done after the exam at the end of the unit. The assessment consisted of four questions ranging from simple to complex and is rated by the complexity of the question. Questions had one point for question 1, two points for question 2, three points for question 3 and four points for question 4. Points were summed to create a total for each student's assessment. This instrument is used for student understanding and retention.

Student concept interviews, see Appendices D and E, were used pre, post, and delayed two weeks for each unit. The instructor rated the students understanding of the concepts from 0 to 10 based on the student's concept map and the answers the student gave to the questions on the interview sheet. Student pre and posttreatment interviews, see Appendix F, were done before treatment and after treatment, respectively. Concept interviews were done during class time on the first day of class, the last day of class and two weeks after the unit was done. Pre and posttreatment interviews were done at the end of the nontreatment unit and after treatment unit 2. The interviews were used to rate each student's understanding, retention, and motivation of the unit. Each interview consisted of up to 11 questions.

Student pre and posttreatment surveys, see Appendices G and H, were used pre and posttreatment and were done at the end of the nontreatment unit and after treatment unit 2 respectively. Student post and delayed unit surveys, see Appendix I, were used post and delayed two weeks for each unit. The surveys were done after the exam at the end of the unit. The survey was used to measure understanding, retention, and motivation. Each survey is basically a self-assessment by the student.

Parent surveys, see Appendix J, were done by parents at the end of each unit. These were used to rate the motivation and engagement of each student. This consisted of five questions asking the parent what they have observed over the past two weeks.

Teacher field observations, see Appendix K, were done after each class. This was done to measure the students' engagement and the teacher's attitude.

Colleague observations, see Appendix L, were done in one classroom session for each unit. This was done by a retired public middle school principal. The main objective of this instrument is to measure the teacher's attitude and motivation.

The teacher's log, see Appendix M, was used to record hours in lesson preparation and grading. This was done on a daily basis.

The teacher's reflective journal, see Appendix N, was done on Saturday morning. This was to reflect on the past week and help assess the teacher's attitude, motivation, and how the preparation went.

The teacher's pre and posttreatment surveys, see Appendices O and P, were used to measure the teacher's attitude, motivation and how it felt with preparation and grading effort.

For understanding of high school physics concepts, I used pre and postunit targeted assessments, pre and postunit interviews, and pre and posttreatment surveys. The pre and postunit targeted assessment were compared by using percent change and normalized gain. The percent change from pre to post unit was calculated with the equation:

$$\text{Percent Change} = \frac{(\text{postunit score} - \text{preunit score})\text{X } 100}{\text{preunit score}}$$

Because the preunit scores were not identical, the normalized gain was calculated using the following equation:

$$\text{Normalized Gain} = \frac{\text{postunit score} - \text{preunit score}}{10 - \text{preunit score}}$$

The pre and postunit interviews used the teacher rating to compare the improvement in level of knowledge for each unit in a similar fashion as the targeted assessments. The pre and posttreatment surveys were used to compare the students' self-assessment of their knowledge level. In each case, this is to compare between the nontreatment unit and the two treatment units.

For long-term retention of high school physics concepts, I used post and delayed targeted assessments, post and delayed interviews, and post and delayed unit surveys. The delayed targeted assessments were compared to the postunit targeted assessments for number of details lost over the two week period. The assessments were compared by using percent change and normalized gain. The percent change from post to delayed unit was calculated with the equation:

$$\text{Percent Change} = \frac{\text{delayed unit score} - \text{postunit score}}{\text{postunit score}}$$

Because the preunit and postunit scores were not identical, the normalized gain was calculated using the following equation:

$$\text{Normalized Gain} = \frac{\text{delayed unit score} - \text{preunit score}}{10 - \text{preunit score}}$$

This normalized gain was compared to the normalized gain for preunit to postunit.

The post and delayed interviews were compared to see how the teacher's rating of the students decreased during the two week time period. The interview ratings were compared in a same way as the delayed targeted assessments. The post and delayed surveys were compared to see how the students' self-evaluation decreased during that time. In each case, this is to compare between the nontreatment unit and the two treatment units. The analysis of long-term memory is complex and the inclusion of normalized gain is used to consider the baseline knowledge levels.

For student engagement and motivation, I used teacher field observations, student interviews, student surveys, and parent surveys. The teacher field observations were based on the teacher's observations from class time. The student interviews had the teacher rating the students' engagement and motivation before and after each unit. The student surveys were compared between before and after each unit to see how motivation and engagement changed. In each case, this was to compare between the nontreatment unit and the two treatment units.

For teacher attitude and motivation, I used observations by a colleague, instructor reflection journal and teacher surveys. Colleague observations were done by a retired principal in a similar class session for each unit. The instructor reflection journal captured the differences in how the instructor felt after each week resulting in qualitative data. The teacher surveys were done before and after the treatment units. The observations were compared to see if and how much the attitude and motivation of the instructor changed between treatment and nontreatment.

Teacher preparation and grading time was recorded in a teacher log. Additionally, there were prompts in the teacher reflective journaling regarding preparation and grading effort. There was also a pre and posttreatment survey by the teacher on the preparation time and grading effort.

The surveys, interviews, and journaling had a mixture of quantitative data and qualitative data. Most of the quantitative data used a five point Likert scale. The qualitative data was a variety of comments to various questions. Interviews were most of the students in the class. Timeline is in Appendix Q.

DATA AND ANALYSIS

The objective of this data analysis is to find the effect of using concept mapping in a high school physics class. This analysis is the result of my study.

The first question related to the students' understanding of the physics unit. I used targeted assessments, concept interviews, and pre and posttreatment surveys to help determine if my application of concept mapping helped my students understand better than my normal style of teaching. Each of these assessments looked at this question from a different point of view.

Targeted assessments were taken by the students before starting a unit and at the completion of the unit for each of the three subject units. Table 2 is an analysis of targeted assessments displaying the understanding for preunit, postunit, the percentage change from pre to postunit, and the normalized gain from preunit to postunit. In each case from preinstruction to postinstruction, there was an increase in understanding, but with the treatment, the increase was greater. The overall postunit assessment and the overall normalized gain show an overall higher score and higher normalized gain for both treatment units. The overall percentage change is higher for treatment unit 1, but about the same between the nontreatment unit and treatment unit 2. The assessment results suggests that treatment was effective in raising the level of concept understanding more than my normal teaching style of lecture, discussion, and problem solving.

Table 2
Targeted Assessments of Students' Improvement of Understanding, (N = 6)

Nontreatment Unit	Assessment Scores			
	Pre*	Post*	% Change	Normalized Gain Post
Overall	1.5	4.3	190	0.33
High	2.0	7.3	270	0.66
Middle	1.5	4.5	200	0.35
Low	1.2	2.2	83	0.11
Treatment Unit 1	**Assessment Scores**			
	Pre*	Post*	% Change	Normalized Gain Post
Overall	0.8	6.1	660	0.58
High	0.6	8.5	1300	0.84
Middle	2.0	5.8	190	0.48
Low	0.1	4.7	4600	0.46
Treatment Unit 2	**Assessment Scores**			
	Pre*	Post*	% Change	Normalized Gain Post
Overall	1.9	5.4	180	0.43
High	4.5	7.5	67	0.55
Middle	1.3	7.3	460	0.69
Low	0.7	2.8	300	0.23

Note. *Preunit and postunit assessment scale was 10= very strong understanding, 0= very poor understanding.

The second instrument used to analyze the effectiveness of this study was concept interviews. Concept interviews were done before and after each unit. Concept interviews consisted of a list of words from the unit that the student used to build a concept map and answer questions from the instructor. Table 3 is an analysis of the concept interview results displaying the increase of understanding from preunit to postunit. In each case from preinstruction to postinstruction, there was an increase in understanding with the treatment. The post interview rating and the overall normalized gain show a higher rating and higher normalized score for both treatment units. The overall percent change is higher with treatment unit 1, but treatment unit 2 is lower than the nontreatment unit. The results of the interviews suggest the treatment was effective in raising the level of concept understanding more than my normal style of instruction.

Table 3
Student Concept Interviews with Concept Maps for Changes in Understanding (N = 5)

Nontreatment Unit			Assessment Scores	
	Pre*	Post*	% Change	Normalized Gain Post
Overall	1.0	2.8	180	0.20
High	2.0	7.0	250	0.63
Middle	1.5	2.5	67	0.12
Low	0.1	1.0	900	0.09
Treatment Unit 1			**Assessment Scores**	
	Pre*	Post*	% Change	Normalized Gain Post
Overall	0.5	4.2	740	0.39
High	0.1	4.0	3900	0.39
Middle	1.3	5.8	320	0.48
Low	0.1	3.0	2900	0.29
Treatment Unit 2			**Assessment Scores**	
	Pre*	Post*	% Change	Normalized Gain Post
Overall	5.2	6.5	25	0.27
High	7.0	9.0	29	0.67
Middle	5.0	6.5	30	0.30
Low	4.5	5.3	18	0.15

Note. *Preunit and postunit assessment scale was 10= very strong understanding, 0= very poor understanding. The instructor rated the students on their level of understanding the concepts.

The final assessment instrument was used to measure the level of the students' perception of their understanding of physics by using a pre and posttreatment survey. There were two surveys, one before the first treatment unit and one after the second treatment unit. The students' overall rating of their own understanding decreased in most cases after the second treatment unit when compared to the pretreatment survey as shown in Table 4. Overall, five of the eight students in the interview group indicated that the concept mapping had value for them. None of the students had a change of more than one in either direction.

Table 4
*Students' Perception of Understanding from Pretreatment to Posttreatmen*t (*N* = 7)

	Pretreatment	Posttreatment	Percent Change
Overall	3.2	3.1	-3%
High Group	5.0	4.5	-10%
Middle Group	3.9	3.8	-3%
Low Group	2.7	2.7	0%

Note. Likert scale 5= very strong understanding, 1= very poor understanding.

When asked how this made a difference in how they understand the world, four out of seven had a relevant answer in both the pretreatment and posttreatment surveys. In addition, in the posttreatment survey to the four relevant answers, another one commented "So vast, I didn't get it." Watching this middle level student improve with concept mapping in class indicated to me that this student had their eyes opened to more of the wonders of physics. When asked what activities helped them learn, a middle level student and a low level student specifically listed concept mapping. One of these wrote in a begrudging manner when the student wrote "To be honest, concept mapping." One of the high level students who answered "No" to using concept mapping in the future and would use a study guide instead of a concept map for an assignment if given the choice explained with the comment "Concept mapping is good for relating concepts, but a study guide is more useful for studying and using for problems." This particular student is very bright and has only just been pushed academically in the Calculus class. I still feel that the reaction is based more on familiarity than on usefulness, but it still indicates that the students' perception of concept mapping is that it did help him to learn in the small amount. According to my weekly reflections, the two middle-level students, outside of class, volunteered that concept mapping did help them understand the concepts and the relationships between the concepts better.

Taking into account the triangulation of data, the assessment and concept mapping data both suggest that concept mapping did help the students to understand physics better. The survey data indicate that students did not perceive that they had greater understanding even though it appears that they had a greater understanding of the concepts.

My first subquestion relates to how well concept mapping enables students to retain understanding of physics concepts. I used targeted assessments, concept interviews, and student surveys to help determine if my application of concept mapping helped my students retain their understanding better than my normal style of teaching.

Targeted assessments were taken by the students at the completion of the unit and two weeks later for each of the three subject units. The targeted assessment consisted of four questions related to the subject matter of the unit. Table 5 is an analysis of targeted assessments displaying level of understanding at postunit, the level of understanding two weeks postunit, the percent change from postunit to 2 weeks postunit, the normalized gain from preunit to postunit, and the normalized gain from preunit to two weeks postunit. Comparing the delay score, percent change, and normalized gain post and delay, treatment unit 1 did better than the nontreatment unit, but treatment unit 2 did worse than the nontreatment unit. The results appear mixed for this treatment.

Table 5
Targeted Assessments of Students' Retention from Postinstruction to Two Weeks Later (N = 6)

Nontreatment Unit	Assessment Scores				
	Post*	Delay*	% Change	Normalized Gain Post	Normalized Gain Delay
Overall	4.3	4.1	-5	0.33	0.31
High	7.3	5.5	-25	0.66	0.44
Middle	4.5	4.5	0	0.35	0.35
Low	2.2	2.8	27	0.11	0.18
Treatment Unit 1	**Assessment Scores**				
	Post*	Delay*	% Change	Normalized Gain Post	Normalized Gain Delay
Overall	6.1	5.2	-15	0.58	0.48
High	8.5	8.0	-6	0.84	0.79
Middle	5.8	6.0	3	0.48	0.50
Low	4.7	2.8	-40	0.46	0.27
Treatment Unit 2	**Assessment Scores**				
	Post*	Delay*	% Change	Normalized Gain Post	Normalized Gain Delay
Overall	5.4	2.4	-56	0.43	0.06
High	7.5	2.8	-63	0.55	-0.31
Middle	7.3	3.0	-59	0.69	0.20
Low	2.8	1.7	-39	0.23	0.11

Note. *Postunit and delayed unit assessment scale was 10= very strong understanding, 0= very poor understanding.

The second instrument used to analyze the effectiveness of this study was concept interviews. Table 6 is analysis of concept interviews displaying the level of understanding at postunit and the level of understanding two weeks postunit. Comparing the delayed score, the overall shows treatment unit 1 as higher normalized gain than the nontreatment unit, but treatment unit 2 was lower than the nontreatment unit. This indicates mixed results with greater retention with treatment 1, but not with unit 2 when compared to the nontreatment unit.

Table 6
Student Concept Interviews of Students' Understanding from Postinstruction to Two Weeks Later (N = 5)

Nontreatment Unit	Assessment Scores				
	Post*	Delay*	% Change	Normalized Gain Post	Normalized Gain Delay
Overall	2.8	2.0	-29	0.20	0.11
High	7.0	2.0	-71	0.63	0.00
Middle	2.5	2.8	12	0.12	0.15
Low	1.0	1.3	30	0.09	0.12
Treatment Unit 1	Assessment Scores				
	Post*	Delay*	% Change	Normalized Gain Post	Normalized Gain Delay
Overall	4.2	5.4	29	0.39	0.52
High	4.0	4.0	0	0.39	0.39
Middle	5.5	6.0	9	0.48	0.54
Low	3.0	5.5	83	0.29	0.55
Treatment Unit 2	Assessment Scores				
	Post*	Delay*	% Change	Normalized Gain Post	Normalized Gain Delay
Overall	6.5	5.1	-22	0.27	-0.02
High	9.0	6.0	-33	0.67	-0.33
Middle	6.5	5.3	-18	0.30	0.06
Low	5.3	4.5	-15	0.15	0.00

Note. *Postunit and delayed unit assessment scale was 10= very strong understanding, 0= very poor understanding. The instructor rated the students on their level of understanding the concepts.

The final assessment instrument for measuring the level of the students' perception of their retention of physics concepts was a postunit and two week delayed postunit survey. The students' overall rating of their own understanding decreased in most cases after the two week delay except for treatment unit 1 as shown in Table 7. For treatment unit 1, the students' assessment of their understanding stayed the same from the close of the unit to two weeks later. Both the nontreatment unit and the treatment unit 2 showed a decrease of over 10% over the two week delay.

Table 7
Change in Students' Perception of Remembering Concepts from Postinstruction to Two Weeks Later (N = 6)

	Post	Delayed	Percent Change
Nontreatment Unit	4.1	3.6	-13%
Treatment Unit 1	3.5	3.5	0%
Treatment Unit 2	3.4	2.9	-17%

Note. Likert scale 5= very strong understanding, 1= very poor understanding.

When you take triangulation of data into account, the results appear consistently mixed for the retention of understanding. Treatment unit 1 did better than the nontreatment unit, but the nontreatment unit did better than the treatment unit 2. This would suggest that other uncontrolled factors affected this outcome.

The second subquestion was about the effect of concept mapping on student engagement and motivation in a high school physics class. I used teacher field observations, pre and posttreatment nonconcept interviews, and pre and posttreatment student surveys to assess this effect. I also had some input from my weekly reflection journal.

From the teacher field observations, there was a noticeable difference between the nontreatment and treatment units. In the nontreatment unit, the students were easily distracted in the lecture/discussion/problem solving time. This was quantified on a 1 to 5 scale with 1 being very distracted to 5 being very engaged. The average rating went from 2.6 for the nontreatment unit to 3.7 for the treatment unit 1 to 4.1 for treatment unit 2. During the introduction to concept mapping, there was an almost universal rejection of concept mapping. This reminded me of when I introduced a new type of assignment to them on creating their own study guides from the unit. They groaned and complained some, but now about two years later, they find that creating a study guide is easy. In the treatment time, my journal entries included my self-reflective phase “feel fairly decent” on lecture/discussion/problem solving time that was repeated several times. This reflected an enhanced engagement during class which in turn made me feel better about class. In the labs, the students were more engaged during nontreatment and treatment according to my field observations. The concept mapping appeared to help engagement greatly in the classroom time.

From the eight student interviews, three liked concept mapping, three did not like concept mapping, and two were fairly neutral. When asked “How did concept mapping help motivate you,” answers ranged from “Irritated me!” to “helped a lot by making you think about the connections.” From a student perspective, concept mapping was neutral for motivation. When asked what activities motivates you, five listed grades, four listed labs, three listed topic and one mentioned liking doing concept maps on the board, but not doing them individually. When asked to explain their motivation rating, most had no response, but one student mentioned that they “could get more points with concept mapping.” There were similar results for engagement with three saying it helped, three saying it did not, and two being neutral. The interview comments indicate that each student had a personal reaction to concept mapping.

From the student surveys, motivation decreased 9% and engagement stayed the same from nontreatment to treatment. The reaction to concept mapping varied widely from student to student. When asked if they would use concept mapping in the future, four answered “No.”, three answered “Maybe.”, and one answered “Probably”. When asked if they would use concept mapping in the future, a high student answered probably, both middle- level students and a low- level student said maybe and four (two high level and two low level) said no.

From the teacher weekly reflections, the students varied widely. A high-achieving student did very well with concept mapping and commented that it could be applied to many other things. The other two high-achieving students were resistant (one was highly resistant) to concept mapping. The two middle students were receptive to concept mapping and it appeared to help them understand the concepts better. After the treatment was completed, these same two students came up to me outside of class and admitted that the concept mapping helped them. Two of the low students were resistant, but positive with concept mapping. The lowest achieving student gave up and put very little effort into his last concept map. In the nontreatment unit, several students were noted as disruptive. In the treatment units, there was no mention of disruption. This is indicative of a greater engagement on the part of the students.

Triangulating this data for student motivation and engagement, it appears that concept mapping did engage the students more although they did not admit it, whereas motivation was more neutral with the exception of a couple of students that received more points with concept mapping.

The third subquestion was how concept mapping affected the teacher's motivation and attitude. I used observations by a colleague, weekly reflective journaling, and pre and posttreatment surveys.

The observations by a colleague were nondeterminative as motivation and attitude were all fives on a five point scale for both nontreatment and treatment observations. One comment he had on all three observations was "Keep it up.", which I found highly complementary. On the observation form, he was asked “If you were in high school, would you like to be in this class? Why?” For the nontreatment unit he responded with “Yes, relationship between kids/teacher very positive. Not a telling situation, but rather a let's figure it out together.” For treatment unit 1, he responded with “Yes, like the "we're in it together" atmosphere.” For the second treatment unit, he responded with “Yes, The atmosphere in the class is healthy. We are in this together. Learning is the priority, but in a very positive rewarding way. Learning is fun!!!” My colleague found my class in general to be healthy and positive. When I called him to ask if he saw any difference between nontreatment and treatment units, he replied “Maybe there was an increased engagement on the part of the students.”

The weekly reflective journaling showed a movement from somewhat negative tone to a positive tone with an exception regarding one student. The teacher field observations had an increased number of comments like “feel pretty good about class” in the treatment units than it did in the nontreatment unit. I had a marked difference in response to the reflective journal question “Do you have any improvements?” In the nontreatment unit, I was wondering about a discipline tool to help focus the lesson. In both of the treatment units, I commented about using a good concept map to start/ guide the lesson would be a good improvement. In response to “What did you learn this week,” I had “need for effective discipline” for the nontreatment unit which changed to “Concept maps are very effective tool to explain concepts to students” for the first treatment unit. Another question that showed a marked difference was “How is this affecting your attitude and motivation?” For the nontreatment unit, the entry was “depresses my attitude and lowers my motivation.” For the treatment units it started with “poor at first until I walked through a concept map with a poor student, then much better" and finished with "positive on my attitude." This demonstrated a strong positive shift in attitude and motivation.

The pre and posttreatment surveys for attitude and motivation showed a 30% increase in attitude and a 20% increase in motivation. In the comments on attitude and motivation, the comment was "I want more and not sure how to achieve it" pretreatment to "Pretty good" for posttreatment. When I asked "What possible improvements could be made?", my pretreatment response was "better labs, text, preparation and communication of expectations" which changed to "I like what I did." All three of these indicated that my attitude and motivation went up with the treatment.

Triangulating these three instruments, it appears to show an improved attitude and motivation of the teacher. The weekly reflections and treatment surveys show a strong indication that the treatment increased attitude and motivation on the part of the teacher.

The fourth and last subquestion was on how concept mapping affected teacher preparation time and grading time. I used a log book to record the time used, weekly reflective journaling to record how I felt about the preparation and grading, and pre and posttreatment surveys. According to the log book, preparation time took 190% more time and grading time took 60% more time with concept mapping. In the weekly reflections, I felt progressively better with each unit so concept mapping had a very positive effect on my preparation. In the treatment surveys, there was a 33% increase in how I felt about preparation time. Preparation time was increased due to creating concept maps of the unit. Also in the treatment surveys, grading felt like it took 50% more time. My normal grading has been number answers, mathematical steps, vocabulary and questions. I replaced a study guide of the unit assignment with a student generated concept map of the unit. Concept map grading is almost like grading a picture. A rubric, see Appendix R, for grading concept maps helps a great deal. I had not recorded how much time I used for preparation or grading before this project. My concept mapping preparation time should take less time now and part of this preparation time will be done before in the summer preparation time. My concept mapping grading time should take less time now although I doubt it will ever get down to the same as my other grading.

INTERPRETATION AND CONCLUSION

The main purpose of this study was to see if incorporating concept mapping into my physics classroom would help my students learn concepts better. Although the numbers show some improvement, the impact is much greater. This impact affected both high and low-achieving students. A couple of students commented that it helped them understand better by forcing them to look at the relationships between concepts. One middle-level student made the statement "So vast, I didn't get it." The treatment has very positively affected this student by opening their eyes and perceiving far more of the wonders of physics. Looking at the slightly decreased students' perception of their understanding, this may actually reflect the students understanding better because they see more now than they saw before about their learning. Many times when I studied a topic, I found out how much I did not know, even though I had learned more than I knew before.

Closely related to purpose was how well the students would retain the concepts and the relationships between them. These data was somewhat mixed, but it still points towards concept mapping having a positive effect on retaining concepts and their relationships. The two treatment results vary so widely on retention and one possibility for the mixed results could be that the second unit was perceived as more abstract than either the nontreatment unit or the first treatment unit. Other possibilities include differences in presentation, and weather causing schedule differences between the two treatment units.

There was a wide spread of motivation reactions although engagement was almost universally enhanced. The reaction to concept mapping ranged from an enthused reaction to a “Do I have to do this?” attitude. Even though there was resistance to doing something new, the students were more engaged in the classroom. When I started these same students in creating their own study guide almost two years ago by taking notes from the textbook chapter, there were complaints and groaning about how hard it was. Now these same students think it is easy to create a study guide from a chapter. If these students have to create concept maps in the future, I think they will find it easier to do.

My attitude and motivation increased as I saw how this helped me create a more thorough preparation, my students to understand the concepts better, and helped my students to engage at a deeper level. The concept mapping took me longer to prepare and grade, but with practice the difference should shrink because I will be more familiar with preparing concept mapping lessons. I feel it will continue to take longer by comparison, but the lesson preparation will be better.

Overall, concept mapping helped in my classroom. From ensuring a more thorough preparation, engaging students at a deeper level in class, and helping the students to understand better through seeing the relationships between concepts, concept mapping appears to be a very beneficial tool.

This study did not turn out as positive as I would have liked and I have identified several points where the project could have been improved. First, there were several weather disruptions which disrupted my class schedule so none of the three units had the same sequence. Second, there was a steep learning curve with learning how to do a concept map. If I was to do this or a similar study again, I would have a three or four week period where concept mapping would be phased in between the nontreatment unit and the treatment units. As it happened in my study, I am not sure how much learning how to actually make a concept map disrupted learning physics. Third, this study is far too small with only eight students to reach solid conclusions. Fourth, the physics study units could have been more similar in complexity to each other. The second treatment unit was more abstract to the students compared to the nontreatment and first treatment unit. The more abstract a unit, the less likely the student will be able to grasp and retain the material solidly. Fifth, the interview process was rushed at several points and at one point was started on a Thursday and finished on a Monday due to weather. Sixth, my assessments could have been improved and in two cases, my assessment tools were not effective in discerning any difference between nontreatment and treatment units. In particular, the colleague observations, the teacher reflective journal and the teacher field observations did not have any questions relating to concept mapping or the effects of concept mapping in the classroom. There are three specific questions I would like to add to the observation and journal assessments. They are “How did concept mapping appear to affect student motivation and engagement compared to the nontreatment unit?", "How did concept mapping appear to affect the attitude and motivation of the instructor compared to the nontreatment unit?", and "How did concept mapping appear to affect the quality of the preparation of the teacher compared to the nontreatment unit?"

In all, it was a very good experience, both for my students and myself.

VALUE

This study was valuable to me, my students, and will be valuable to other teachers and students. Action research, concept mapping, and physics can positively affect both teacher and learner in many ways.

My students were affected in several ways. First, they participated in an action research project, which allowed them to see ongoing research. Second, they were able to learn how to do concept mapping. This in turn helped them to look for relationships between concepts. Third, it helped them to be more engaged in class. Fourth, they were able to learn a couple of physics units at a deeper level. This will help them become better students. I do not know the future of any of my students, but I am rather sure their knowledge of physics and concept mapping will help them in their future studies.

This study has also affected me as a teacher in several ways. It has helped me grow as a teacher with learning new techniques to better engage, empower, and assess my students. This project has also helped me become a more effective learner. Lastly, it has taught me how to initiate, do, and finish an action research study. As I do my preparation for the next school year this summer, I will be incorporating concept mapping into my teaching style. I feel that it will help me create a more integrated lesson so the students can understand concepts and their relationships to each other better. As I pursue my questions as a learner, the action research will help guide me to finding answers and more questions.

The process of learning and doing action research has provided me with better tools to find more effective ways to help my students learn. As an example, in one of my other classes, I was puzzled why my class did poorly on one chapter and very well on the next chapter, so I used an assessment tool to find out why. By using the assessment tool, I learned that the first chapter was abstract to the students while the second chapter was more concrete. This has helped understand that I need to identify ways to make the first chapter more concrete and understandable to my students. Another example is the teacher reflective journal which is proving to be very valuable to me is. I continued to use this tool after the project was done and plan to use it next year. It has provided a way to keep track of what is going on with each student, what is working or not working in the classroom, and what is going on with the instructor. Just taking a short couple of minutes at the end of each class can make a large difference by being able to see patterns through time.

It is my hope that this study can help other teachers and students learn more about action research, concept maps and physics. Action research provides a way to help find problems in the classroom, develop new teaching strategies, and test teaching strategies. I am very grateful for the opportunity to learn and do this project. I have learned to keep learning and questioning, which is a valuable lifelong lesson for my teaching,

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APPENDICES

APPENDIX A

LESSON PLANS

Lesson Plan

My normal lesson plan for a unit is as follows:

1. Monday: opening two hour laboratory consisting of demonstrations followed by two to three experiments introducing the main concepts of the unit.
2. Wednesday: lecture/ discussion/ problem solving. An assignment with five student questions is due.
3. Thursday: lecture/ discussion/ problem solving. Study guide and practice problems are due.
4. Monday: Two hour laboratory consisting of two to three additional experiments. Review questions and extra practice problems are due.
5. Wednesday: Review day. Review through unit concepts with interactive discussion and problem solving.
6. Thursday: Exam day. Field notebook and laboratory write up are due.

Lecture/ discussion/ problem solving is a very interactive time flexing between lecture on the unit’s topics, discussion on the unit’s topics and problem solving depending on the students’ needs.

During the project, there were many problems with snow days and early closings that affected my normal schedule to the extent that no unit was done the same way. As an example, only treatment unit 2 had two laboratory days.

Nontreatment Unit

Wednesday: Started with three demonstrations on momentum. We continued with lecture/ discussion/ problem solving majoring on linear momentum, conservation of linear momentum, and impulse. The three demonstrations were 1. a can on side with ball inside, move in direction of opening, stop the can and the ball rolled out, 2. A drinking glass, stiff sheet, toilet paper roll, and a ball stacked in a tower. Pull the sheet out and the ball dropped into the glass, 3. Dropped a raw egg in bowl where it broke, dropped another egg from greater height unto suspended cloth sheet and it did not break.

Thursday: Lecture/ discussion/ problem solving on angular momentum and conservation of angular momentum. Five question assignment was due.

Monday: Laboratory day. Had the students do the momentum experiments. Study guide and practice problems were due.

Wednesday: Discussion and problem solving. Extra practice problems and review questions due.

Thursday: Review day. Reviewed unit and answered any remaining questions.

Monday: Exam day. Mini review followed by exam. Field notebooks and laboratory write ups were due.

Treatment Unit 1. Periodic Motion.

Wednesday: Introduced concept mapping. We worked through several examples on board, then interactively and cooperatively went through building a concept map for simple periodic motion.
Wednesday: Opened with giant pendulum demonstration daring students to face the pendulum. We walked through some of the student concept maps on the board. The five question assignment was due.
Thursday: We spent most of the day doing problem solving on the board. Practice problems and concept map of the unit were due.
Monday: Laboratory day. Had the students do the periodic motion experiments. Review questions and extra practice problems were due.
Wednesday: Review day. Interactively and cooperatively built a concept map of the unit on the board and did some problem solving.
Thursday: Exam day. Field notebooks and laboratory write ups were due.
Treatment Unit 2. Waves
Monday: Opened class with three demonstrations; 1. blowing on a couch shell horn, 2. using a cord attached to the wall to show resonance in standing waves, and 3. using a slinky to show longitudinal waves. Had the students do the sound laboratory.
Wednesday: Lecture/ discussion/ problem solving which turned into a wide ranging discussion on light waves. The five question assignment was due.
Thursday: Interactively and cooperatively built a concept map on the board about sound waves. We worked on some problems on the board. Concept map of unit and practice problems were due.
Monday: Laboratory day. The students finished any sound wave experiments and did the light wave experiments. Extra practice problems and review questions were due.
Wednesday: Review day. We interactively and cooperatively built an overall concept map of the unit. We also had some discussion and problem solving.
Thursday: Exam day. Field notebooks and laboratory write ups were due.

APPENDIX B

LABORATORY EXPERIMENTS

Physics Experiments Momentum 2014/1/6

Be sure to follow the field notebook procedures. What predictions do you have in each case? Equipment will be available until the exam.

1. Use a grooved board and marbles to investigate collisions.
a. With the board flat on a table and marbles in the groove, see what happens with marble collisions. See what variations you can do and what can you learn from them. Try same mass and size marbles first.
b. What happens if you try same size, but different mass marbles in your collision?
2. Use a grooved board and marbles to investigate collisions.
a. With the board on an incline, see if you can do a marble collision?
b. Try as many variations as you can.
3. Use poker chips to do 2 dimensional collisions. Measure your angles and how far the chips went after the collision.
a. Try to do straight on first.
b. Try to do off center collisions.
4. You may want to repeat the experiment with twirling a mass and measuring the speed, radius and magnitude of angular momentum by using the apparatus described on page 308 of your textbook. Can you think of another way to do this?
5. Using the office chair, hand weights, and the bike gyroscope, experiment with angular momentum.
a. Spinning in the office chair holding the hand weights, can you measure the difference in speed as you move the hand weights in and out.
b. What effects does spinning in the office chair and holding the bike gyroscope have?
6. What explanations do you have for this? Can you take the laws of motion and explain what is happening in each case?

Extra

7. Use 2 sticky golf balls on string to investigate an inelastic collision.
a. Set up the 2 golf balls as a simple string pendulum.
b. If you hold one golf ball up and let it swing into the other golf ball, how high up does the center of mass go compared to how high the first gold ball was?
8. Using a lazy susan and a pie tin with some water in it, what can you discover about the motion of the water as you spin the lazy susan?

Physics Experiment Periodic Motion

Be sure to follow your field notebook procedures and adequately record your information. If it is not in your field notebook, it does not exist.

Equipment will be left in the cabinet so if you do not finish in class, you can finish later. There are some calibrated masses, but you will need to create other masses as well to get at least 3 masses for each spring. You will also need to figure out accurate ways to measure for this experiment. Each lab group will have a half hour on the large pendulum if they desire to use it.

1. Find spring constant of two different springs.
   a. Use at least 3 different masses on each spring
   b. Do at least 5 trials on each mass spring combination to find a mean average for the data point.
2. Using the spring constants from #1, verify the period equation.
   a. Do both springs
   b. Use at least 3 different masses on each spring
   c. Do at least 5 trials on each mass spring combination to find a mean average of the period.
3. Verify the period equation for a simple pendulum.
   a. Verify that different masses do not vary the period. Use at least 3 different masses.
   b. Use at least 3 different lengths of pendulums.
   c. Do at least 5 trials on each length to find a mean average of the period.

Physics Experiment for Sound Waves

You have a variety of metal tubes, a sheet containing the frequencies of a piano keyboard, access to a piano and a variety of instruments to measure distance.

What can you find out about the resonant frequencies of these metal tubes?

How does the length and diameter of the tubes affect the primary resonant frequency?

Other groups may have tubes made of a different material. Does the type of metal affect the resonant frequency?

Physics Light Wave Laboratory

There are two parts to this laboratory with each part demonstrating something about light wave properties. You will be measuring the wavelength of microwaves and measuring the wavelength of a laser light. In addition, you should be able to calculate the speed of light. What can you find out in this lab?

Part One:

Equipment:

A microwave
A flat serving tray
Velveeta cheese

Process:

1. Arrange the Velveeta cheese on the flat serving tray so it creates a continuous sheet of cheese on the tray.

2. Take out any rotating tray and equipment to turn the tray.
3. Put the cheese tray in bottom of the microwave in a matter so the tray will not move.
4. Carefully cook the cheese until some soft spots show up in the cheese.
5. Measure the distance between the soft spots.

Questions:

1. What does the distance between the soft spots mean?
2. What other information about the microwave radiation can you find on the microwave?
3. Can you find the speed of the microwave radiation?

Part Two:

Equipment:

Tape measure or meterstick

Laser pointer (DO NOT look directly at or shine directly into someone's eyes).

Diffraction grating with a known spacing

Diffraction grating with an unknown spacing

A dim room

Process:

1. Shine the laser through the diffraction grating and notice that there are multiple points of light on the wall.
2. Measure the angles of points of light from the center point of light.
3. Given the spacing on the one diffraction grating, find the spacing on the other diffraction grating.

Questions:

1. What is the wavelength and frequency of your laser?
2. What is the spacing on the unknown diffraction grating?

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APPENDIX C

STUDENT TARGETED ASSESSMENTS

Targeted Assessment Student Number _________________ 1/6

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way. You can choose to not answer any question that you do not want to answer, and you can stop at any time.

Nontreatment Unit (Momentum) Preunit.

1. What is the equation to describe linear momentum?

2. What is conservation of momentum? List an example.

3. Describe linear momentum and how it relates to the laws of motion.

4. What is recoil velocity and what is an application of it?

Targeted Assessment Student Number ________________ 1/16

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way. You can choose to not answer any question that you do not want to answer, and you can stop at any time.

Nontreatment Unit (Momentum) Postunit.

1. What is the equation to describe impulse?

2. What is angular momentum?

3. Give examples of linear momentum and how we can use it?

4. How does momentum apply to a rocket?

Targeted Assessment Student Number ________________
1/20

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way. You can choose to not answer any question that you do not want to answer, and you can stop at any time.

Treatment Unit 1 (Periodic Motion) Preunit.

1. What is the formula for Hooke's law?

2. In a mass spring system, the period varies based on what variable?

3. Describe periodic motion and how it relates to the laws of motion.

4. Why was the development of the quartz clock important?

Targeted Assessment Student Number ________________ 1/30

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way. You can choose to not answer any question that you do not want to answer, and you can stop at any time.

Nontreatment Unit (Momentum) Delayed 2 Weeks.

1. What is the equation for angular momentum?

2. How fast does a 1400 kg Prius have to go to have the same momentum as a 2800 kg Ford F150 going 30 mph?

3. Give examples of angular momentum and how we can use it.

4. In a Newton's Cradle, if one ball is pulled back and let swing into the other four balls, why does only one ball swing out on the other side in response?

Treatment Unit 1 (Periodic Motion) Postunit.

1. What is equilibrium position?

2. In a pendulum system, what two types of energy continually interchanges?

3. Describe the periodic motion of a simple pendulum.

4. Why did Newton want a more accurate clock and how does that relate to periodic motion?

Targeted Assessment Student Number ________________

2/3

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way. You can choose to not answer any question that you do not want to answer, and you can stop at any time.

Treatment Unit 2 (Waves) Preunit.

1. What is a wave?
2. What is the Doppler effect?
3. Describe wave motion and how it relates to the laws of motion.
4. How are sound and light waves similar and dissimilar to each other?

Targeted Assessment Student Number ________________

2/13

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way. You can choose to not answer any question that you do not want to answer, and you can stop at any time.

Treatment Unit 1 (Periodic Motion) Delayed 2 Weeks.

1. What is restoring force?

2. In a simple string pendulum system, the period varies based on what variable?

3. How does the periodic motion of a spring pendulum relate to a simple string pendulum?

4. Why was the development of an accurate chronometer important?

Treatment Unit 2 (Waves) Postunit.

1. What is wavelength?

2. What is the energy of an EM photon with a frequency of 3×10^{14} /sec given that Planck's constant is 6.63×10^{-34} J sec?

3. Describe sound waves and what effects do they have.

4. Explain what happens in the photoelectric effect.

Targeted Assessment Student Number ________________

2/27

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way. You can choose to not answer any question that you do not want to answer, and you can stop at any time.

Treatment Unit 2 (Waves) Delayed 2 Weeks.

1. What is the photoelectric effect?
2. What is redshift in starlight?
3. Describe the wave motion of light and what effects it has.
4. Explain wave interference.

APPENDIX D

STUDENT PRE AND POSTUNIT CONCEPT INTERVIEW

Student Pre and Postunit Concept Interview Student number ______ Date ________

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way. You can choose to not answer any question that you do not want to answer, and you can stop at any time.

The main concept of this unit was ____.

1. How do these terms relate to each other?

Nontreatment	Treatment 1	Treatment 2
Momentum	Periodic Motion	Wave
Impulse	Hooke's Law	Sound Waves
Conservation of momentum	Equilibrium Position	Light Waves
Recoil Velocity	Restoring Force	Frequency
Angular Momentum	Spring constant	Photon
Angular velocity	Amplitude	Work function
Conservation of angular Momentum	Conservation of energy	Photoelectric effect

2. What is the main idea of the chapter? Please explain your answer.

3. How could you use this concept?

4. What does this help explain about the universe and the world?

5. Comments: Is there anything else you would like the teacher to know?

Interviewer Ratings

1. Interviewer rating of student understanding on a scale of 1 (not understanding) to 5 (understands very well).

APPENDIX E

STUDENT DELAYED UNIT CONCEPT INTERVIEW

Student Delayed Postunit Concept Interview Student number _______ Date _____

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way. You can choose to not answer any question that you do not want to answer, and you can stop at any time.

The main concept of this unit was ____.

1. How do these terms relate to each other?

Nontreatment	Treatment 1	Treatment 2
Momentum	Periodic Motion	Wave
Impulse	Hooke's Law	Sound Waves
Conservation of momentum	Equilibrium Position	Light Waves
Recoil Velocity	Restoring Force	Frequency
Angular Momentum	Spring constant	Photon
Angular velocity	Amplitude	Work function
Conservation of angular Momentum	Conservation of energy	Photoelectric effect

2. Upon reflection of this main concept, what is the main point of learning this? Please explain your answer.

3. How could you use this concept?

4. What does this concept help explain about the universe and the world?

5. Comments. Is there anything else you would like the teacher to know?

Interviewer Rating

Interviewer rating of student understanding on scale of 1 (not understanding) to 5 (understands very well).

APPENDIX F

STUDENT PRE AND POSTTREATMENT INTERVIEW

Student Pre and Posttreatment Interview Student number __________ Date ______

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way. You can choose to not answer any question that you do not want to answer, and you can stop at any time.

Pre-treatment Interview

1. What was motivating and exciting in the last unit?

2. How well and in what ways did the past unit and teaching style keep your interest?

3. Comments. Is there anything else you would like the teacher to know?

Posttreatment interview

4. What was motivating and exciting for you in the last 2 units?

5. In what ways were you motivated in these units? What motivated you in these units?

6. How did concept mapping help motivate you?

7. How well did concept mapping help hold your interest in what was being presented?

8. Did concept mapping help you focus better in class?

Interviewer ratings

1. Interviewer rating of student motivation of pretreatment on a scale of 1 (antipathy) to 3 (neutral) to 5 (very strong desire).
2. Interviewer rating of student engagement on a scale of 1 (very distracted) to 5 (very interested).

APPENDIX G

STUDENT PRETREATMENT SURVEY

Student Pretreatment Survey Student number ___ Date ______

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way. You can choose to not answer any question that you do not want to answer, and you can stop at any time.

The main concept of this unit is ____..

1. How would you rate your current understanding of this concept on a scale of 1(not understanding) to 5 (understands very well)?
2. Please explain your answer?

3. How do you think this unit will make a difference in how you understand the world and use the concepts in the world?

4. What activities in this unit motivated you? Please explain your answer.

5. Would you like to learn more about this topic? 1(not wanting) to 5 (wanting very much).

6. How motivated were you in this unit on a scale of 1 (hated it) to 3 (neutral) to 5 (very strong desire)?

7. What activities in this unit help you to learn?

8. How engaged were you in this unit on a scale of 1(very distracted) to 5 (very interested)?

APPENDIX H

STUDENT POSTTREATMENT SURVEY

Student Posttreatment Survey Student number ___ Date ________

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way. You can choose to not answer any question that you do not want to answer, and you can stop at any time.

The main concept of these units were ____.

1. How would you rate your current understanding of these concepts on a scale of 1 (not understanding) to 5 (understands very well)?

2. Please explain your answer

3. How did this unit make a difference in how you understand the world and use the concepts in the world?

4. How are the concepts and information you learned in this unit valuable to you?

5. What activities in this unit motivated you? Please explain your answer.

6. Would you like to learn more about this particular concept on a scale of 1 (not at all) – 5 (want to learn more)?

7. How would you rate your level of motivation on a scale of 1 (hated it) to 3 (neutral) to 5 (very strong desire)? Please explain your answer.

8. What activities in this unit help you to learn?

9. How would you rate your level of engagement on a scale of 1 (very distracted) to 5 (very interested)? Please explain your answer.

Treatment questions

1. Did concept mapping help you understand the unit better on a scale of 1 to 5 with 1 being it hindered greatly and 5 being it helped greatly?
2. Do you think you will use concept mapping in the future? Please explain your answer.
3. If you had a choice between doing a concept map of a unit or doing an outline study guide as we have been doing, which would you choose? Please explain your answer.

APPENDIX I

STUDENT POST AND DELAYED UNIT SURVEY

Student Post and Delayed Unit Survey Student number ________ Date ______

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way. You can choose to not answer any question that you do not want to answer, and you can stop at any time.
The main concept of this unit was ____.

1. How would you rate your current understanding of this concept on a scale of 1 (not understanding) to 5 (understands very well)?
2. Please explain your answer.
3. In what ways did this unit make a difference in how you understand the world and use the concepts in the world?

4. How are the concepts and information you learned in this unit valuable to you?

APPENDIX J

PARENT SURVEY

Parent Survey Student number __________ Date _________

Participation in this research is voluntary and participation or non-participation will not affect a student's grades or class standing in any way. You can choose to not answer any question that you do not want to answer, and you can stop at any time.

Scale 1 to 5 (1. Lowest, most unlike, easiest; least motivated 3. Middle; 5.Highest, most like, hardest, most motivated)

The main concept of this unit was ____.

1. How would you rate your student's motivation during this unit on a scale of 1 (antipathy) to 3 (neutral) to 5 (highest)?

2. How would you rate your student's attitude during this unit on a scale of 1 (lowest) to 5 (highest)?

3. Did your student mention any examples of the main topic of the class? How often or how many? Mention any examples.

4. How likely was your student to work on homework without your asking on a scale of 1 (did not have to ask) to 5 (have to ask all the time)?
5. What do you think is your student's level of understanding of this unit on a scale of 1 (lowest) to 5 (highest)?

APPENDIX K

TEACHER FIELD OBSERVATIONS

Teacher Field Observations

Date _______________

Scale 1 to 5 (1. Lowest, most unlike, easiest; least motivated 3. Middle; 5.Highest, most like, hardest, most motivated)

Postclass time observations

1. How did each student appear to be engaged today on a scale of 1 to 5 with 5 being the most engaged?
   1.
   3.
   5.
   7.
   9.
   11.
   13.
   15.
2. Explain EACH

3. How do you feel about the class today?

4. How could you have improved the lesson today?

APPENDIX L

COLLEAGUE CLASSROOM OBSERVATIONS

Classroom Observations

Date ________________

The 1 to 5 scale is 1 being a poor attitude or engagement and 5 being a very good attitude or engagement.

Class time observations

1. How did the students appear to be engaged today on a scale of 1 to 5?
   Comments (please note good behavior and poor behavior examples):

2. Did the teacher's attitude and motivation encourage and motivate the students on a scale of 0 to 8 with 0 being no students motivated and 8 being 8 students motivated?

3. How was the teacher's motivation today on a scale of 1 to 5?

4. How was the teacher's attitude towards planning and teaching this lesson on a scale of 1 to 5?

5. If you were in high school, would you like to be in this class? Why?

6. Comments on teacher attitude and motivation.

7. What possible improvements could be made to this lesson?

APPENDIX M

TEACHERS LOG

Teacher Log
Date _______________
Evening/morning Journal book
How many hours in preparation today?

How many hours grading today?

Total hours today?
Overall comments----

APPENDIX N

TEACHER REFLECTIVE JOURNAL

Teacher Reflective Journal

Date _______________

Scale 1 to 5 (1. Lowest, most unlike, easiest; least motivated 3. Middle; 5.Highest, most like, hardest, most motivated)

Weekly Journaling

1. How do you feel this unit is going?
2. Do any students stand out in a positive or negative way? Add student notes

a. Student 1

b. Student 3

c. Student 5

d. Student 7

e. Student 9

f. Student 11

g. Student 13

h. Student 15

3. Do you have any improvements?
4. Any regrets?
5. What did you learn this week?
6. How is this affecting your attitude and motivation?
7. How did preparation go this last week on a scale of 1 to 5 with 1 being very poor?
8. How could you have done preparation better?
9. How did grading go this last week on a scale of 1 to 5 with 1 being very poor?
10. How could you have done grading better?

Be sure to explain each.

APPENDIX O

PRETREATMENT TEACHER SURVEY

Pretreatment Teacher Survey

Date _______________ To be filled out on Friday morning after the previous 2 weeks.

The 1 to 5 scale is 1 being a poor attitude or motivation and 5 being a very good attitude or motivation.

1. How was your attitude towards planning and teaching the nontreatment unit on a scale of 1 to 5?

2. These last 2 weeks, what was your motivation on scale of 1 to 5?

3. How pleased was I with how things went in the nontreatment unit on a scale of 1 to 5?

4. What possible improvements could be made to the notreatment units?

5. Do you have any regrets from this unit?

6. Comments on attitude and motivation for the nontreatment unit.

7. How do you feel about your preparation time for the nontreatment unit on a scale of 1 to 5 with 1 totally unprepared and 5 being totally prepared?

8. How long did it seems to do lesson prep for the nontreatment units on a scale of 1 to 5 with 1 being much shorter than normal and 5 being much longer than normal?

9. How long did it seems to do grading in the nontreatment units on a scale of 1 to 5 with 1 being much shorter than normal and 5 being much longer than normal?

10. Comments on preparation time for the nontreatment unit.

APPENDIX P

POSTTREATMENT TEACHER SURVEY

Posttreatment Teacher Survey

Date ________________ To be done on Friday morning reflecting on past 4 weeks.

The **1 to 5 scale** is 1 being a poor attitude or engagement and 5 being a very good attitude or engagement.

1. How was your attitude towards planning and teaching the treatment units on a scale of 1 to 5?

2. These last 4 weeks, what was your motivation on scale of 1 to 5?

3. How pleased was I with how things went in the treatment units on a scale of 1 to 5?

4. What possible improvements could be made to the treatment units and using concept mapping?

5. Do you have any regrets from these units?

6. Comments on attitude and motivation for the treatment units.

7. How do you feel about your preparation time for the treatment units on a scale of 1 to 5 with 1 totally unprepared and 5 being totally prepared?

8. How long did it seems to do lesson prep for the treatment units on a scale of 1 to 5 with 1 being much shorter than normal and 5 being much longer than normal?

9. How long did it seems to do grading in the treatment units on a scale of 1 to 5 with 1 being much shorter than normal and 5 being much longer than normal?

10. Comments on lesson preparation and on grading time.

APPENDIX Q

TIMELINE

Timeline

Start Project Implementation: January 08, 2014

There was logging evening and/or morning each day for the teacher starting on 1/8/2014 and ending on 2/20/2014.

There were teacher observations after each class.

Nontreatment Unit Momentum

1/8/2014 to 1/20/2014: Class Instruction, Lab Activities and Discussions

1/8/2014 Introduction

1. Introduced the schedule to the students.
2. Administered prenontreatment assessments.
3. Introduced momentum unit with demonstrations.

1/9/2014 Lecture day

Lectured and discussed momentum

1/13/2014 Lab day

1. Linear collisions with marbles and poker chips.
2. Angular momentum with a mass on a string and using a bike gyroscope on an office chair..

1/15/2014 Lecture day

1. Lecture/ discussion/ problem solving
2. Colleague observations

1/16/2014 Review day

Reviewed with discussion and problem solving

1/20/2014 Exam day

1. Administered exam
2. Administered pretreatment unit 1 assessments
3. Administered pretreatment assessments

Treatment Unit 1 (Periodic Motion)

1/22/2014 to 2/06/2014: Class Instruction, Lab Activities and Discussions

1/22/2014 Introduced Concept Mapping.

1. Used concept mapping interactively and cooperatively going through periodic motion and periodic motion.
2. Handed out review questions on concepts, including concept maps in review questions.
3. Explained change in study guide notes to concept map on unit.

1/29/2014 Lecture day

1. Giant pendulum demonstration
2. Walked through student concept maps on board

1/30/2014 Lecture day

Classroom problem solving

2/3/2014 Lab day

1. Lab with spring pendulums and simple pendulums
2. Administered delayed nontreatment assessments

2/5/2014 Review day

1. Reviewed using concept maps and solving problems
2. Observations by colleague.

2/6/2014 Exam day

Administered posttreatment unit 1 assessment.

Treatment Unit 2 (Waves)

2/10/2014 to 2/20/2014: Class Instruction, Lab Activities and Discussions

2/10/2014 Lab day

1. Sound wave laboratory with a variety of tubes.
2. Administered pretreatment unit 2 assessments.

2/12/2014 Lecture day

Lecture and discussion on light waves

2/13/2014 Lecture day

1. Worked through concept maps
2. Worked on problems

2/17/2014 Lab day

1. Speed of light measurement
2. Wavelength using diffraction grating

2/19/2014 Review day

1. Reviewed using concept maps
2. Observations by colleague

2/20/2014 Exam day

1. Administered exam.
2. Administered posttreatment unit 2 assessments.
3. Administered delayed treatment unit 1 assessments.
4. Administered posttreatment assessments.

(Administration of interview assessments were interrupted due to early closing and finished on 2/24/2014).

2/24/2014 to 3/6/2014: Data Collection Cleanup

2/24/2014

1. Finished administering posttreatment unit 2 interview assessments.
2. Finished administering delayed treatment unit 1 interview assessments.
3. Finished administrating posttreatment interview assessments

3/6/2014 End of Project Implementation

Administered delayed treatment unit 2 assessments.

3/7/2014 to 5/31/2014: Analyze Data and Finish Writing Paper

APPENDIX R

RUBRIC FOR CONCEPT MAPPING

Rubric for Concept Mapping

This rubric is for scoring concept maps.

1. Propositions. Count the number of valid top down connections with valid linking words. Multiply by 1.

2. Hierarchy. Count the number of valid hierarchial levels. Multiply by 5.

3. Cross links. Count the number of valid meaningful cross connections. Multiply by 10.

4. Examples. Count the number of examples. Multiply by 1.

5. Sum up the total from lines 1 through 4 for the score of the concept map.

I normally did scoring in this order: 1. Examples, 2. Propositions, 3. Hierarchy levels, and 4. Cross links. It was easier for me identify examples and simplify the remaining scoring by using a color pencil to mark what I had counted. Using a different color for each type made this easier as I found that I could get lost in trying to count each part.

There are other more complex scoring rubrics which take into account improper links and vague links.

This is fairly close to what Novak and Gowan used in their book Learning How to Learn on page 36 in table 2.4.