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The Impact of Writing Intensive Professional Development on High School Teachers' Science Content Knowledge of Energy in Systems

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Abstract - The Communication In Science Inquiry Project (CISIP) investigated the impact of writing intensive, inquiry based professional development on high school teachers' science content knowledge of *Energy in Systems*. In particular, we investigated whether different forms of assessment provided different information about the depth of teacher knowledge. We developed a two-tier Energy Test, linked to both national and state science standards, which was administered both before and after science teacher participation in 23 hours of professional development on energy in biological and societal systems. Our study found that we were successful in relaying content knowledge to the teachers. When we analyzed misconceptions in distracter choices and written responses on the same test, however, we found we were successful in some areas, but not in others. The application of knowledge gained about energy in systems through writing scientific explanations was the least successful of all.

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I. INTRODUCTION

As the quest for renewable, affordable energy increases, we need a scientifically literate population that can evaluate energy sources with regard to the impact on the environment, as well as the economic consequences of choosing one energy source over another (Hudson, 2005). At the crux of this debate is the effect decisions will make on the quality of life. Students, as future decision makers, must be included in current energy debates (Weyman, 2009). As a society, we expect science teachers to develop students into scientifically literate citizens who are informed about, and can discuss, the merits and costs associated with the development and use of various forms of energy to power our society. Thus, we raise the question as to whether teachers have the knowledge necessary to teach the interdisciplinary theme of energy flows and reservoirs in biological and societal systems. To answer this question, we conducted a study to determine the impact of a writing intensive professional development on science teachers'

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knowledge about energy concepts and to use appropriate claims, evidence, and reasoning when crafting scientific explanations about energy.

II. RESEARCH QUESTIONS

1. What is the impact of writing intensive, inquiry-based professional development on teachers' knowledge of Energy in Systems?
2. What misconceptions about Energy in Systems were changed as a result of the professional development?
3. What do different forms of assessment reveal about the depth of teacher knowledge?

III. LITERATURE REVIEW

a) *Teacher Subject Knowledge and Effectiveness*

In order to be effective, teachers must have extensive subject matter knowledge (Loucks-Horsley, Hewson, Love, & Stiles, 1998). Using pedagogy that supports a student's ability to think deeply about content requires teachers to learn more about the subjects they teach (Shulman & Sparks, 1992; National Board for Professional Teaching Standards, 1989). However, mastery of content knowledge is not sufficient for excellent teaching (Banilower, Heck, & Weiss, 2007; Feiman-Nemser & Parker, 1990), but it is necessary for the development of pedagogical content knowledge (Abell, 2007).

Science teacher effectiveness is linked to training (Druva & Anderson, 1983). In particular, teacher professional development that focuses on science content and pedagogy increases students' conceptual understanding (Cohen & Hill, 1998; Fennema et al., 1996; Kennedy, 1998; Garet, Porter, Desimone, Birman, & Yoon, 2001). Furthermore, teachers with more content knowledge are more likely to teach science processes and be less teacher-centered than teachers with limited content knowledge (Dobey & Schafer, 1984) who avoid inquiry activities, relying on worksheets and textbooks instead (Lee, 1995).

b) *Understanding Energy Concepts*

Energy is a unifying theme that runs throughout life, physical, and Earth and space science. It is a key phenomenon embedded in concepts such as work, force, motion, photosynthesis, and chemical reactions. (Else, 1988; Watts, 1983). Therefore, we chose to focus on energy use in biological systems, and societal

systems, broadly characterized as *the capacity to do work and ability to cause change*.

In biology, understanding *photosynthesis*, the process in which organic material is synthesized from inorganic substances using the energy of light, and the role it plays in understanding both the life cycles of plants and animals, and energy flow through ecosystems (Çepni, Taş, & Köse, 2006) is very difficult (Bahar, Johnstone & Hansell, 1999; Lawson & Thompson, 1988; Storey, 1989). Research has found that students do not understand the energy relationship among the sun, plants, and animals. Nor do they perceive the relationship between biology and chemistry, necessary for understanding photosynthesis (Hirça, Çalik, & Akdeniz, 2008).

A common photosynthesis misconception is that the source of plant cellular material comes from "plant food" and substances in the soil (Stavy, Eisen and Yaakobi, 1987). This misconception ignores the biosynthesis that occurs within plant cells (Cakiroglu & Boone, 2002). The role of chlorophyll in absorbing light energy to convert to chemical energy is also often misunderstood (Barker, 1985; Simpson & Arnold, 1982). Sunlight is thought to be an *ingredient* in the reaction, a molecule like carbon dioxide, instead of an energy source (Barker & Carr, 1989; Simpson, 1983). Also common is that photosynthesis and respiration only involve exchange of gases ignoring the complex biological processes involved. As a result, photosynthesis is sometimes seen as being the respiration of plants (Amir & Tamir, 1990) so that animals can breathe (Roth & Anderson, 1985).

Energy transfer, the movement or flow of energy into, out of, or within a system is another area of difficulty. It often conjures up the misconception that energy flows from one substance to another like a fluid (Duit, 1984; Driver, Squires, Rushworth, & Wood-Robinson, 1994). *Energy conservation*, the principle that the total energy of an isolated system remains constant regardless of change within the system, is not a prevalent idea (Summers & Kruger, 1994). *Energy conservation* is commonly understood as "saving energy" by engaging in tasks such as turning off a light bulb (Carr & Kirkwood, 1988; Goldring & Osborne, 1994; Tatar & Oktay, 2007).

Energy conservation can also be problematic in another way. Some teachers understand *energy degradation* (energy is always transferred from a more to a less useful form) as happening only when energy is not conserved (Pinto, Couso, & Gutierrez, 2005). *Energy degradation* is also seen as a decreasing the *quantity* of energy rather than decreasing the *quality*, availability or usefulness of energy (Pinto, Couso, & Gutierrez, 2005). Teachers are also generally not aware of the concept of *energy efficiency* as defining the ratio between useful energy output of a conversion system and energy input

Nevertheless, teachers can learn about energy efficiency, in professional development, when presented explicitly, and distinguished from energy conservation (Summers, Kruger, Mant, & Childa, 1998).

Students often understand *energy* differently than scientists (Solomon, 1983). For example, students may understand energy to be a property of living things, humans, movement, or a fuel which is used up (Black & Solomon, 1983; Solomon, 1985; Watts, 1983). Students may think that energy can only be transformed into one form at a time (Brook & Wells, 1988), that energy transformation only occurs when the effects can be perceived (Brook & Driver, 1986), or that certain forms of energy such as light, sound, and chemical energy, do not cause change (Carr & Kirkwood, 1988). Other students believe that energy cannot be measured (Solomon, 1985; Watts, 1983), or confuse energy with other concepts such as food, force, or temperature (Anderson, Sheldon & Dubay, 1990).

c) *Scientific Explanations*

Science content knowledge and the ability to use it to make informed social decisions are aspects of scientific literacy. Within scientific practice, the results of inquiry are established and published in the form of *explanations* which attempt to make clear connections between claims, evidence, and reasoning that links them (Haack, 2003). An integral part of writing scientific explanations is the ability to recognize and reproduce these patterns, but cognitive psychologists have found that adolescents have difficulty relating data to explanatory theories (Yore, Hand, Goldman, Hildebrand, Osborne, Treagust & Wallace, 2004).

Science teachers may also have difficulties writing scientific explanations. Pre-service teachers find science writing more difficult than other types of writing (Robertson, 2004), and are better at using evidence to support claims than they are at linking appropriate reasoning to evidence (Sadler, 2006). High school science teachers are also able to produce acceptable claims, but providing supportive evidence is more difficult. The greatest difficulty for teachers is providing appropriate reasoning to link evidence and claims (Baker, Bueno, Watts, Perkins, Sen, Lewis & Lang, 2010).

IV. THE COMMUNICATION IN SCIENCE INQUIRY PROJECT (CISIP)

This study focused on one aspect of CISIP professional development; writing scientific explanation using claims, evidence, and reasoning. CISIP stresses that the development of structured and coherent scientific ideas is facilitated by learning to talk and write in science genres (Kelly, 2007). CISIP trains teachers to help students talk, think, and write like scientists. An integral part of CISIP training is learning how to teach students to write scientific explanations. "(Baker, et al, 2009)"

V. STRUCTURE OF THE PROFESSIONAL DEVELOPMENT INTERVENTION

The science content materials used the theme *Energy in Systems*. Because of the varied backgrounds of science teachers, we presented energy broadly and as used in the geosciences. We selected energy because of its social relevance, and centrality to all the sciences. Teachers in the professional development acquired pedagogical knowledge and skills as well as a deeper understanding of overlapping scientific fields.

The themes for *Energy in Systems* included: (1) energy flow through a system-sources, sinks, transfer, storage; (2) energy resources, transformation, and conservation; (3) energy density and energy efficiency; (4) renewable and non-renewable resources; and (5) cost and benefit evaluation of using various energy sources. Teachers tracked energy fluxes in biologic and anthropomorphic components of the Earth system and learned about radioactivity, photosynthesis, fossil fuels, and combustion. They created and solved quantitative problems in energy transfer and density, explored case studies of environmental, economic, and energy issues (e.g., wind energy vs. nuclear), conducted photosynthesis experiments, analyzed fossil fuel samples, and constructed solar powered systems.

a) Daily Activities

Day one - prior to content instruction, teachers were administered a pre-test of basic ideas relating to energy (*Energy Test*). After the pre-test, teams investigated energy storage and transfer in a system. Teachers reflected on this activity by writing in their notebooks. A whole-group discussion about energy flow followed, using energy flow through trophic levels of an ecosystem as an example of an energy system. Teachers then investigated the conversion of light to chemical energy during photosynthesis as an example of transfer of energy from light to leaf systems. In pairs, they formulated their own scientific questions, planned, and conducted an investigation. Next, they wrote scientific explanations using claims, evidence, and reasoning.

Day two - teachers discussed energy storage and transfer, using money as an analogy. Afterwards, they participated in an interactive lecture on the comparative nature, advantages, and disadvantages of different energy resources and conversion systems currently used. The teachers then explored the concept of *energy density*, defined as the energy stored in a given system per unit mass or unit volume. Finally, working in groups, they wrote energy density problems for use in their classrooms, and evaluated them with peers.

Day three - teachers participated in a Science Curriculum Topic Study (SCTS; Keeley, 2005) comparing major concepts and identifying interconnections

among topics followed by a focused on student misconceptions of photosynthesis and energy. Next, teachers wrote a scientific explanation using a simple data table. They were then given a base rubric for scoring their explanations. Subsequently, they were given another rubric which contained exemplars for each scoring category and asked to re-score their explanations. They then wrote contextualized photosynthesis rubrics, using the information from the SCTS and misconceptions literature. Using these rubrics, they scored a "mystery explanation" of the photosynthesis lab written by one of their peers, and provided written feedback. The explanations were returned to their writers, and rewritten, incorporating the feedback.

Day four - teachers played the *Stabilization Wedges Game*, created by the Princeton University Carbon Mitigation Initiative (2009) and adapted for our use. Teachers decided which stabilization wedges to choose to maximize carbon emission mitigation bearing in mind the environmental, economic and social costs. Participants then wrote scientific explanations for a mock Global Nations International Climate Summit. After writing, teams of three shared their scientific explanations with each other. Teachers then developed and record a two-minute video to advocate for one agreed-upon explanation.

Day five - teachers took the Energy Test post-assessment.

VI. STUDY DESIGN

Eleven high school science teachers participated in 35 hours of professional development during the summer. The 11 teachers, (9 female, 2 male), represented 7 schools and had been teaching from 1 to 30 years. Nine of the teachers taught biology, two chemistry, and one each physics, physical science, and earth and space science (total exceeds 11 because 3 teachers taught 2 disciplines). All majored in their content areas and were certified to teach in their content areas. Participation was voluntary. The sample was self-selected without a comparison group.

We analyzed the pre- post- test multiple choice items statistically (t-test and percentages) and the written explanations qualitatively. Due to the small sample size, additional statistical analysis was precluded. Writing samples of scientific explanations were analyzed using a rubric developed for this purpose. Three members of the research team scored all written data independently, then met to discuss scores to ensure inter-rater reliability.

a) Validity of the Energy Test

The Energy Test is a 30-item two-tier multiple-choice assessment. Each item was written with one correct and three distracter options. Distracters were common misconceptions documented in the research

literature. The development of the Energy Test was a recursive process in which items were designed, evaluated, and modified to determine whether they were appropriate, meaningful, and useful.

Content validity was established using two methods. First, items were written by a university faculty member with experience in research and teaching about energy in Earth and societal systems. Second, items were reviewed by the research team to insure that they reflected the professional development activities; science standards and the research literature. Validity was further supported by the professional development providers who determined whether the items reflected the professional development activities.

We chose a two-tier format because it has been widely used to identify misconceptions in science (Anderson, Fisher, & Norman, 2002; Treagust, 1988). More recently, we used a two-tier test to identify and evaluate teacher conceptions about flooding (Lewis, van der Hoven Kraft, Bueno Wilson & Lang, 2010) during previous professional development. In our test, respondents selected an answer to an item and then explained the answer with an open response in a space in which they could write or draw. This format allowed us to assess surface knowledge and in-depth knowledge, as well as changes in misconceptions from pre to post test. The written portion of the Energy Test was analyzed using the misconceptions identified in the research literature.

For analysis, scores were transformed as follows: Multiple Choice (MC): Correct answer = 2 points, all other answers = 0 points; Reasoning: correct/complete answer = 2 points, partially correct answer = 1 point; blank/incorrect answer = 0 points. Using this transformation, scores for each item reflect the following item response values:

- 0 = Neither MC nor reasoning is correct
- 1 = MC is incorrect, reasoning is partially correct
- 2 = MC is correct, reasoning is incorrect
- 3 = MC is correct, reasoning is partially correct
- 4 = MC is correct, reasoning is correct and complete

For this analysis, we considered scores of "3 or 4" to be acceptable, while scores of "0, 1, or 2" needed improvement.

b) Scientific Explanations

Scientific explanations rewritten after the photosynthesis activity were then scored as a measure of understanding using a rubric with five levels (0-4) where 0 indicates no claim, evidence or reasoning to 4 indicating appropriate claim, evidence and reasoning.

VII. ANALYSIS AND FINDINGS

a) Energy Pre- Post- Test

Pre/post changes were statistically significant as indicated by a paired-samples t-test (pre M=65.18,

SD= 13.62, post M=91.45, SD=10.88, $t=5.78$, $p<.001$) with 120 total points possible for the test. The number of responses in which no part of the response was correct dropped from 25% to 8%, while the number of responses in which both the multiple choice and corresponding explanation were correct increased from 30% to 58% of the responses (Figure 1). Pre-test percentage correct ranged, from 39% correct, to 77%, with a mean of 56%. Post-test scores ranged from 65% to 93%, with a post-test mean of 77%.

b) Teacher Misconceptions

Both the item distracters and the written response of the Energy Test were analyzed for the nine misconceptions in the research literature (Figure 2). We found that ten out of eleven teachers (91%) held at least one misconception. Teachers held common energy misconceptions to varying degrees, and the post- test indicated that the professional development provided mixed results in alleviating them (Table 1, Table 2).

i. M1. Energy is confused with other concepts

Three teachers (27%) held this misconception on the pre- test, which was reduced to one on the post-test. An example of a response exhibiting this misconception is: Q: In what form is energy stored in foods? A: Food is converted into chemicals for the organism to use.

ii. M2. Energy is associated only with living things

Although no teacher held this misconception on the pre-test, one teacher's written response expressed this misconception on the post-test. Q: Energy can be defined as...A: All energy comes from the sun and is utilized within living systems (teacher 1, post-test).

iii. M3. Energy is associated only with movement

Three teachers (27%) had responses which suggested they held this misconception on the pre- test, but it did not appear on the post-test. An example of a response which exhibited this misconception is: Q: Energy can be defined as...A. the movement of molecules either in a positive or negative direction.

iv. M5. Energy can be created, destroyed, expended, or used up

Six teachers (55%) responded suggesting they held this misconception on the pre-test. Five of these teachers still held the misconception on the post-test, and one did not. However, two additional teachers gave responses which indicated they held this misconception on the post- test, for a total of eight (73%). The most common expression of this misconception was: Q: What is always true about any process that converts energy from one form to another? A: 10% is used – some energy is lost in the process.

v. M6. Energy cannot be quantified or measured

The responses of six teachers (55%) indicated they held this misconception on the pre-test; five of these teachers still held it on the post- test. One did not

express it. An additional three teachers' responses indicated they held this misconception on the post-test. A typical expression of this misconception was: Q: what is always true about any process that converts energy from one form to another? A: Energy is neither +/-, but when it changes, we can only theoretically track it all.

vi. *M8. Energy change only occurs when the effects are perceivable*

Although no teachers wrote responses suggesting they held this misconception on the pre-test, one teacher's post- test response revealed she might. Q: Energy can be defined as...A: Energy causes changes in matter from one form to another.

vii. *M9. Energy is a substance, like a fuel, which is used up*

Four teachers (36%) had responses which suggested they held this misconception. All four teachers still held the same misconception at the end of professional development. Q: A "nonrenewable" resource is defined as one that is...A: All used up, changed chemically.

c) *Scientific Explanations*

Only 27% of science teachers wrote an accurate claim addressing their research question before feedback (Figure 3). After feedback, that number more than doubled to 64%. Seventy-two percent either wrote no claim, an inaccurate claim, or a claim which did not address their research question before feedback. That number decreased to 36% after feedback.

Less than half (36%) of the teachers were able to provide sufficient evidence from their investigation to properly support their claims, but after peer feedback that percentage increased to 55% (Figure 4). On the other hand, 64% of teachers either did not provide any evidence to support their claims, provided evidence which did not support their claims, or included data in the form of observations from their investigations. After re-writing their explanations almost half (45%) still did not supply appropriate evidence to support claims.

A majority of the teachers (82%) did not provide adequate reasoning to link their evidence to their claims before feedback (Figure 5). This number scarcely changed after feedback, with 72% providing reasoning that was unclear, no reasoning, or reasoning that did not link to claim, evidence, or scientific principle. Only 18% of teachers provided appropriate reasoning which explained how the data counted as evidence to support the claim; that percentage increased slightly to 27% after peer feedback.

d) *Differences by Demographics*

Although it might have been informative to look at differences statistically by demographic characteristics, the sample size precluded this analysis. However, an examination of the demographics revealed no patterns that could provide additional insights. No

pattern was associated with grade level taught, highest degree, or coursework. Since ten of the eleven teachers were certified to teach biology, an examination of pretest patterns by area of certification was also precluded. It should be noted that nine of the teachers had misconception 5 (energy can be created, destroyed, expended, or used up) which could be related to their biology background.

VIII. CONCLUSION AND DISCUSSION

Our evidence suggests that some high school science teachers may not possess the deep understanding of energy in systems required to successfully prepare their students to make future decisions about energy resources and their use. In addition, they may not possess the skills necessary to teach students how to write convincing scientific arguments about energy. The teachers' inability to write a scientific explanation based on their energy experiment indicates that their understanding of the application of energy concepts was shallow. These two findings do not bode well for a future generation who will be required to make increasingly difficult decisions about energy resources and their use.

The writing intensive CISIP professional development increased teachers' content knowledge of Energy in Systems, as indicated by the Energy Pre-Post Test results. However, Energy in Systems is a complex topic which both crosses disciplinary boundaries and conceptual boundaries because it is invisible. As a result, it has been heavily studied, and many misconceptions have been documented. What is disturbing about our findings is the depth to which these misconceptions penetrate the thinking of even seasoned high-school teachers. Of the nine misconceptions in our framework, we found evidence of all but two in either the teachers' distracter selections or their written responses. Despite our best efforts to provide professional development which was heavily grounded in research, our evidence suggests we did little to rectify misconceptions in these adult learners. In fact we may have confused some teachers to the point where their memorized explanations were troubled and they were no longer confident in them. Some misconceptions do seem to be more pervasive than others, however.

The misconceptions seem to be of three varieties, those that are non-persistent, those which are persistent, and those which are strongly persistent. Included in the non-persistent variety are the ideas that Energy is associated only with living things, energy is associated only with movement, and energy change occurs only when the effects are perceivable. In the case of energy being associated with movement, it seems that teachers were confused about the differences between kinetic and potential energy and, after being abundantly addressed during the

professional development, the teachers corrected their answers on the post-test. The expression of the misconception that energy is associated only with living things may have been a result of poor wording by the teacher, rather than an expression of a true misconception. The same may hold true for the statement which declares that 'energy causes changes in matter from one form to another', a response which indicates that the teachers may think that energy change only occurs when the effects are perceivable, but may sloppy writing, as it was not expressed on the pre-test.

Two of the misconceptions, however, appear to be a bit harder to dislodge. On the pre-test, three teachers confused energy with other concepts. By the post-test, however, only one made this mistake. It could very well be that teachers had simply not thought about energy for a while, and at the end of the institute had their memories refreshed. The idea that energy is a substance which is used up only appeared in the answer to one of the test questions, and may be a function of commonly-held beliefs about the definition of a non-renewable resource. The distracter which prompted a *non-renewable resource* was one which is...no longer available for use...prompted written explanations that described energy as being "used up". All four teachers who selected this incorrect response wrote the same explanation on the pre- and post-Energy Test.

On the other hand, two misconceptions stood out as being strongly persistent. The first, which states that energy can be created, destroyed, expended, or used up, was intentionally embedded in the distracters of two test questions. Six out of eleven teachers chose the distracter which claimed 'one form of energy is destroyed and another form is created at the same time'. In addition to selecting this response, written explanations reinforced this misconception. At the end of the professional development, this misconception had surfaced in eight out of the eleven teacher's Energy Tests. We believe that some teachers may have misunderstood an energy source, the sun, to be something that creates energy rather than an object which makes energy available. Two additional teachers confused energy conversion to a form which cannot be used to power societal needs with energy destruction. These concepts were discussed at length during the professional development, but apparently not effectively enough for all the participants. In some cases it seems that, while teachers had the Law of Conservation of Energy memorized, they may not have the deeper understanding necessary to truly comprehend it in terms of an energy system.

Another strongly persistent misconception states that energy cannot be quantified or measured. As was the case before, this misconception was written into several Energy Test distracters. Six out of the eleven

teachers incorrectly chose the distracter which stated 'not all energy in the process can be accounted for'. Unfortunately this number had increased to eight on the post- Energy Test. In addition, many of the teacher's written responses echoed this misconception. Explanations also included a reference to energy being lost, suggesting that the teachers thought the energy was not only unusable for human systems, and therefore 'lost', but what was 'lost' could not be accounted for through measurement. To remediate this idea in the future, we suggest that quantitative examples where all parts of the energy system are accounted for be used, something that we did not do.

Even though the teachers know, on a rote memorization level, that energy cannot be created, destroyed, or used up; they have a problem understanding on a deep level that energy can be accounted for or measured. To have energy simply vanish solves the problem of energy degradation into an unusable state, and the inefficiency of modern-day energy transformation for societal needs.

Analysis of the Energy Test found differences in scores from pre- to post- tests, but when we dug a little deeper we found that simply looking at pre- and post-test results was inadequate to get a clear picture of teacher understanding. When we investigated the presence or absence of indicators of misconceptions, we found that, while some misconceptions seem amenable to change, others are resistant. Even when teachers were provided with a variety of hands-on opportunities to engage in the science it was not sufficient to dispel misconceptions. In some cases, we confused the teachers; an indication that the teachers knowledge was not stable, but weak to begin with. To determine whether the knowledge was inert or useful, we needed to see if it could be used to support claims and evidence.

Another way to measure conceptual understanding is to examine whether teachers can use that conceptual understanding to frame scientific experiments. What we found was that, after being provided with peer feedback, teachers did a good job with writing claims and providing evidence to support them, but they were still lacking when it came to figuring out how the experiment fit into the larger conceptual framework of energy in a system.

The application of knowledge is the most difficult, and our study found decreasing evidence for teacher understanding as we asked them to move from rote memorization to experimental application of scientific learning. Our study found that, depending on how you measure results, you can have different conclusions about the impact of interventions. Our pre- to post- Energy Test results indicated that we were successful in relaying knowledge to the teachers on a surface level.

Our misconception analysis found that nearly all the teachers held at least one misconception. Energy being confused with other concepts, associated with movement, living things, or perception appears relatively easy to dispel. But the ideas that energy can be created, destroyed, used up or "lost" remained stubbornly intact, as did the complimentary idea that energy lost could not be accounted for or measured. So we appear to have been successful in some areas, but not in others.

The application of knowledge gained about energy in systems was the least successful of all. We were able to increase teachers' abilities to write solid claims and support them with evidence, but teachers were not able to see the inquiry investigation as a model of energy in systems. They were stuck on the idea that photosynthesis turns sunlight into gas, not that it is an example of light energy being transformed into chemical energy.

The end result of our study shows that, depending on how you measure knowledge, you can generate different conclusions about how much was learned. When we looked at the pre- and post- Energy Test, we found we were successful in increasing knowledge with statistically significant results. When we analyzed misconceptions in distracter choices and written responses to the same test, we found we were successful in some areas, but not in others. When we looked at teachers' abilities to apply their knowledge and see it as an example of the larger conceptual framework of energy in systems, we were the least successful.

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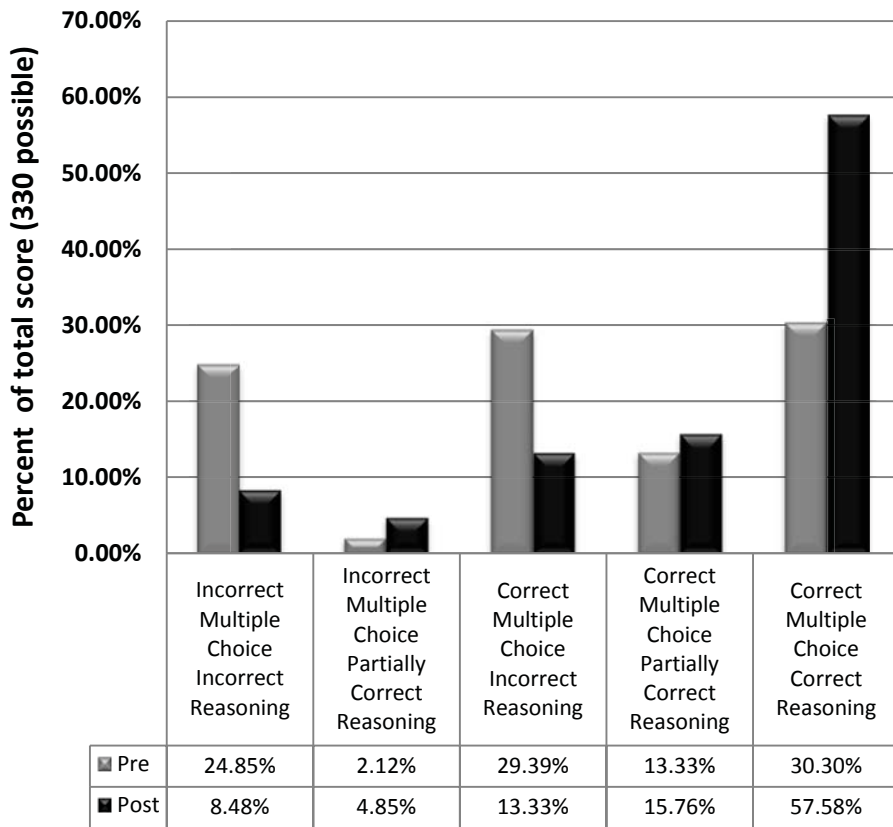


Figure 1 : Science teacher scores for pre- and post- Energy Tes

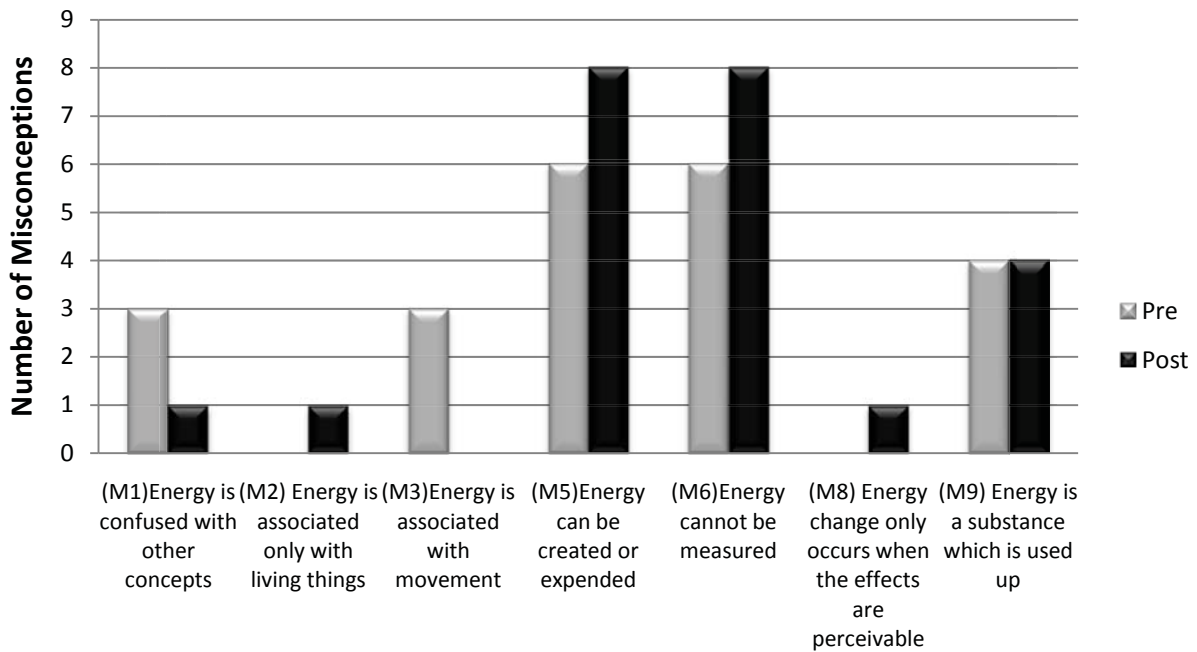


Figure 2 : Energy Misconceptions Exhibited by Teachers Pre and Post Intervention

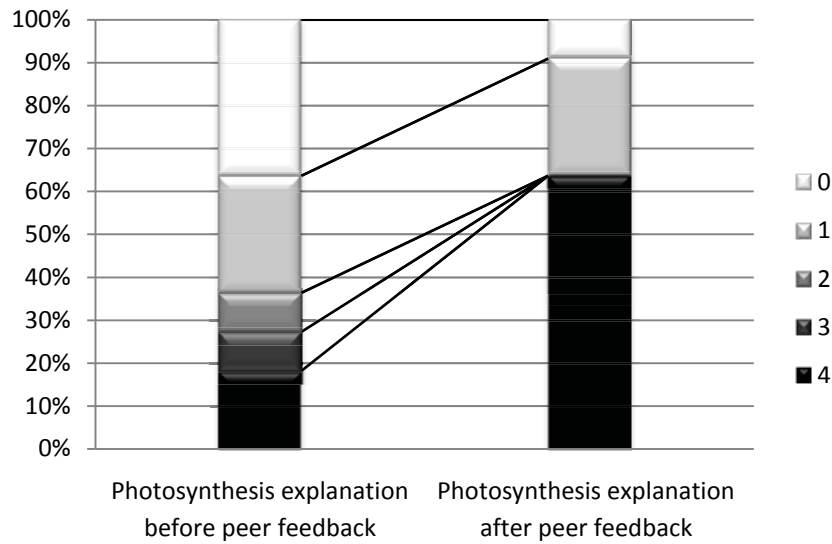


Figure 3 : Science teacher photosynthesis explanation scores for Claim

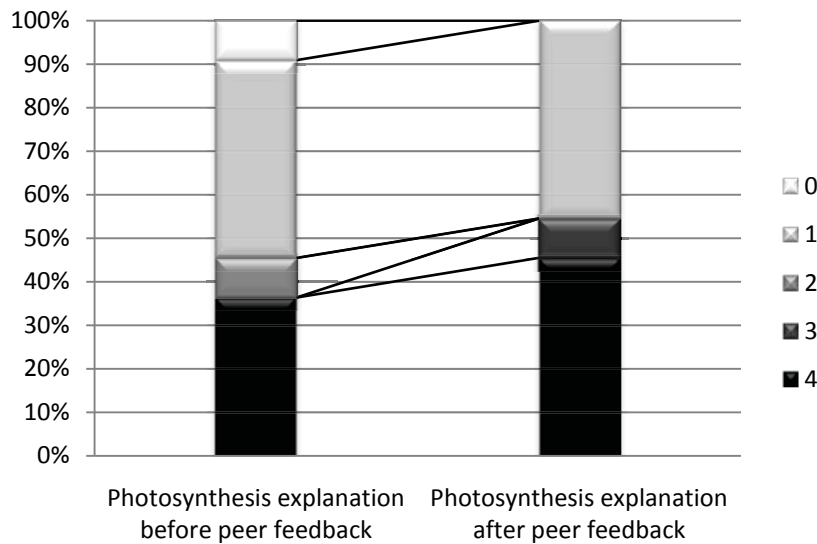


Figure 4 : Science teacher photosynthesis explanation scores for Evidence

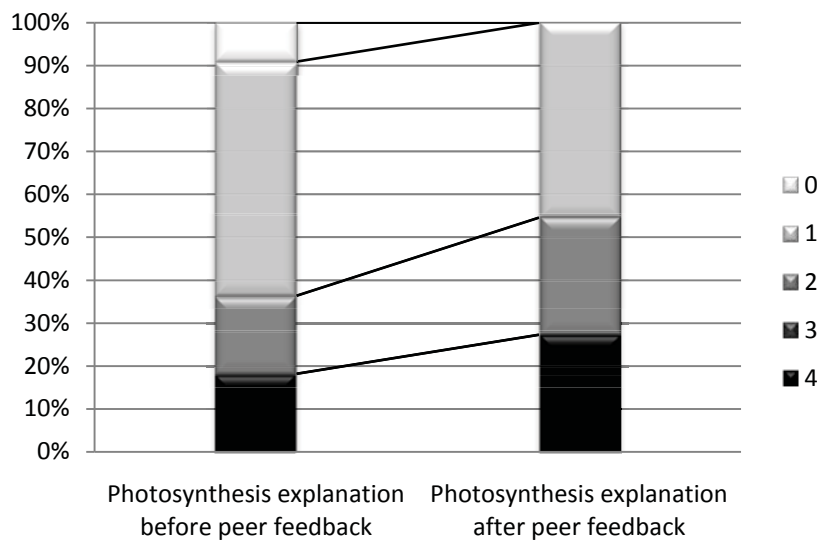


Figure 5 : Science teacher photosynthesis explanation scores for Reasoning

Table 1 : Teacher Energy Misconceptions from Energy Test Questions

Teacher	Pre-test	Post-test	+ change	No change	confusion
1		M2			X
		M5			X
	M6	M6		X	
	M9	M9		X	
2	M6		X		
3					
4	M1		X		
	M3		X		
	M5	M5		X	
	M6	M6		X	
5	M1	M1		X	
	M3		X		
	M5	M5		X	
	M6	M6		X	
6	M3		X		
	M5	M5		X	
	M6	M6		X	
	M9	M9		X	
7	M5	M5		X	
	M6	M6		X	
8	M1		X		
		M5			X
9		M6			X
	M5	M5		X	
10		M6			X
		M8			X
		M9			X
	M9	M9		X	
11	M5		X		

Table 2 : Change in Energy Test Multiple Choice Selection on Items Displaying Energy Misconceptions through either Distracter Selection or Written Responses

Misconception	Test	Teacher											Change	
		T1	T2	T3	T4	T5	T6	T7	T8	T9	T10	T11		
M1 Energy is confused with other concepts such as food, force, temperature, etc.	Pre				+	+				+				
	Post				+	+				+				2 no change
M2 Energy is associated only with living things such as humans, growth, fitness, exercise, food, etc.	Pre	+												
	Post	-												1 negative
M3 Energy is associated only with movement	Pre				-	+	-							
	Post				+	+	+							2 positive 3 no change
M4 Some forms of energy -- light, sound, and chemical -- do not make things happen	Pre													
	Post													
M5 Energy can be created, destroyed, expended, or used up	Pre	+			-	-	-	-	+	-	+	-		
	Post													

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