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This qualitative study investigates how biology majors explain energy consumption issues. In particular, we focus on two energy consumption activities that account for about two-thirds of global carbon dioxide emissions in 2011: burning fossil fuels for transportation and using electricity. We conducted in-depth clinical interviews with twenty U.S. students and twenty Chinese students. We compared these two groups of students in terms of two aspects of explanation: 1) naming scientific terms in the explanation, and 2) explaining an energy consumption issue. Regarding naming, we examined the frequency of naming different terms of scientific concepts and principles in students' explanations. Regarding explaining, we developed a rubric that differentiates three levels of explaining: informal explanations that are based upon intuitive ideas (Level 1), school science explanations that are based on alternative conceptions about matter and energy (Level 2), and scientific explanations that demonstrate the scientific understanding of concepts/principles about matter and energy (Level 3). The results revealed that scientific terms appeared most frequently in scientific explanations (Level 3), but they also appeared in many school science explanations (Level 2) and in some informal explanations (Level 1). We further describe how scientific terms were used in explanations at different levels. We found although Chinese students named scientific terms more frequently and demonstrated a better performance in explaining, they still produced more informal explanations and school science explanations than scientific explanations. In general, the results suggest the importance of promoting students' abilities to use scientific terms correctly and meaningfully in explaining real-world environmental events in both countries.

Keywords: naming, explaining, environmental literacy, energy consumption

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INTRODUCTION

Both the United States and China are facing significant environmental challenges. Recognizing these challenges, both countries have developed national science standards that emphasized promoting students' environmental literacy (National Research Council [NRC], 2012; 中华人民共和国教育部, 2003). However, national and international large-scale assessments and surveys indicated reasons for concerns for environmental education in both countries. The Program for International Student Assessment (PISA) assesses students' ability to perform scientific tasks in a variety of situations, ranging from those that affect their personal lives to wider issues for the community and the world. The 2006 PISA results showed that the United States ranked significantly below average in environmental science performance, and that about 24.4% of U.S. 15-year-olds did not reach the baseline level, at which students began to demonstrate a basic understanding about science-related life situations (Organisation for Economic Co-operation and Development [OECD], 2009). The above evidence suggests that a major concern for environmental education in the U.S. is whether U.S. students understand enough scientific knowledge to develop a basic understanding of environmental issues.

Although Chinese students demonstrated high achievement levels in PISA as well as other large-scale international assessments (OECD, 2013), they may not be more capable in applying knowledge to environmental issues. According to a large-scale survey conducted by the Ministry of Education, only 9.3% of teachers and 5.4% of students recognized that the school curriculum was relevant to their life experience; about 78% of the respondents thought that what the exams tested were irrelevant to what they needed to know as citizens (Liu, 2006). This discrepancy between school science learning and students' life experience may have negative consequences. A national survey carried out by China Association for Science and Technology (CAST) showed that only two percent of Chinese residents were able to use scientific knowledge to explain environmental events (Jia, 2004). In brief, a major concern for environmental education in China is whether Chinese students are able to apply the knowledge learned in school science classrooms to real-life situations.

To contribute to promoting environmental education in both countries, we conducted a qualitative study to examine U.S. and Chinese college students' understanding of energy consumption issues. This is an important topic because the United States and China are the top carbon emitters in the world (International Energy Agency [IEA], 2013; Olivier, Janssens-Maenhout, Muntean, & Peters, 2013); it is urgent for the younger generation in both countries to develop a sophisticated understanding of the impact of people's daily energy consumption activities on the atmosphere. More specifically, an environmentally literate citizen should understand matter transformation and energy transformation in various energy consumption issues in order to make informed decisions on energy-related environmental issues. In the present study, we used a clinical interview approach to examine biology majors' explanations of two energy consumption issues: burning fossil fuels for transportation and using electricity. According to IEA report (2013), burning fossil fuels for transportation and using electricity are two sectors that produced nearly two-thirds of global carbon dioxide emissions in 2011. It is also important to note that the knowledge required to explain these two issues is emphasized as core content in science curriculum in both countries. In addition, that knowledge is included in introductory-level biology and chemistry courses in universities. Therefore, we would expect the college students to have a good understanding about the two energy consumption issues.

It is commonly accepted that memorizing, recalling, and reciting scientific facts, concepts, and principles is much easier than applying concepts and principles to real-world situations (Bransford, Brown, & Cocking, 2000). In a previous study, we found that Chinese high school students tended to use scientific words more frequently than their counterparts in the United States (Jin & Anderson, 2012b). Therefore, we investigated and compare two dimensions of explaining energy consumption issues: 1) naming—naming scientific terms and 2) explaining—using ideas at different sophistication levels to explain an energy consumption issue. Accordingly, the research question is: How do U.S. and Chinese biology majors compare in naming scientific terms and explaining energy consumption issues?

Conceptual framework

Based on relevant literature, we developed our conceptual framework. The framework differentiates two dimensions of explaining energy consumption issues. One dimension is naming; it refers to students' ability to name scientific terms when asked to explain energy consumption issues. We specifically focus on terms about the concepts and principles that scientists use to explain the two energy consumption issues. The other dimension is explaining; it refers to students' ability to use relevant concepts and principles to construct explanations about the energy consumption issues.

Naming

These terms in Table 1 are nouns or noun phrases that scientists use to explain the two energy consumption issues: burning fossil fuels for transportation and using electricity. In particular, scientists use these terms to explain how entities (i.e., matter and energy) change in processes (i.e., matter transformation and energy transformation in combustion and using electricity) following the fundamental principles of physics (i.e., matter conservation, energy conservation, and energy degradation). When asked to explain energy consumption issues, students may or may not use these terms. It is important to note that students may use scientific terms in ways that either do not make sense in the language contexts or convey alternative conceptions.

Table 1. Terms used in scientific explanations about energy consumption issues

Category	Scientific Terms
Matter	carbon-containing organic molecules/substances or organic molecules/substances (含碳有机物, 有机物), hydrocarbon (碳氢化合物，烃), chemical bonds (化学键), any chemical formula of organic molecules (任何有机物的分子式)
Energy	light energy (光能), chemical energy or chemical potential energy (化学能， 化学势能), mechanical energy (机械能), kinetic/motion energy (动能), electrical energy (电能), heat energy (热能)
Processes	combustion (燃烧), energy transformation (能量转换), matter transformation (物质转换), oxidation (氧化)

Principles	energy conservation or the first law of thermodynamics (能量守恒，热力学第一定律), and matter conservation (物质守恒), heat dissipation, energy degradation, or the second law of thermodynamics (热能损耗，能量耗散，热力学第二定律)

Explaining

Scientific terms are words that have specialized meanings. Some scientific terms are technical words that are unfamiliar to students, while others are ordinary words but with non-vernacular meanings (Fang, 2004). Acquisition of these scientific terms presents a special challenge for students. Research in the acquisition of vocabulary knowledge suggests that when learning new words, students often do not use the words with semantic appropriateness in a sentence (Paribakht & Wesche, 1997). The same situation could happen in learning scientific terms. Semantic appropriateness means that words are used appropriately and meaningfully in sentences. For example, in the sentence, "Jim eats light energy", the use of the phrase "light energy" is grammatically correct, but semantically inappropriate; it is not used in a meaningful way. This sentence indicates that the student just memorized the term and had no idea about light energy. Therefore, this sentence does not provide any useful information of the student's idea about eating foods. It is also important to note that being able to use a scientific term in a sentence semantically does not guarantee correct application of the concept/principle referred by the term.

Based on the above idea about vocabulary acquisition and our previous studies with K-12 students' understanding of biological and chemical processes (Jin & Anderson, 2012a, 2012b; Jin, Zhan, & Anderson, 2013; Jin & Wei, 2014), we developed a rubric that contains three qualitatively different levels of explaining energy consumption issues. Scientific terms are used differently at these three levels. At level 1, either no scientific term is used, or a scientific term is used without semantic sense. At this level, students may also name a scientific term, but admit that they do not know the meaning of the term. In brief, at Level 1, no relevant concept/principle is applied and the explanation is based on informal ideas. At Level 2, a relevant scientific term is used semantically in a sentence, and the relevant concept/principle is applied to the energy consumption issue, but the application of the concept/principle suggests alternative conceptions. In this sense, explanations at Level 2 are based on alternative conceptions of scientific concepts and principles. At Level 3, a scientific term is used with semantic appropriateness, and the relevant scientific concept/principle is correctly applied to the energy consumption issue. Therefore, explanations at Level 3 are based on conceptual understanding of scientific concepts and principles. These levels are elaborated below.

- *Level 1. Informal explanations, in which scientific terms may be named, but relevant concepts/principles are not applied.* Informal explanations are constructed around every day informal ideas and commonsense; they are not about the application of scientific concepts or principles. Students may describe macroscopic observations, but do not provide any explanation about the mechanisms regarding why and how things happen. For example, a common informal explanation for a car using gasoline to move is that the car must use gasoline to move, because that is how the car is designed for. This explanation does not provide any information about the mechanism of how gasoline powers the car. Students may also explain energy consumption issues in terms of invisible mechanisms/processes, but these hidden mechanisms/processes often indicate intuitive ideas and have nothing to do with application of concepts or principles. For example, students may explain that gasoline evaporates when it is used to power the car. This intuitive idea is developed mostly based on their observation that gasoline is consumed and exhaust gases are emitted from the car's tailpipe. It is not about application of any concept or principle of matter/energy. It is possible that scientific terms may appear in informal explanations. In most situations, the scientific terms are used in sentences without semantic sense. Or, the terms are used semantically, but the relevant concepts/principles referred by the terms are not applied (e.g., students simply state that they believe a scientific term should be used to explain the energy consumption issue, but do not know how to apply the concept/principle).

- *Level 2. School science explanations, in which scientific terms are used with semantic appropriateness, and the relevant concepts/principles are applied.* However, the application of the concepts and principles are incorrect and suggest alternative conceptions. At level 2, students use the concepts and principles about matter and energy to explain the energy consumption issues, but they cannot correctly apply these concepts and principles. In other words, they construct school science explanations that convey alternative ideas about matter and energy. Some common alternative conceptions are listed as the follows: 1) Matter transmutation (Andersson, 1986, 1990): A substance turns into other substances mysteriously; this process does not involve reactions among substances. 2) Matter-energy conversion (Jin & Wei, 2014): Matter turns into/from energy in chemical reactions. 3) Energy changing forms without heat dissipation: Energy changes from one form to other forms; heat dissipation is not identified in these processes.
- *Level 3. Scientific explanations, in which scientific terms are used with semantic appropriateness, and the relevant concepts/principles are applied. The application of the concepts/principles is correct and indicates scientific understanding.* At level 3, students provide scientific explanations about the energy consumption issues. They apply scientific concepts and principles correctly to the energy consumption issue. Their explanations are based on scientific ideas about matter and energy. These ideas are: Matter transforms between organic and in-organic forms in combustion; fossil fuels provide energy in combustion, because they are organic materials that contain C-C and C-H bonds. Energy changes from one form to other forms in combustion and using electricity; heat is always released as a byproduct in these processes. Scientific terms are used in these explanations in ways that make semantic sense and have scientific meanings.

METHODS

Participants

Table 2. Participants

	US Students	Chinese Students
Ethnicity	1 Asian American 1 Hispanic American 18 non-Hispanic White American	20 Han Chinese
Gender	9 females 11 males	15 females 5 males

Our participants were forty second/third year biology majors. Among them, twenty students were from two national universities in China, and twenty students were from two public universities at the United States. All students had completed at least one introductory level course in science (e.g., introductory biology, introductory chemistry). The demographic backgrounds of the participant students are presented in Table 2.

Clinical interview tasks

We designed two interview tasks. The first task is about burning gasoline for transportation. It contains three sets of questions that focus on structure of matter, matter transformation, and energy transformation.

Task 1. Car Running on Gasoline

Figure 1. Picture for interview task 1

Structure of Matter

- Why do people use gasoline instead of water to move their cars?
- How is gasoline different from water?
- Is it possible that with new technology we can actually use water to move cars? How? Why?
- Do you think gasoline can power the car because it has some special structure? What is that?
- You mentioned organic molecules/substances. What are organic molecules/substances?

Matter Transformation

- A car consumed 1 gallon of gasoline to move 35 miles. Assume that we could figure out a way to collect all exhaust gases. There is no other exhaust material. Please compare the mass of the gasoline with the mass of the exhaust gases. Which one is greater? Why?
- You talked about combustion. Could you provide more explanation?

Energy Transformation

- Does the car need energy in order to run?
- Where does the energy come from?
- When the car is running, do you think that it has energy? What kinds of energy are involved?
- You said that when the car is running, it has [kinetic/motion] energy. So, when the car is completely off, where does that [kinetic/motion] energy go?
- Do you think [kinetic/motion] energy still exists somewhere? Does it disappear? Is it still energy? Does it changes into other things?

The second task is about using electricity: opening a refrigerator to lower the temperature in a closed room. It was modified from a written item designed by a research team at Arizona State University (Swackhamer, 2005a, 2005b). Since matter is not involved, this task only contains one set of questions about energy transformation.

Task 2. Using Electricity

Energy Transformation

The air conditioner breaks down in your dorm room. In an attempt to keep the room cool for the rest of the afternoon, you open the door of a refrigerator that you have in your room.

- How would the average temperature of your room change?
- Do you think that the average temperature will change significantly or slightly? Why?
- Do you think that the temperature will increase or decrease? Why?
- You talked about energy/heat. How is that related to the change of the temperature?
- Where did that energy come from?
- Where did that energy go?

Data analysis

We analyzed data in three steps. First, the interview protocol has two tasks; the first task contains three question sets, and the second task contains one question set. We therefore used the four question sets as the units of analysis. Accordingly, each interview was segmented into four episodes:

- Episode 1. Car Running on Gasoline—Structure of Matter
- Episode 2. Car Running on Gasoline—Matter Transformation
- Episode 3. Car Running on Gasoline—Energy Transformation
- Episode 4. Using Electricity—Energy Transformation

Second, we conducted an analysis for the dimension of naming. A researcher used Table 1 to identify the terms used in each episode. Another researcher read the results and checked whether all terms were identified. Occasionally we discussed whether a certain term should be identified as a scientific term or not. For example, we discussed whether the term "heat" should be identified as a scientific term, since it is also used in everyday life. We examined students' interviews, and found that some students used the term with its scientific meaning, whereas others imposed informal ideas to the term. That is, students used the term "heat" in different ways.

As elaborated above, the main purpose of developing the explaining levels is to capture the patterns regarding how students use terms and apply the concept/principle referred by the term. Therefore, we decided to keep heat as a scientific term.

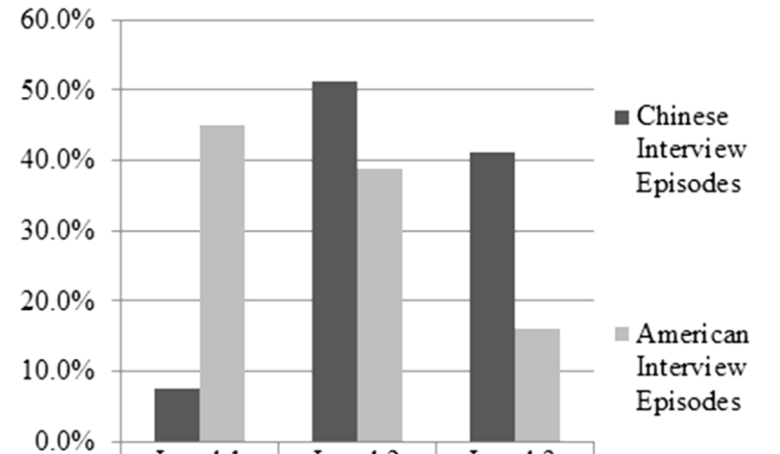
Third, we conducted an analysis for the dimension of explaining. First, two researchers used the explaining levels elaborated in the framework section to score each episode. Next, we measured inter-rater reliability using Cohen's Kappa statistics. The Kappa value is 0.89, suggesting almost perfect agreement (Landis & Koch, 1977). Finally, we discussed the discrepancy in coding and reached agreement on the final scores.

FINDINGS

We report both quantitative and qualitative findings in this section. First, we present our quantitative results about student performance in the two dimensions of understanding: naming and explaining. Second, we use interview excerpts as examples to discuss how students named scientific terms and how they explained energy consumption issues.

Student performance in naming and explaining

First, we measured student performance in explaining energy consumption issues. The results are presented in Figure 2. For the Chinese students, about 51.3% of the episodes were scored as Level 2 and about 41.3% episodes were scored as Level 3. This evidence suggests that although many Chinese students applied relevant scientific concepts/principles to the energy consumption issues, they often could not apply these concepts/principles correctly. For the U.S. students, about 43.8% of the episodes were scored at Level 1, and only 17.5% of the episodes were scored at Level 3. This evidence suggests that many U.S. students used informal ideas to explain energy consumption issues, and that very few U.S. students correctly applied scientific concepts/principles. In comparison, Chinese students demonstrated a better performance in explaining than U.S. students.



	Level 1	Level 2	Level 3
Chinese Interview Episodes	7.5%	51.3%	41.3%
American Interview Episodes	45.0%	38.8%	16.3%

Figure 2. Student performance in explaining energy consumption issues

Table 3. Frequency of scientific terms used in episodes at three levels

Levels	Chinese Interview Episodes		US Interview Episodes		All Interview Episodes	
	Number of Episodes	**Number of Terms**	**Number of Episodes**	**Number of Terms**	**Number of Episodes**	**Number of Terms**
Level 1	6	5	36	14	42	11
Level 2	41	64	31	43	72	107
Level 3	33	73	13	31	46	104
Total	80	142	80	88	160	230

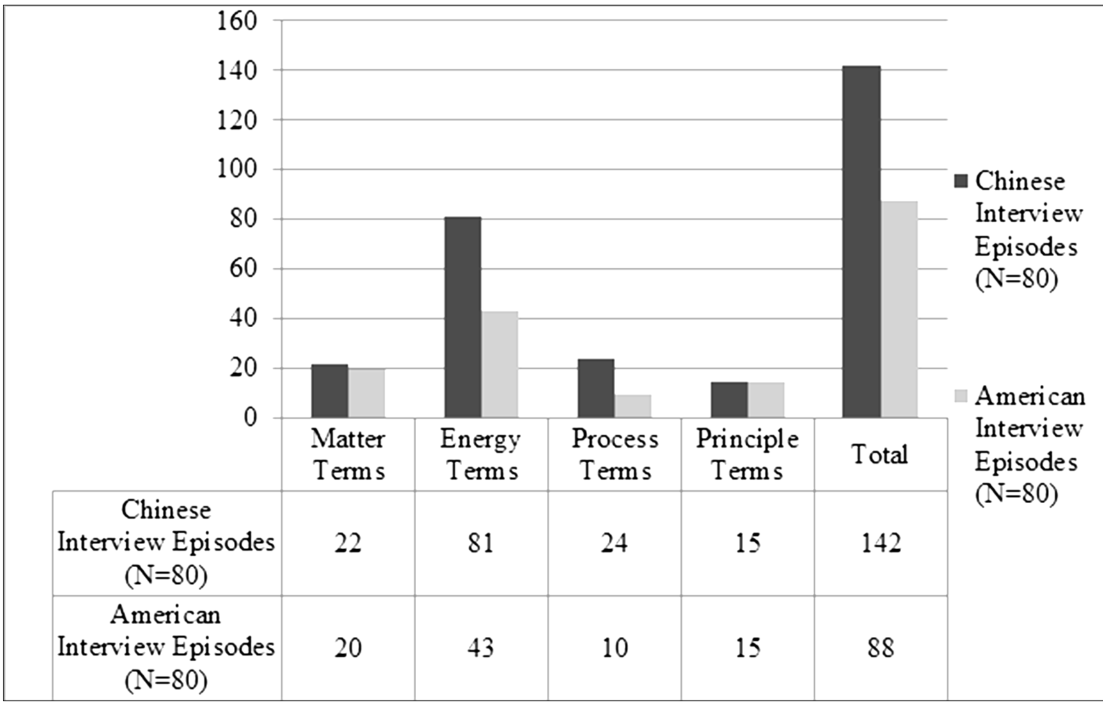


Figure 3. Frequency of different scientific terms used in explanations

Second, we examined how frequently students named scientific terms in their explanations. We present the results in Table 3 and Figure 3. Table 3 shows the number of scientific terms used in episodes that were scored at different levels. For episodes at a certain level, we added the number of different terms named in each episode together. Table 3 shows that the scientific terms were named significantly more frequently in Chinese interview episodes than U.S. interview episodes. For all interview episodes, scientific terms were named 11 times in 42 level 1 episodes, 107 times in 72 level 2 episodes, and 104 times in 46 episodes, indicating that scientific terms were used more frequently in episodes at a higher level. Moreover, in 64 out of 142 occasions for Chinese interviews and 43 out of 88 occasions for U.S. interviews, scientific terms were named, but the explanations were scored at Level 2. In these occasions, students named a scientific term, but did not correctly apply the concept/principle referred by the term; instead, their application of the concept/principle often implied alternative ideas about matter and energy.

Figure 3 shows the frequency of scientific terms belonging to different categories: matter, energy, processes, and principles. It shows that the Chinese students and the U.S. students named matter terms and principle terms with about the same frequency. However, the Chinese students named energy terms and process terms more frequently than the U.S. students. As a result, the Chinese students named scientific terms significantly more frequently than the U.S. Students (142 for Chinese students as opposed to 88 for U.S. students).

In summary, the results suggest that Chinese students tended to name scientific terms more frequently than U.S. students; they also demonstrated a better understanding in explaining energy consumption issues. However, for both groups of students, applying the scientific concepts/principles referred by the terms was a challenge because many responses fell into Levels 1 and 2; those explanations utilized informal ideas or alternative ideas about matter and energy.

Examples of naming and explaining

In this section, we use individual interview excerpts to depict how students named scientific terms and applied relevant scientific concepts and principles in explanations at different levels. In the interview excerpts, we underline the scientific terms.

Scientific Terms Named in Informal Explanations (Level 1). We present an interview excerpt (Excerpt 1) to depict how scientific terms were used in informal explanations. In the interview excerpt, the interviewer asked the student why people used gasoline instead of water to run their cars. The student said, "I think gas [gasoline] has a very high heat of vaporization compared to water." This sentence contained a scientific term—heat, but the term did not fit the sentence semantically. That is, the phrase, "high heat of vaporization", is not meaningful. Therefore, the interviewer prompted the student by asking: "What do you mean by that?". The student's responses suggested reasoning in terms of hidden mechanisms. The hidden mechanism is: It takes more energy to evaporate gasoline, so gasoline will have more energy, and more energy will be extracted from gasoline. This hidden mechanism reflects *intuitive and idiosyncratic* ways of thinking; it is not about applying the concept of heat energy. In her later explanation, the student also named another term, carbon-based compound, but she did not use the term to explain why gasoline instead of water was used to power cars. In other words, the student named the word, but did not relate it to the energy consumption issue under discussion. In addition, this student provided a macroscopic explanation: Water is not used to power cars, because it is bad for pistons. Although the student named two scientific terms (i.e., heat and carbon-based compound), she did not apply any concept/principle about matter and energy. Instead, she used informal ideas to construct explanations. Therefore, the episode was coded as Level 1 for explaining.

Interview Excerpt 1

Interviewee: U.S. Student

(Task: Car Running on Gasoline; Question Set: Structure of Matter)

Interviewer: Now, let's look at another scenario, Okay? So, why do people use gasoline instead of water to run their cars?

Student: I think the gasoline provides more energy after it's burned than water.

Interviewer: So, you mean water also provides energy but it's just less?

Student: Maybe just very, very small amount, I think. So I think gas has a very high heat of vaporization compared to water.

Interviewer: What do you mean by that?

Student: It's just it takes a lot of energy to evaporate it, because I think it's a carbon-based compound. So, I think it takes a lot of energy to get into it, and once you get into it, a lot of energy extracts. Like, say I have a cup of water and a cup of gasoline. The gasoline is going to provide for the car longer obviously, because of that evaporation reason. I guess it just has more energy inside the compound, and water just won't last the car very long at all. And, I think it's like you're not supposed to put water in the engine and it's like really bad for the pistons and stuff like that, I think.

Scientific Terms Named in School Science Explanations (Level 2). We found that many of our participant students used scientific terms appropriately from a semantic perspective; they also applied the concept/principle referred by the terms. However, these students often tried to reconcile the scientific ideas and their intuitive understanding. As a result, the scientific meanings of the concept/principle were often modified. In other words, misconceptions or alternative ideas were constructed. We present four interview excerpts as examples for this pattern. These excerpts are about different tasks and different questions sets. The selection of the episodes is align with the design of the interview protocol. For the task of car running on gasoline, we used episodes about three questions sets, including structure of matter, matter transformation, and energy transformation. For the task about using electricity, we used an episode about one question set, i.e., energy transformation. We chose more examples for school science explanations (Level 2), because these explanations indicate what usually happens when students are learning scientific knowledge in schools, and how prior knowledge influences the process of learning science.

First, in an interview with an U.S. student, the interviewer asked the student to explain where the kinetic energy went when the car stopped. An excerpt from that interview is presented below (Excerpt 2). In the excerpt, the sentences highlighted in italics show how the student tried to reconcile the scientific principle and his intuitive understanding of car running. The scientific principle is the law of the conservation of energy—energy cannot be created or destroyed. The student's intuitive understanding focused on how gasoline was used to power the car; it did not consider where energy went after the car stopped. The student stated that the kinetic energy must go somewhere because of the law of the conservation of energy, but he could not explain where that energy was. So, he guessed that the energy was probably in the gas tank. The student did not apply the conservation law correctly, because he did not recognize heat dissipation: i.e., Energy is conserved in this situation, and the kinetic energy transformed into heat mostly through friction.

Interview Excerpt 2

Interviewee: U.S. Student

(Task: Car Running on Gasoline: Question Set: Energy Transformation)

Interviewer: So we talked about when the car is running, it has kinetic energy right?

Student: Yeap.

Interviewer: So when the car stops, where is that kinetic energy?

Student: It stops and is it still on?

Interviewer: It stops moving.

Student: Well, let's see. If the car is running, well, the engine is still running at that point.

Interviewer: No. The engine stops. Yeah, the car is off.

Student: Well, I don't think it could have any kinetic energy then, because none of the parts are moving. Nothing is actually happening because it's not running anymore.

Interviewer: So if it does not have kinetic energy. You know, we talked about when the car is on it has <u>kinetic energy</u>, right?

Student: Yeah.

Interviewer: And when it stops, it does not have any kinetic energy.

Student: Correct.

Interviewer: So where does…

Student: So where does it go?

Interviewer: Yeah. Where does it go?

Student: Let's see. *I never thought about that before. I like that question. I didn't think of that one.* So, when it's running it has kinetic energy, when it stops, it doesn't. It's probably a really simple answer.

Interviewer: So do you think that energy is kind of used up?

Student: *The energy is never going to go away, just because of <u>the law of the conservation of energy</u>. But maybe, I guess it might have the potential energy because the engine is still there, all the parts are still there but it's just not turned on. But that doesn't really make a lot of sense, because it doesn't matter what engine you have, you don't have any gasoline then you are not going anywhere.* So, if you turn off the engine it's almost like just running out of gas. So, I guess the energy that's necessary and sufficient for you to have some sort of energy source which as outside of the engine, powering engine. *I guess, I can tell from that, it all depends on the energy source, as to where the <u>kinetic energy</u> goes. If that energy source isn't running through the engine, then you don't have any <u>kinetic energy</u>, so I guess it stays in the gas tank.*

In another interview, a Chinese student named the law of the conservation of mass, but did not correctly apply the law. An excerpt from that interview is presented as Excerpt 3. The interviewer asked the student to compare the mass of the gasoline that was used to run the car with the mass of exhaust materials from the tailpipe. The student stated that the mass of the exhaust gases should be equal to the mass of the gasoline. The interviewer pressed the student to explain. The student stated that her conclusion was based on the law of the conservation of mass (sentences highlighted in italics). In this case, the student applied the law to a "transmutation process" (Andersson, 1986, 1990), in which gasoline mysteriously turned into exhaust gases as a result of burning. Transmutation process is a common misconception about chemical reaction. The student did not recognize that oxygen reacted with gasoline to produce the exhaust gases (i.e., mostly carbon dioxide and water).

Interview Excerpt 3
Interviewee: Chinese Student
(Task: Car Running on Gasoline; Question Set: Matter Transformation)

Interviewer: A car used about one liter of gasoline to run a certain distance. Assume that we had some kind of high technology that enabled us to collect all exhaust materials from the tailpipe. Could you compare the mass of the one-liter gasoline with the mass of exhaust gases? Which one is greater?

Student: I think the mass of the collected materials is lighter.

Interviewer: Why?

Student: Because it is impossible that we collected all materials from the tailpipe.

Interviewer: Assume that we collected all of them.

Student: *Then, I think the mass of the gasoline should equal to the mass of the exhaust gases.*

Interviewer: Why?

Student: *Because of <u>the law of the conservation of mass</u>*

A third example for Level 2 is presented in Excerpt 4. An U.S. student stated that fossil fuels produced energy because they contained "carbon bonds". The interviewer further asked him to explain the meaning of carbon bonds. The student stated that organic molecules had carbon bonds. The interviewer then asked him to explain the meaning of organic molecules. He explained that organic molecules provided energy because they contained three elements—carbon, hydrogen, and oxygen. Although the student identified key elements of organic molecules, he did not recognize the special structure of organic molecules—organic molecules are a group of molecules that all contain C-C and/or C-H bonds, and therefore provide energy in the combustion process. In this sense, he did not apply the concept of organic molecules scientifically.

Interview Excerpt 4
Interviewee: U.S. Student
(Task: Car Running on Gasoline; Question Set: Structure of Matter)

Interviewer: What kind of chemical structure makes them [fossil fuels] special?

Student: I mean, I guess the carbon, whatever the structure is in it, has the carbon. Breaking those bonds is what produces energy, like the fuel of the cars. So, since they contain similar carbon bonds I would say.

Interviewer: What do you mean by 'carbon bonds?'

Student: *I guess <u>organic molecules</u> like carbon, hydrogen, and oxygen. Molecules that have carbon chains and large amount of carbon atoms all connected together.*

Interviewer: So could you talk more specifically about that because you are talking about carbon, hydrogen, and oxygen. I mean its bonds between carbon and hydrogen or bounds between hydrogen and oxygen? I am kind of a bit confused.

Student: *I guess like, I mean I don't know. I feel like all fuels contain these three elements primarily and I think that ethanol and regular fuel have similar structures of those three elements.*

Interviewer: By three elements you mean…?

Student: *Carbon, hydrogen and oxygen.*

In the next and final example, a Chinese student applied the law of energy conservation incorrectly. He stated that the temperature would not change because of the law of the conservation of energy. The interviewer asked him to provide more details. He then explained that there was no energy exchange between the room and the outside environment because the room is closed. The student named the conservation law. Regarding applying the law, he attempted to identify input energy and output energy, but did not recognize that the closed room was not a closed system, and that electrical energy was an input energy of the system.

Interview Excerpt 5

Interviewee: Chinese Student

(Task: Using Electricity; Question Set: Energy Transformation)

Interviewer: So, my question is will the temperature of the room go up, go down, or remain the same?

Student: It should not change.

Interviewer: Why?

Student: *Because <u>the law of the conservation of energy</u>.*

Interviewer: Can you provide more details?

Student: The room is closed, so there is not energy exchange with the outside environment. In this situation, the temperature will not change.

Scientific Terms Used in Scientific Explanations (Level 3). Finally, we use two examples to show how students used scientific terms to construct scientific explanations about energy consumption issues. As shown in Excerpt 6, a Chinese student used process terms (i.e., combustion and energy transformation), energy terms (i.e., chemical energy), and matter terms (i.e., chemical bonds, carbon-hydrogen bonds, hydrocarbons, and carbon-carbon bonds) to explain why gasoline provided energy. The interviewer asked the student to explain whether the property of providing energy is related to the structure of matter. The student then provided an detailed explanation regarding how gasoline provided energy. His explanation indicated that he identified the special structure of fuels—they all contain carbon-hydrogen and carbon-carbon bonds, which are associated with chemical energy.

Interview Excerpt 6

Interviewee: Chinese Student

(Task: Car Running on Gasoline; Question Set: Structure of Matter)

Interviewer: Why do people use gasoline rather than water to power their vehicles?

Student: Gasoline can react with oxygen in <u>combustion</u>. In this process, energy is released. It is a process of <u>energy transformation</u>.

Interviewer: How do you know gasoline provide energy?

Student: [No response].

Interviewer: Do you think this has anything to do with the structure of gasoline?

Student: *This is determined by structure. It provides <u>chemical energy</u>.*

Interviewer: Why do you think it provides chemical energy?

Student: *It has some special <u>chemical bonds</u>.*

Interviewer: Can you explain what kinds of chemical bonds?

Student: *For example, gasoline has <u>carbon-hydrogen bonds</u>. <u>Hydrocarbons</u> contain <u>carbon-carbon bonds</u>.*

In Excerpt 7, the U.S. student provided a scientific explanation of energy transformation in the event of a running car. He first explained that the energy to power the car is chemical energy provided by the gasoline. The interviewer further probed his idea by asking, "So, you mean the energy is created in the process?" The student corrected the interviewer by stating the first law of thermodynamics—energy is never created nor destroyed. He further applied this law to the context of car running: "So, I wouldn't say it's created but it's transformed into -- the chemical energy is transformed into the mechanical energy." The interviewer further probed to find out if the student had also applied the second law of thermodynamics to this event—whether the student recognized heat dissipation. The interviewer asked, "So, the car runs for a while and stops. I mean it's completely off. So, where does the energy of running go?" The student provided a scientific explanation; he explained that most energy is lost through heat to the universe.

Interview Excerpt 7
Interviewee: U.S. Student
(Task: Car Running on Gasoline; Question Set: Energy Transformation)

Interviewer: So, where does that energy come from?

Student: The energy to run the car?

Interviewer: Uh-hmm.

Student: Well, it comes from the <u>potential energy</u> that's stored in the gasoline and the engine. I believe -- I'm not really too knowledgeable on how cars runs -- but I believe it's just the -- maybe the <u>oxidation reaction</u> of the gasoline.

Interviewer: So, you mean the energy is created in the process?

Student: *Well, energy is never created nor destroyed. So, I wouldn't say it's created but it's transformed into -- the chemical energy is transformed into the <u>mechanical energy</u>.*

Interviewer: Where is the chemical energy?

Student: It's in the gas -- in the gasoline.

Interviewer: Gasoline. So, when the car is running, it has energy, right?

Student: Uh-hmm.

Interviewer: So, the car runs for a while and stops. I mean it's completely off. So, where does the energy of running go?

Student: Oh, when the car stops?

Interviewer: Yeah.

Student: *Most energy is lost through heat to the universe. The heat of the universe increases with the loss of <u>heat</u> from the system.*

DISCUSSION AND CONCLUSION

As China and the United States are the top two carbon emitters in the world, it is particularly important for citizens in both countries to develop sophisticated understanding of energy consumption issues. In this study, we examined how U.S. and Chinese biology major students used scientific terms to explain two important energy consumption issues: burning fossil fuels for transportation and using electricity. We discuss three implications of this study for promoting students' scientific and environmental literacy.

First, the results indicated that both Chinese and U.S. students named scientific terms when explaining energy consumption issues, but their explanations did not necessarily demonstrate the correct application of scientific concepts and principles. Although scientific terms appeared most frequently in Level 3 episodes, they did appear in some Level 1 and Level 2 episodes. This evidence suggests that *naming* scientific terms is a necessary but insufficient condition for providing a sound scientific explanation. This finding is aligned with previous studies (Jin & Anderson, 2012b; Marek, 1986) that suggest that students may use the terminology of "food chain", and "ecosystem" without really grasping a scientific understanding of energy flow or biotic-abiotic relationships of those concepts. As Marek (1986, p. 35) puts it: "Knowing the terminology associated with the scientific phenomenon does not mean that students understand the phenomenon itself."

Second, this study compared Chinese students' and U.S. students' naming and explaining. In a previous interview study on Chinese and U.S. K-12 students' understanding of carbon-transforming processes (photosynthesis, cellular respiration, digestion and biosynthesis, and combustion), we found that, at the high school level, Chinese students began to use scientific terms more frequently than U.S. students, although their understanding of science is not better than their U.S. counterpart. This pattern did not appear at elementary and middle school levels (Jin & Anderson, 2012b). In the present study, we found that Chinese biology majors named scientific terms more frequently and provided more scientific explanations than U.S. biology majors, specifically when the terms are related to energy and process. Therefore, we are left with following questions: Do U.S. and Chinese students develop the naming and explaining abilities differently, as they progress from elementary schools to colleges? How do they compare in naming and explaining at different school levels? Do the patterns found in biology majors also appear in college students with other science majors? We call for more large-scale quantitative studies to compare Chinese and U.S. students in naming scientific terms and applying scientific concepts and principles. The products and approaches of this study (e.g., identification of scientific terms to be used in explanations, and development of the three levels of explaining) provide a foundation for such large-scale studies.

Finally, the results suggest challenges to promoting scientific understanding of energy consumption in both countries. U.S. students named scientific terms less frequently than Chinese students, and about 45.0% of their explanations were scored at Level 1—explanations based on everyday informal ideas. Although Chinese students demonstrated a better ability to explain and used scientific terms more frequently, they still provided more informal explanations and school science explanations than scientific explanations. The results also suggest that although many students named scientific terms in their explanations, they did not correctly apply the relevant concepts and principles. Instead, students tended to reconcile their existing intuitive ideas and scientific concepts and principles. As a result, they constructed many alternative ideas about scientific concepts and principles. Therefore, we call for more curriculum and instructional opportunities that emphasize using the scientific terms correctly and meaningfully in explaining real-world phenomena.

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