May 2018

Enhancing student ability to transfer energy concepts in postsecondary science education through explicit instruction of concepts, student self-reflection, and guided practice in knowledge transfer

Jim Harmon
Western Washington University

Lauren Gray
Western Washington University

An instructional intervention to prepare students for transfer of energy concepts from physics to other STEM disciplines

Jim Harmon, Lauren Gray, Dr. Andrew Boudreaux

Western Washington University

OVERVIEW: SCED 201-2-3-4 is a coherent sequence of science courses for pre-service science teachers. Starting with physical Science, SCED 201, the courses are designed to facilitate student transfer of energy concepts across science disciplines. However, barriers remain to student ability to transfer knowledge. For this reason, we designed instructional interventions designed to explicitly present energy as a cross cutting concept, and to present transfer of knowledge as an explicit goal of education. In addition to enhancing student abilities in transfer of energy concepts, these instructional interventions are designed to develop, among pre-service teachers, a pedagogical awareness of cross cutting concepts and transfer of knowledge.

ABSTRACT: While concepts of energy and matter apply across science disciplines, students have difficulty transferring their knowledge of energy concepts from one science discipline to another. Traditionally, instruction of physical sciences, chemistry, and life sciences are presented independently of one another; with energy concepts introduced in isolated contexts and with differing emphases. Specific instructional strategies have been shown to improve student transfer of knowledge: metacognitive student reflection, and explicit framing of knowledge transfer as a concept. This study applies these instructional strategies to the design of instructional *interventions* which are integrated into an introductory physics course for pre-service primary teachers. We measure the impact of these interventions, quantitatively and qualitatively, in a controlled study.

Design of Instructional Intervention - A 3-Part Sequence

We developed an instructional intervention to support student ability to transfer energy concepts from an original learning context in physics to the subsequent study of biology, geology, and chemistry. The intervention is added to an existing physics curriculum, and uses a model of "forward-looking transfer of learning" (Ferlazzo, 2015). The intervention involves 3hrs of class time and 2hrs of HW spread over the 10 week physics course, and has a three-part structure:

1 **Energy as a Crosscutting Concept -**
- introduction to Next Generation Science Standards (NGSS) which emphasize energy as a cross cutting concept
- Group discussions of teaching energy as a cross cutting concept in K-8 science education

2 **Far Transfer as a Goal of Instruction:**
- Introduction to transfer as an explicit goal of education
- Individual, metacognitive reflection on far transfer of knowledge.
- Collaborative work identifying value of far transfer in educational settings

3 **Guided Practice with Far Transfer:**
- Individual and collaborative identification of strategies to facilitate far transfer
- Students guided to recognize that "energy in physics" is the same as "energy in biology, chemistry, and geology"
- Collaborative work on far transfer task: Robyn eats …

Measuring Impact of the Intervention

Quantitative Analysis

Two tests determine student's understanding of physics content (CPT), and their ability to transfer the content to a chemical context (TrT). These tests in tandem generate a quantitative measurement to help determine the efficacy of the intervention.

Qualitative Analysis

Why Measure Qualitatively? To better understand how the intervention may influence the pedagogy of pre-service teachers, by assessing their:
- understanding of transfer of knowledge as a concept of learning theory
- understanding of transfer of knowledge as an explicit goal of education
- Recognition of energy as a cross cutting concept.
- value energy as a cross cutting concept.

Qualitative Methods: students respond to writing prompts before and after the interventions, probing for students' emerging constructs of transfer of knowledge and energy as a cross cutting concept. We will use Thematic Analysis (Braun, 2017) to process and code student responses.

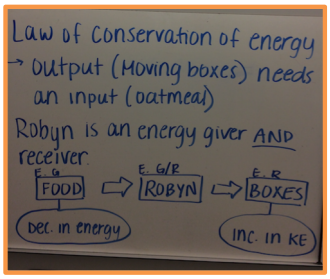
Qualitative Data Collection for Pilot Implementation

Example: Collaborative student work on a transfer task

Transfer task: Robyn is planning to do some work in her garage over the weekend. On Saturday morning, she eats a good breakfast of oatmeal. Then, she spends two hours moving many heavy boxes from the floor of the garage up to a high shelf. While lifting the boxes, Robyn becomes quite warm and takes off her jacket.

Part a. Create a scientific explanation to answer the question Why was Robyn able to continue lifting heavy boxes after eating a breakfast of oatmeal?

Part b. Create a scientific explanation to answer the question Why did Robyn become very warm when lifting the heavy boxes?



Examples: Student writing from reflection Assignment

Student reflections: ***Energy as a Cross Cutting Concept***

"When teachers are teaching energy as a cross-cutting concept, it is showing how this world is all one big system. Everything in this world is … understood based on the topic of energy."

"Until this article, I never really thought of the energies being used the same way. I always thought that energy you create inside your body by eating was different than the energy that is used in creating bonds or attachments like DNA. I guess when you think about it, it is all energy."

"I think that there are a lot of benefits to teaching energy as a cross-cutting subject. It has been proven that it is easier for students to learn things if it's connected to things they already know. …it will make it easier for them to grasp since …it will add onto their concept of energy"

Student reflections: ***Transfer as a goal of instruction***

"I have always done well with traditional methods and memorization in the short term for tests, but I think that this doesn't do anyone any favors. Specifically because of the idea of transfer and how if you truly learn something deeply enough to understand it from several angles (or at least angles that make sense to YOU), then the learning will benefit you in other arenas."

SUMMARY AND NEXT STEPS: We have developed and piloted an instructional intervention in a physics course for preservice elementary teachers, with the 2-part goal of building student capacity to transfer energy concepts across science disciplines, and to foster pedagogical perspective around energy as a cross cutting concept and transfer of knowledge as a goal of education. Next steps will include analyzing qualitative data using Thematic Analysis. Qualitative data analysis will further refine the content and delivery of the instructional intervention. Additionally, we will use the pilot results to adapt the writing prompts to an interview protocol. We will conduct think aloud interviews with summer quarter SCED 201 students. This will allow us to make changes to the intervention writing prompts and better elicit student views.

References

Eisenkraft A. et al. (2014) Introduction: Why Focus on Energy Instruction?. In: Chen R. et al. (eds) Teaching and Learning of Energy in K – 12 Education. Springer, Cham.

Ferlazzo, L. (2015). How Can You Get Students to Transfer Their Knowledge and Skills from One Class to Other Classes and Outside-of-School Situations? Building a Community of Self-Motivated Learners : Strategies to Help Students Thrive in School and Beyond. (pp. 121-143). New York, NY: Routledge.

NGSS Lead States (2013). Teaching and Learning Extension A, Reading: The Next Generation Science Standards and Next Gen Pet. Washington, DC: The National Academies Press.