

Pairing Lesson Analysis with Constructivism:
Designing and Studying an Online Energy Course for Teachers

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Abstract

The *Energy: A Multidisciplinary Approach for Teachers* (EMAT) project, currently in its fourth of five years, is advancing knowledge in the field of teacher professional development (PD) by merging two facets of PD that have hitherto been studied separately and testing hypotheses about the degree to which this pairing enhances teacher and student learning and teacher practice. These facets are structured constructivist experiences (enacted by the BSCS 5E Instructional Model) and experiences grounded in situated cognition learning theory (enacted by a video-based lesson analysis process). Teachers reflect on research-based teaching practices in the lesson analysis process through Science Content Storyline and Student Thinking Lenses. The research project tests longitudinal impacts on teachers' content knowledge, pedagogical content knowledge, and teaching practices and students' content knowledge, contributing much needed data for future PD projects. The course is creative both in its grounding of PD in classroom experience and in its plan to motivate teachers by leveraging their sense of urgency and the growing scientific data and tools related to alternative energy resources. Data collected are informing a full revision of the course as well as helping address significant gaps in our understanding of online PD.

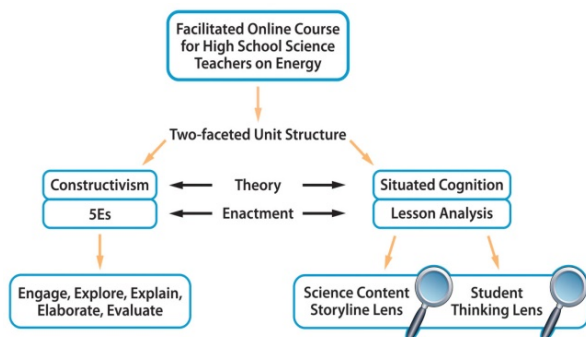
Pairing Lesson Analysis with Constructivism:

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Energy concepts are fundamental to all science disciplines, and a basic understanding of energy is essential to thoughtful civic participation on issues of foremost national interest. BSCS in collaboration with Oregon Public Broadcasting (OPB), the National Teachers Enhancement Network (NTEN) at Montana State University, the National Renewable Energy Laboratory (NREL), and the Great Lakes Bioenergy Research Center (GLBRC) are designing and studying the use of an innovative online, multimedia, professional development course focused on energy-related concepts within a context of the production and use of alternative energy. The course is known as *Energy: A Multidisciplinary Approach for Teachers* (EMAT), and it emphasizes three big ideas, all associated with Crosscutting Concept #5 within the *Next Generation Science Standards* (NGSS Lead States, 2013), namely: 1) Energy is neither created nor destroyed; 2) Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems’ possibilities and limitations; and 3) No energy transfer is 100% efficient, some energy always leaves the system in a nonuseful form as heat. The course takes advantage of the affordances of a multimedia environment, incorporating animations, classroom videos, and interactive learning experiences as part of the overall instruction.

The first goal of the project is to enhance teacher content knowledge and pedagogical

Figure 1. Course structure by unit.



content knowledge (PCK) related to energy concepts in order to ultimately improve student learning. The target audience is high school science teachers who serve students from demographic groups typically underrepresented in the sciences. The course will integrate two

powerful research-based facets: structured constructivist experiences using the BSCS 5E Instructional Model, and experiences grounded in situated cognition learning theory using a video-based lesson analysis process. Rigorous evidence indicates that *both* facets of the course can enhance teachers' understanding of key energy concepts (Bybee et al., 2006; Roth et al., 2011). Constructivist learning opportunities will promote conceptual understanding of key energy concepts by providing teachers opportunities to build their understanding through carefully structured experiences. Lesson analyses will enhance teachers' science content knowledge and PCK as they reflect deeply on lessons using two lenses: the Science Content Storyline Lens and the Student Thinking Lens (Figure 1). While these two facets of PD have been used and studied independently, EMAT is merging them in a single online course such that they may synergistically promote teacher learning.

The second goal of the research project is to study the promise of efficacy of the various components of the course. In spite of the rapid expansion of online PD, little is known about best practices for its design and implementation (Dede et al., 2006). In particular, there remains a dearth of evidence linking PD of any kind to student learning. Most PD research is evaluative in nature and fails to attend to longitudinal effects of the PD. We will improve upon typical PD research by answering the following research questions:

1. Do teachers demonstrate improved content knowledge about energy concepts after participating in the course? If so, is the difference statistically and practically significant?
2. Do teachers demonstrate improved PCK as evidenced by their ability to analyze student thinking and analyze lessons for coherent science content storylines after participating in the course? If so, is the difference statistically and practically significant?

3. After participating in the course, do teachers help students attain higher posttest scores (pretest adjusted) than they did for their prior year's students, taught before teachers' participation in the course? If so, is the difference statistically and practically significant?

The Need for EMAT

Teachers need to understand their subject matter deeply and flexibly so they can address student misconceptions and help students relate one idea to another. Teachers also need to see how ideas connect across science disciplines and to everyday life. This kind of understanding provides a foundation for PCK that enables teachers to make abstract ideas accessible to their students (Shulman, 1987). Studies of instructional practice show that teachers with weaker content knowledge use fewer research-based instructional strategies (Carlsen, 1993). Weaker content knowledge is also associated with difficulties developing conceptual content storylines (Sanders, Borko, & Lockard, 1993). Teachers with weak content knowledge are thus less likely to engage in practices that help their students learn fundamental science concepts. As a result, a large percentage of science teachers are in critical need of support to enhance their content knowledge and PCK.

We chose to support teachers in their content knowledge and PCK related to energy for a variety of reasons. An understanding of energy is paramount for scientifically literate citizens. Science educators have long recognized the importance of energy as a core organizing concept, as reflected in the high number of energy-related concepts in the National Science Education standards (NSES) and American Association for the Advancement of Science (AAAS) Benchmarks (NRC, 1996; AAAS, 1993). The Department of Energy has also taken a leading role in mapping an energy literacy framework. There is a growing national call for action to develop alternative energy solutions to help secure US economic vitality and security and to help mitigate climate change (NAS, 2008). The course described in this study is leveraging this

growing sense of urgency to increase teachers' motivation to learn and successfully teach about energy.

Theoretical Framework for the Study

The facilitated online PD course uses a powerful, two-faceted theoretical approach: situated cognition and constructivist learning theories. According to situated cognition theory, learning is naturally tied to authentic activity, context, and culture (Brown, Collins, & Duguid, 1989). The situated cognition approach to PD provides contexts in which teachers can integrate the many complex aspects associated with teaching. The contexts will “enable teachers to see content and teaching issues embedded in real classroom contexts; ... treat content as central and intertwined with pedagogy; [and] focus on the specific content ... teachers are teaching” (Roth et al., 2011). Grounding teachers' learning in the context of teaching practice raises motivation as teachers grapple with ideas within situations where they will be using the knowledge (Garet et al., 2001). The situated cognition approach contrasts sharply with traditional PD programs that are typically short-term, isolated from teachers' classrooms, and approach content-deepening and pedagogy as distinct objectives (Ball & Cohen, 1999). The constructivist approach to PD allows teachers to grapple with their own prior conceptions about energy, develop explanations from evidence within a coherent conceptual framework, and reflect on their thinking as their conceptual understanding develops. Constructivist approaches have been shown to be effective for science content learning for both students (Wilson, Taylor, Kowalski, & Carlson, 2010) and teachers (Raya-Carlton, Weaver, & Krebs, 2010).

Methodology, Research Methods, Design, and Study Context

Our research examines the extent to which we can attribute changes in teacher content knowledge and PCK as well as enhancements to student learning to teachers' participation in the course. As such, we would like to make a causal link between an intervention and outcomes.

This methodology requires the use of comparison groups as well as baseline measures in order to enhance the confidence we can have in making causal claims.

Our study uses a cohort-control quasi-experimental design. Teachers in the research project participate over two school years. Teachers' students the first year constitute the comparison group, and their students in the second year constitute the treatment group. Teachers take the course in the summer between the two school years. We used this design to understand how teachers' participation in the course might have enhanced students' understanding of major energy concepts. We recruited 35 teachers from across the US to participate in the project, with a preference given to those teachers who taught students from racial/ethnic groups that are typically underrepresented in the sciences (including African American, Latino, American Indian, and Native Hawaiian/Pacific Islander students).

To measure changes in teacher content knowledge, teacher participants completed a pretest prior to and a posttest following each unit. We included a separate measure for teachers' PCK. Before and after the course, teacher participants watched four 5-minute classroom videos that provided rich opportunities to comment on student thinking about energy concepts and on the science content storyline associated with the lessons. Researchers coded teacher responses following the protocol by Roth and colleagues (2011). Coders jointly coded approximately 20% of the entire sample and demonstrated reasonably good calibration (Cohen's kappa was 0.738; the intraclass correlation, two-way mixed effects, absolute agreement was 0.898). To measure student learning, we asked teachers to administer pretests and posttests to both the comparison students and the treatment students. Thus, we were able to determine if the course precipitated changes in teacher knowledge that are reflected in higher student achievement. Because treatment occurs at the teacher rather than student level, we used multilevel modeling for the analyses. Student posttest was the outcome variable; pretest and demographic variables served as

covariates; and we had a treatment variable (at level 2) indicating whether students received instruction prior to or following their teacher's participation in the course.

Findings and Analysis

Matched pairs t-tests for the teacher content assessments indicate that teachers made significant gains with large effect sizes on each of the three major ideas of the course: energy conservation ($p = .043$; $d = 0.50$ with a confidence interval for the effect size (CI_d) of $[0.05, 1.94]$); efficiency ($p < .001$; $d = 0.60$, $CI_d = [0.29, 0.91]$); and systems thinking ($p < .001$; $d = 1.03$, $CI_d = [0.49, 1.57]$). Figure 2 illustrates these results.

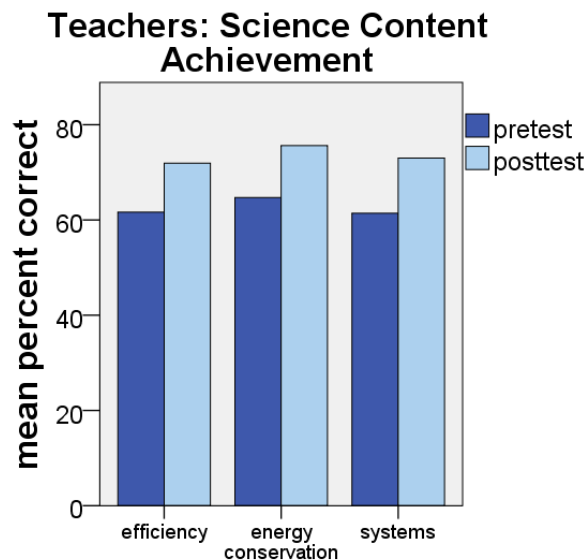


Figure 2. Teacher science content knowledge gains associated with three key ideas.

Matched pairs t-tests for the PCK assessment reveal that teachers made large, significant gains from pretest to posttest related to the Student Thinking Lens, that is, revealing, supporting, and challenging student thinking on energy-related ideas ($p < .001$; $d = 1.16$, $CI_d = [0.67, 1.65]$). Teachers also made large, significant gains from pretest to posttest related to the Science Content Storyline Lens ($p < .001$; $d = 1.581$; $CI_d = [0.96, 2.21]$). Notably, the pre-post effect sizes are

comparable to what Roth and colleagues (2011) found in the face-to-face version of lesson analysis PD (the STeLLA project with $d = 1.31$ for the Student Thinking Lens and $d = 1.07$ for the Science Content Storyline Lens).

We have completed analyses of student data for the first field test but have not yet completed analyses for the second field test. We used multilevel models to examine student achievement. Level 1 included student pretests as well as demographic variables; level 2 included the treatment variable. Student gender, English language learner status, and race/ethnicity were significant predictors of the total student posttest score (boys did better, native English speakers did better, and students who are not members of an underrepresented racial/ethnic group also did better). The treatment variable at level 2 was not a significant predictor ($p = .781$; Hedge's g effect size = 0.024, $CI_g = [-0.189, 0.239]$), indicating that students taught after their teacher took the course performed no differently than students taught prior to when their teacher took the course. There were no significant interaction effects between the treatment variable and student demographics. In other words, not only was there no main effect of treatment, there was also no differential effect of treatment for students from groups that are traditionally underrepresented in the sciences.

Interpretations. The data from the first field test show that a teacher's participation in the course *did not* improve student achievement on an assessment of key energy concepts, even though teachers did make significant gains in terms of their content knowledge and PCK. Our team discussed reasons for why this may be the case. In particular, we questioned the extent to which the aspects of the course that are situated within the highly relevant classroom context specifically draw out the three key learning goals on which students were tested. Even though the content portions of the course addressed the three big ideas, the classroom videos and synchronous discussions centered around more narrowly focused topics, including teaching

nuclear decay, electrical induction, and photosynthesis and respiration. In terms of changing their classroom practice, we suspect that teachers may have applied their learning only to the narrowly focused topics that we showcased through videos in the classroom settings. We used the student achievement finding from the first field test to make revisions prior to the second field test. The analyses of student data from the second field test are currently underway. We are also currently analyzing classroom videos as a measure of teacher practice (including videos from before the course as well as after the course). Upon completion of these analyses, we will be better able to understand how the online instantiation of an effective face-to-face PD model may be falling short in terms of enhancing student achievement.

Alternative interpretations, threats to validity. For teacher measures, we used a pre-post design. There are several threats to validity associated with this design. First, the effect may simply reflect a test-retest effect. This is particularly true for the content assessments that included both multiple choice and open-ended items. We think this is less likely for the PCK measure, which was entirely open-ended and required teachers to attend to a wide variety of strategies associated with the student thinking and Science Content Storyline Lenses. In addition, teachers in the study were a self-selected group. Thus, the findings from this study may not be generalizable to a wider audience of teachers (outside of those who choose to participate in professional development opportunities as part of a research project).

Contribution to the Teaching and Learning of Science

The course is contributing to the field's understanding of lesson analysis PD and how that PD might be made both scalable and sustainable. Roth and colleagues (2011) found that face-to-face lesson analysis PD with elementary teachers can enhance not only teacher knowledge and practice but also student knowledge. We are extending that research to high school teachers and attempting to have an impact using a facilitated, online format. Our findings suggest that this

online format grounded in constructivism and situated cognition is effective for enhancing teacher learning, but we may need to refine the approach to ensure that the effects on teachers also ultimately influence student achievement.

Our results are valuable to science teacher educators and researchers because they speak to the possibilities and limitations for taking a powerful model of face-to-face PD and making that model both more scalable and more sustainable. Effective PD models that are not scalable will never truly transform science teaching and learning. This study shows that it is possible to enhance teacher content knowledge and PCK through a facilitated, online course. However, it is less clear if the enhancements to teacher learning will ultimately help teachers better support student learning. The results of the first field test indicate that the online model is not as effective as face-to-face versions have been in the past.

This study has implications for science teacher education. We expound on the nature of a PD model that has had some success in reaching a wide audience of teachers (teachers who are diverse both in terms of their disciplinary content areas and in terms of their geographic locations). Others considering the development of in-service teacher PD will be able to learn from our efforts. We are beginning to get a better sense of which impacts of the face-to-face PD are replicable and which effects are more challenging to replicate in an online environment. Specifically, the face-to-face versions of lesson analysis PD have included curriculum units for teachers to use and to serve as a model as they design their own future instruction. It may be that the inclusion of curriculum materials is an essential element to the PD. In that case, it will be more challenging to create a model that serves a wide variety of high school teachers from a variety of disciplines.

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