

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

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7 **Abstract**

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

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21 **Index terms**— earth science education, professional development, energy in systems, scientific explanations,  
22 scientific literacy.

23 **1 Introduction**

24 As the quest for renewable, affordable energy increases, we need a scientifically literate population that can evaluate  
25 energy sources with regard to the impact on the environment, as well as the economic consequences of choosing  
26 one energy source over another (Hudson, 2005). At the crux of this debate is the effect decisions will make on  
27 the quality of life. Students, as future decision makers, must be included in current energy debates (Weyman,  
28 2009). As a society, we expect science teachers to develop students into scientifically literate citizens who are  
29 informed about, and can discuss, the merits and costs associated with the development and use of various forms  
30 of energy to power our society. Thus, we raise the question as to whether teachers have the knowledge necessary  
31 to teach the interdisciplinary theme of energy flows and reservoirs in biological and societal systems. To answer  
32 this question, we conducted a study to determine the impact of a writing intensive professional development on  
33 science teachers' knowledge about energy concepts and to use appropriate claims, evidence, and reasoning when  
34 crafting scientific explanations about energy.

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36 **2 II.**

37 Research Questions

38 **3 Literature Review a) Teacher Subject Knowledge and Effectiveness**

40 Science teacher effectiveness is linked to training (Druva& . In particular, teacher professional development  
41 that focuses on science content and pedagogy increases students' conceptual understanding (Cohen & Hill,  
42 1998;Fennema et al., 1996;Kennedy, 1998; Garet, Porter, Desimone, Birman, & Yoon, 2001). Furthermore,  
43 teachers with more content knowledge are more likely to teach science processes and be less teacher-centered  
44 than teachers with limited content knowledge ??Dobey& Schafer, 1984) who avoid inquiry activities, relying on  
45 worksheets and textbooks instead (Lee, 1995).

46 **4 b) Understanding Energy Concepts**

47 Energy is a unifying theme that runs throughout life, physical, and Earth and space science. It is a key  
48 phenomenon embedded in concepts such as work, force, motion, photosynthesis, and chemical reactions. (Else,  
49 1988;Watts, 1983). Therefore, we chose to focus on energy use in biological systems, and societal

50 **5 G**

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

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

64 Energy transfer, the movement or flow of energy into, out of, or within a system is another area of difficulty.  
65 It often conjures up the misconception that energy flows from one substance to another like a fluid (Duit,  
66 1984;Driver, Squires, Rushworth, & Wood-Robinson, 1994). Energy conservation, the principle that the total  
67 energy of an isolated system remains constant regardless of change within the system, is not a prevalent idea  
68 (Summers & Kruger, 1994). Energy conservation is commonly understood as "saving energy" by engaging in  
69 tasks such as turning off a light bulb ??Carr & Kirkwood, 1988;Goldring& Osborne, 1994; ??atar & Oktay,  
70 2007).

71 Energy conservation can also be problematic in another way. Some teachers understand energy degradation  
72 (energy is always transferred from a more to a less useful form) as happening only when energy is not conserved  
73 ??Pinto, Couso, & Gutierrez, 2005). Energy degradation is also seen as a decreasing the quantity of energy rather  
74 than decreasing the quality, availability or usefulness of energy (Pinto, Couso, & Gutierrez, 2005). Teachers are  
75 also generally not aware of the concept of energy efficiency as defining the ratio between useful energy output of  
76 a conversion system and energy input . Nevertheless, teachers can learn about energy efficiency,in professional  
77 development, when presented explicitly, and distinguished from energy conservation (Summers, Kruger, Mant,  
78 & Childa, 1998).

79 Students often understand energy differently than scientists (Solomon, 1983). For example, students may  
80 understand energy to be a property of living things, humans, movement, or a fuel which is used up (Black  
81 & Solomon, 1983;Solomon, 1985;Watts, 1983). Students may think that energy can only be transformed into  
82 one form at a time (Brook & Wells, 1988), that energy transformation only occurs when the effects can be  
83 perceived (Brook & Driver, 1986), or that certain forms of energy such as light, sound, and chemical energy, do  
84 not cause change ??Carr & Kirkwood, 1988). Other students believe that energy cannot be measured (Solomon,  
85 1985;Watts, 1983), or confuse energy with other concepts such as food, force, or temperature .

86 **6 c) Scientific Explanations**

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

93 Science teachers may also have difficulties writing scientific explanations. Pre-service teachers find science  
94 writing more difficult than other types of writing (Robertson, 2004), and are better at using evidence to support  
95 claims than they are at linking appropriate reasoning to evidence (Sadler, 2006). High school science teachers are

96 also able to produce acceptable claims, but providing supportive evidence is more difficult. The greatest difficulty  
97 for teachers is providing appropriate reasoning to link evidence and claims (Baker, Bueno, Watts,Perkins, Sen,  
98 Lewis & Lang, 2010).

99 IV.

## 100 **7 The Communication in Science**

101 Inquiry Project ( isip) This study focused on one aspect of CISIP professional development; writing scientific  
102 explanationnsusing claims, evidence, and reasoning.CISIP stresses that the development of structured and  
103 coherent scientific ideas is facilitated by learning to talk and write in science genres (Kelly, 2007). CISIP trains  
104 teachers to help students talk, think, and write like scientists.An integral part of CISIP training is learning how  
105 to teach students to write scientific explanations. ” ??Baker, et

## 106 **8 C**

107 In biology, understanding photosynthesis, the process in which organic material is synthesized from inorganic  
108 substances using the energy of light, andthe role it plays in understanding both the life cycles of plants and  
109 animals, and energy flow through ecosystems ( Köse, 2006) is very difficult (Bahar, Johnstone & Hansell,  
110 1999;Lawson & Thompson, 1988;Storey, 1989). Research has found that students do not understand the energy  
111 relationship among the sun, plants, and animals. Nor do they perceive the relationship between biology and  
112 chemistry, necessary for understanding photosynthesis (Hir a, alik, & Akdeniz, 2008).

113 “plant food” and substances in the soil (Stavy, Eisen and Yaakobi, 1987). This misconception ignores the

## 114 **9 2009)” a) Daily Activities**

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

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

127 Day three -teachers participated in a Science Curriculum Topic Study (SCTS; Keeley, 2005) compareingmajor  
128 concepts and identifying interconnections among topics followed by a focused on student misconceptions of  
129 photosynthesis and energy. Next, teachers wrote a scientific explanation using a simple data table. They were  
130 then given a base rubric for scoring their explanations. Subsequently, they were given another rubric which  
131 contained exemplars for each scoring category and asked to re-score their explanations.

132 They then wrote contextualized photosynthesis rubrics, using the information from the SCTS and misconcep-  
133 tions literature. Using these rubrics, they scored a ”mystery explanation” of the photosynthesis lab written by  
134 one of their peers, and provided written feedback. The explanations were returned to their writers, and rewritten,  
135 incorporating the feedback.

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

142 Day five -teachers took the Energy Test postassessment.

## 143 **10 VI.**

## 144 **11 Study Design**

145 Eleven high school science teachers participated in 35 hours of professional development during the summer. The  
146 11 teachers, (9female, 2 male), represented 7 schools and had been teaching from 1 to 30 years. Nine of the  
147 teachers taught biology, two chemistry, and one each physics, physical science, and earth and space science (total  
148 exceeds 11 because 3 teachers taught2 disciplines). All majored in their content areas and were certified to teach  
149 in their content areas. Participation was voluntary. The sample was selfselected without a comparison group.

150 We analyzed the pre-post-testmultiple choice items statistically (t-test and percentages) and the written  
151 explanations qualitatively.Due to the small sample size, additional statistical analysis was precluded. Writing

## 19 B) TEACHER MISCONCEPTIONS

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152 samples of scientific explanations were analyzed using a rubric developed for this purpose. Three members of the  
153 research team scored all written data independently, then met to discuss scores to ensure inter-rater reliability.

### 154 12 a) Validity of the Energy Test

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

### 157 13 Global

### 158 14 Structure of the Professional Development Intervention

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

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

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

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

177 For analysis, scores were transformed as follows: Multiple Choice (MC): Correct answer = 2 points, all  
178 other answers = 0 points: Reasoning: correct/complete answer = 2 points, partially correct answer = 1 point;  
179 blank/incorrect answer = 0 points. Using this transformation, scores for each item reflect the following item  
180 response values: 0 = Neither MC nor reasoning is correct 1 = MC is incorrect, reasoning is partially correct 2 =  
181 MC is correct, reasoning is incorrect 3 = MC is correct, reasoning is partially correct 4 = MC is correct,

### 182 15 reasoning is correct and complete

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

### 184 16 b) Scientific Explanations

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

### 188 17 VII.

### 189 18 Analysis and Findings a) Energy Pre-Post-Test

190 Pre/post changes were statistically significant as indicated by a paired-samples t-test (pre  $M=65.18$ ,  $SD= 13.62$ ,  
191 post  $M=91.45$ ,  $SD=10.88$ ,  $t=5.78$ ,  $p<.001$ ) with 120 total points possible for the test. The number of responses  
192 in which no part of the response was correct dropped from 25% to 8%, while the number of responses in which  
193 both the multiple choice and corresponding explanation were correct increased from 30% to 58% of the responses  
194 (Figure 1). Pretest percentage correct ranged, from 39% correct, to 77%, with a mean of 56%. Post-test scores  
195 ranged from 65% to 93%, with a post-test mean of 77%.

### 196 19 b) Teacher Misconceptions

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

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201 **20 i. M1. Energy is confused with other concepts**

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

205 **21 ii. M2. Energy is associated only with living things iii. M3.**  
206 **Energy is associated only with movement**

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

210 **22 iv. M5. Energy can be created, destroyed, expended, or**  
211 **used up**

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

217 **23 v. M6. Energy cannot be quantified or measured**

218 The responses of six teachers (55%) indicated they held this misconception on the pre-test; five of these teachers  
219 still held it on the post-test. One did not. Although no teacher held this misconception on the pre-test, one  
220 teacher's written response expressed this misconception on the post-test. Q: Energy can be defined as?A: All  
221 energy comes from the sun and is utilized within living systems (teacher 1, post-test).

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223 We chose a two-tier format because it has been widely used to identify misconceptions in science (Anderson,  
224 Fisher, & Norman, 2002; Treagust, 1988). More recently, we used a two-tier test to identify and respondents  
225 selected an answer to an item and then explained the answer with an open response in a space in which they  
226 could write or draw. This format allowed us to assess surface knowledge and in-depth knowledge, as well as  
227 changes in misconceptions from pre to post test. The written portion of the Energy Test was analyzed using the  
228 misconceptions identified in the research literature.

229 evaluate teacher conceptions about flooding (Lewis, van der Hoven Kraft, Bueno Wilson & Lang, 2010) during  
230 previous professional development. In our test, express it. An additional three teachers' responses indicated they  
231 held this misconception on the post-test. A typical expression of this misconception was: Q: what is always true  
232 about any process that converts energy from one form to another? A. Energy is neither +/-, but when it changes,  
233 we can only theoretically track it all.

234 **25 vi. M8. Energy change only occurs when the effects are**  
235 **perceivable**

236 Although no teachers wrote responses suggesting they held this misconception on the pretest, one teacher's post-  
237 test response revealed she might. Q: Energy can be defined as?A: Energy causes changes in matter from one  
238 form to another. vii. M9. Energy is a substance, like a fuel, which is used up Four teachers (36%) had responses  
239 which suggested they held this misconception. All four teachers still held the same misconception at the end  
240 of professional development. Q: A "nonrenewable" resource is defined as one that is?A: All used up, changed  
241 chemically.

242 **26 c) Scientific Explanations**

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

247 Less than half (36%) of the teachers were able to provide sufficient evidence from their investigation to properly  
248 support their claims, but after peer feedback that percentage increased to 55% (Figure ??). On the other hand,  
249 64% of teachers either did not provide any evidence to support their claims, provided evidence which did not  
250 support their claims, or included data in the form of observations from their investigations. After re-writing their  
251 explanations almost half (45%) still did not supply appropriate evidence to support claims.

252 A majority of the teachers (82%) did not provide adequate reasoning to link their evidence to their claims  
253 before feedback (Figure ??). This number scarcely changed after feedback, with 72% providing reasoning that

254 was unclear, no reasoning, or reasoning that did not link to claim, evidence, or scientific principle. Only 18% of  
255 teachers provided appropriate reasoning which explained how the data counted as evidence to support the claim;  
256 that percentage increased slightly to 27% after peer feedback.

257 **27 d) Differences by Demographics**

258 Although it might have been informative to look at differences statistically by demographic characteristics, the  
259 sample size precluded this analysis. However, an examination of the demographics revealed no patterns that could  
260 provide additional insights. No pattern was associated with grade level taught, highest degree, or coursework.  
261 Since ten of the eleven teachers were certified to teach biology, an examination of pretest patterns by area of  
262 certification was also precluded. It should be noted that nine of the teachers had misconception 5 (energy can  
263 be created, destroyed, expended, or used up) which could be related to their biology background.

264 **28 VIII.**

265 **29 Conclusion and Discussion**

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

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

283 The misconceptions seem to be of three varieties, those that are non-persistent, those which are persistent,  
284 and those which are strongly persistent. Included in the non-persistent variety are the ideas that Energy is  
285 associated only with living things, energy is associated only with movement, and energy change occurs only  
286 when the effects are perceivable. In the case of energy being associated with movement, it seems that teachers  
287 were confused about the differences between kinetic and potential energy and, after being abundantly addressed  
288 during the professional development, the teachers corrected their answers on the post-test. The expression of the  
289 misconception that energy is associated only with living things may have been a result of poor wording by the  
290 teacher, rather than an expression of a true misconception. The same may hold true for the statement which  
291 declares that 'energy causes changes in matter from one form to another', a response which indicates that the  
292 teachers may think that energy change only occurs when the effects are perceivable, but may sloppy writing, as  
293 it was not expressed on the pre-test.

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

303 On the other hand, two misconceptions stood out as being strongly persistent. The first, which states that  
304 energy can be created, destroyed, expended, or used up, was intentionally embedded in the distracters of two  
305 test questions. Six out of eleven teachers chose the distracter which claimed 'one form of energy is destroyed  
306 and another form is created at the same time'. In addition to selecting this response, written explanations  
307 reinforced this misconception. At the end of the professional development, this misconception had surfaced in  
308 eight out of the eleven teacher's Energy Tests. We believe that some teachers may have misunderstood an energy  
309 source, the sun, to be something that creates energy rather than an object which makes energy available. Two  
310 additional teachers confused energy conversion to a form which cannot be used to power societal needs with  
311 energy destruction. These concepts were discussed at length during the professional development, but apparently

312 not effectively enough for all the participants. In some cases it seems that, while teachers had the Law of  
313 Conservation of Energy memorized, they may not have the deeper understanding necessary to truly comprehend  
314 it in terms of an energy system.

315 Another strongly persistent misconception states that energy cannot be quantified or measured. As was the  
316 case before, this misconception was written into several Energy Test distracters. Six out of the eleven teachers  
317 incorrectly chose the distracter which stated 'not all energy in the process can be accounted for'. Unfortunately  
318 this number had increased to eight on the post-Energy Test. In addition, many of the teacher's written responses  
319 echoed this misconception. Explanations also included a reference to energy being lost, suggesting that the  
320 teachers thought the energy was not only unusable for human systems, and therefore 'lost', but what was  
321 'lost' could not be accounted for through measurement. To remediate this idea in the future, we suggest that  
322 quantitative examples where all parts of the energy system are accounted for be used, something that we did not  
323 do.

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

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

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

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

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

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

356 The end result of our study shows that, depending on how you measure knowledge, you can generate different  
357 conclusions about how much was learned. When we looked at the pre-and post-Energy Test, we found we were  
358 successful in increasing knowledge with statistically significant results. When we analyzed misconceptions in  
359 distracter choices and written responses to the same test, we found we were successful in some areas, but not in  
360 others. When we looked at teachers' abilities to apply their knowledge and see it as an example of the larger  
361 conceptual framework of energy in systems, we were the least successful. <sup>1</sup>



Figure 1:



Figure 2:



Figure 3: Figure 1 :



Figure 4:

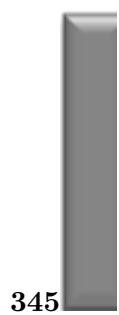


Figure 5: Figure 3 :Figure 4 :Figure 5 :

The Impact of Writing Intensive Professional Development on High School Teachers' Science Content  
 Knowledge of Energy in Systems  
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Figure 6:

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

Figure 7: Table 1 :

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**2**

D D D

D )

Global Misconception M1 Energy is confused with other concepts such as food, force, Test Teacher T1 T2

Jour-  
nal of  
Hu-  
man  
Social  
Sci-  
ence  
(

M3

Energy is associated Pre  
only with  
movement

- + -

Post

+ +

+

+ +

M4

Some forms of energy -light, sound, Pre  
and chemical -do not  
make things

happen Post

+ - - - -

M5

Energy can be created, Pre  
destroyed,

+

expended, or used up

-

Figure 8: Table 2 :



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