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# Teacher Professional Development for Energy Literacy: A Comparison of Two Approaches

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**Abstract**

In this program and practices feature, we describe two different models of teacher professional development designed to help teachers build their own energy literacy while gaining tools to bring energy literacy to their classrooms. Through a review of the literature we identify principles by which to compare and evaluate the two approaches. Both were successful in helping teachers to build energy literacy; each had a mix of advantages and disadvantages when compared to the literature.

**Keywords:** Energy literacy, teacher professional development, webinars, workshops

## Introduction

The world, and the US in particular, is challenged to meet the energy demands of a growing population in a way that is sustainable and just for all. Finding a solution to this complex problem requires a multi-pronged approach that includes but is not limited to changes in human behavior, the development of more efficient machines and the development of new sources of energy. Energy systems, transportation, buildings and industry have all been identified in the 5th report of the Intergovernmental Panel on Climate Change (IPCC) as areas that might reasonably be transformed to reduce climate change impacts (IPCC, 2014). The transportation sector in particular is challenged by public demand, policy and resource security to find adequate replacements for non-renewable fossil fuels. This paper describes two professional development experiences for teachers conducted as part of a large research project that is investigating the creation of biojet fuel made from wood waste, and is tasked with increasing efficiency for each supply chain step from forestry operations to conversion processes; creating new bio-based products; providing economic, environmental and social sustainability analyses; engaging stakeholder groups; and improving bioenergy literacy for students, educators, professionals and the general public.

We explore two different formats designed to support educators in developing their own energy literacy while building skills to teach energy literacy in the classroom. Specifically, this paper compares the relative advantages and challenges of the two formats in terms of working with teachers to address complex problems in the classroom.

The goals of our teacher professional development, and of our science outreach programs under this project in general are:

1) to increase the energy literacy of students and teachers in the Pacific Northwest by providing direct education and resources for teaching and learning about energy in place-based contexts
2) to connect teachers and students to ongoing scientific research in the broad area of bioenergy and the specific area of woody biomass based biofuel
**3)** to create an ongoing dialog between the education /outreach teams and the science team for mutual benefits
4) to use the Northwest Advanced Renewables Alliance (NARA) project as a case study of one way that researchers are looking at addressing the complex questions associated with providing energy in a sustainable way.

## Review of the literature

### *Energy Literacy Education*

Scholars have pointed to low levels of energy literacy as a challenge needing to be addressed in the US as we face increased population, increased demand for energy and climate impacts from our current energy practices (e.g. DeWaters and Powers, 2011; Weber and Stern, 2011) . By DeWaters and Powers definition, an energy literate individual

> *is one who has a sound conceptual knowledge base as well as a thorough understanding of how energy is used in everyday life, understands the impact that energy production and consumption have on all spheres of our environment and society, is sympathetic to*

> *the need for energy conservation and the need to develop alternative to fossil fuel-based energy resources, is cognizant of the impact that personal energy-related decisions and actions have on the global community, and – most importantly—strives to make choices and exhibit behaviors that reflect these attitudes with respect to energy resource development and energy consumption (p.1700).*

After assessing energy literacy in students in New York State, DeWaters and Powers (2011) found that of the several dimensions of energy literacy (cognitive, affective, behavior and self-efficacy), cognitive knowledge is the least likely to be associated with the other components. In other words, it is not sufficient to focus solely on knowledge with respect to energy literacy, but rather educational interventions need to address more holistically the attitudes and values that students hold with respect to energy. They suggest, among several things, an interdisciplinary holistic approach that integrates social and natural sciences and improved flow of information between researchers and educators; the inclusion of global perspectives and the relationship between global decisions and local impacts, specifically the environmental, social, economic and political concerns associated with these choices; curriculum that is hands on, inquiry-based, experiential and grounded in problem-solving; the use of relevant projects and case studies; and these educational opportunities should use the local community as a learning lab (DeWaters and Powers, 2011).

*Critical pedagogy of place and place-based education for addressing complex problems*

The concepts described by DeWaters and Powers have been supported by proponents of place-based education. Place-based education is a philosophy of education that encourages exploration of local issues to connect learners to broader environmental topics (Sobel, 1996, 2008, Smith, 2002, Greunewald, 2003). Place-based learning has been found to connect learners to place and create partnerships between schools and communities to solve problems (PEEC, 2010). While some have suggested that the place-based pedagogy is limiting when it comes to exploring global phenomena, evidence exists that the approach is an effective way to make complex global problems like climate change relevant and accessible for students (Pruneau et al 2001; Pruneau et al, 2003; LeDuc & Crate, 2013; Somerville, 2010). Buxton (2010) has described a model of social problem-solving through science (SPSS) that was grounded in the idea that a science curriculum should give students the tools to ask critical questions about the world around them and to take action based on those reflections. The authors found that the SPSS approach allowed middle school students and teachers to 1) recognize how "ways of thinking" associated with the dominant Western culture has led to some of the world's environmental challenges, 2) understand how to make decisions that better support living in harmony with ecological systems, and 3) connect these understandings to concepts mandated by the science standards that teachers need to address.

*Public Science Outreach*

A large part of our approach to building our energy literacy programs has involved researchers that engage with our programs through an "outreach" lens, presenting their current work to the public. More than ever, scientists are being asked to connect their science to "broader audiences," including K12 students and teachers. The benefits of public outreach are thought to

include increased public support for science, more sophisticated decision-making on the part of the public, and bringing new perspectives to scientific research by engaging with audiences beyond those who are intimately familiar with the work (Varner, 2014). However, public outreach has often been approached as a one-way dissemination of information from "expert" to "audience." This "deficit-model" of outreach education has been criticized for a number of reasons, including the assumption that bridging a knowledge gap is sufficient to make real change in public opinion and behavior regarding complex environmental issues (Varner, 2014). Varner suggests the adoption of a new model of outreach, in part based on Fischoff (2013) who wrote

> *Effective science communications inform people about the benefits, risks, and other costs of their decisions, thereby allowing them to make sound choices… The goal of science communication is not agreement, but fewer, better disagreements. If that communication affords [scientists and the public] a shared understanding of the facts, then they can focus on value issues. (Fischoff, 2013, p. 14033 as cited in Varner, 2014, p. 334)*

Varner's suggested model of science outreach includes three phases: development, implementation and evaluation. The model suggests that effective outreach starts with explicit goals that include understanding about the audience, consider of the values, attitudes and beliefs that the audience may hold and an effort to connect learning to personal meaning for participants, activities that support the overall learning goals, and efforts to gather assessment and evaluation information to understand if goals were met.

*Place-based, problem-based teacher professional development on site and over a distance*

To address our overarching goals of increasing energy literacy, connecting teachers to emerging bioenergy science and form a dialog between education and emerging science, we designed two different models of teacher professional development. One of the additional challenges that we sought to address through these workshops is the challenge of delivering a place-based curriculum, while also bringing the educational experience to a geographically diverse group of teachers. Because of limitations of staff time and financial resources, we have chosen to base our models on a hybrid of face-to-face and online interactions that uses a place-based framework but maximizes the geographic scope of our reach (Bodzin, 2010).

## Workshop Formats

Based on the goals, challenges and recommendations described above, we designed two different workshop formats that sought to address public science outreach and teacher professional development through both online and face-to-face formats drawing from place-based and problem-based pedagogical frameworks and science outreach communication.

## Workshop Format One: online webinar series delivered monthly for seven months

In the first workshop format, we used a series of webinars to support teachers who are engaged as coaches for a problem-solving competition called Imagine Tomorrow, sponsored by Washington State University.

*Participants and Support to Participants*

Our participants were teachers committed to serving as coaches for student teams developing projects for the Imagine Tomorrow problem-solving competition. Participants were recruited through various avenues, including an open email to Imagine Tomorrow's (a science fair competition in the Pacific Northwest) list of 5,000 email addresses that included past teacher coaches as well as industry sponsors and judges. Participants from previous workshops were invited to participate, and new participants were recruited through various channels, including school administrators. The research area encompasses the four-state region of Oregon, Idaho, Montana and Washington and our goal was to have representation from all four states. In the end, we were able to recruit five teachers from Idaho, five teachers from Montana, and sixteen teachers from Washington. Although several Oregon teachers showed initial interest, they did not ultimately participate. Each participant was provided a stipend of $1000 for their work in supporting Imagine Tomorrow teams and their participation in our program. They were free to use the money as best suited their needs.

*Workshop Goals*

The purpose of our workshop series was to give teachers content, facilitation and financial support with the goal of increasing the overall quality of support given to student groups as they work on problem-solving projects for the competition. In connecting to this ongoing work we were able to build on many place-based projects already taking place within teachers' communities.

Additionally, we wanted to provide an easy opportunity for scientists to engage with these teachers. We provided the overall curriculum structure and asked scientists to make presentations that would support the overall content goals. This work is situated within the larger context of problem-based learning and building energy literacy amongst citizens of the Pacific Northwest, the region where this bioenergy research is taking place.

The guiding questions for the webinar series included:

- What resources exist for teaching bioenergy literacy?
- What is the NARA project doing to advance bioenergy in the Pacific Northwest?
- How can these ideas contribute to my students' projects for the Imagine Tomorrow Competition?

*Technology support*

All webinars were delivered using the "GoToMeeting" platform. Communication in advance of the workshops was done largely through email. Participants were asked to record video responses to pre-workshop questions through the online platform Flipgrid. Pre-workshop interviews with presenters were recorded using a Skype audio recording feature and sent to teachers as a "podcast" as a preview of the webinar topic. Other technologies have been explored in past workshops; however, the technologies used were selected for their stability in the educational environment that we operate from.

*Workshop Content*

Every month a different professional gave a presentation during a webinar broadcast to teachers from across three of the four states in the region. Each webinar started with an

introduction to the presenter and a review of the project goals. This was followed by a 20 minute lecture during which participants could type questions into a chat window within the webinar "environment." Questions were answered by workshop facilitators as much as possible, or were saved to ask the presenters following the lecture. After the lecture, participants had an additional 20 – 30 minutes in which they could ask questions of the presenter. Following the formal presentation and questions we had an informal "check in" with teachers about how their project work was coming.

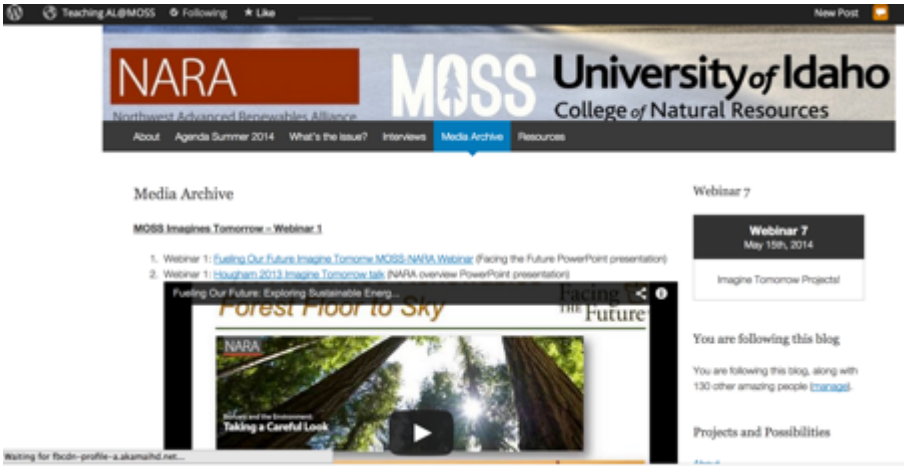


Figure 2 Webinar media archive

The first webinar in the series introduced the overall research project and explained the goals of the larger team that is assessing the economic, social and environmental feasibility of creating a bioenergy supply chain in the Pacific Northwest based on creating bio-based jet fuel and valuable co-products from wood waste. The research team is proposing to develop a supply chain coalition and processes for using forestry residuals (slash piles) and other wood waste (e.g. construction and demolition materials), isolating the sugars from the wood for conversion into an isobutanol-based jet fuel, and taking the leftover materials (a mix of lignins and sugars) to create other valuable co-products.

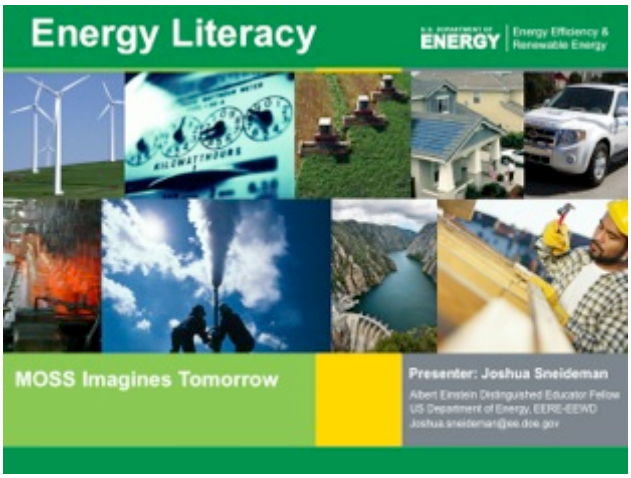


Figure 1 Energy Literacy Webinar (credit: J. Sneideman)

The first presenters were from a national curriculum development non-profit organization called Facing the Future (FtF). FtF creates global sustainability education curriculum materials and provides professional development for teachers. They presented a curriculum that they had developed in partnership with the NARA project called *Fueling our Future* (Hendrickson et al, 2014).

The second webinar featured an Einstein Fellow from the Department of Energy who presented "Energy Literacy Principles: Essential Principles and Fundamental Concepts for Energy Education." The Energy Literacy Framework is "an interdisciplinary approach to teaching and learning about energy" (DOE, 2014), which includes seven essential principles and associated foundational concepts that have been identified as the key concepts that people need to understand in order to make informed energy decisions. The document was developed with the input from over 20 educational partners and 13 federal agencies. We also presented a curriculum resource, the Energy Literacy Matrix (http://energyliteracyprinciples.org/), developed

by members of the NARA team to facilitate the teaching and learning of energy literacy, with a specific focus on bioenergy. It contains videos, research articles, presentations and lesson plans, all aligned to the Energy Literacy Principles.

The third webinar drew on the expertise of a graduate student who was studying successful methods for coaching Imagine Tomorrow teams. He presented his preliminary findings, which were very well received by the participating teachers.

The next three webinars were given by NARA researchers, who were asked to prepare a 20-minute presentation on their research and its place within the overall project as well as ideas for how aspects of their work might be feasible projects for teams for the Imagine Tomorrow competition.

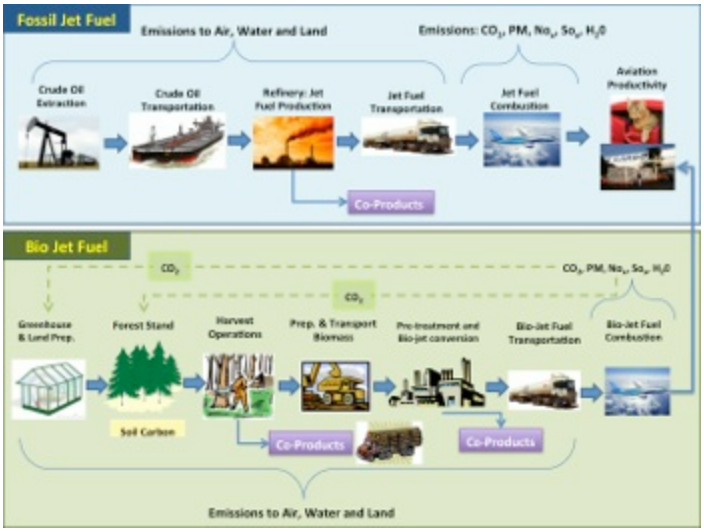


**Figure 3 Life Cycle Assessment (Credit: I. Ganguly)**

The fourth webinar, and the first of several research presentations, was given by a bioregional planner and focused on supply chain logistics. The researcher described the wood to biofuels supply chain, important regional assets (e.g., rail lines, idle saw and paper mills) for initiating a biofuels industry, and different supply chain models based on feedstock availability. The supply chain analysis provides a good platform for addressing the social, economic and environmental aspects of a wood-based biofuels industry in the Pacific Northwest.

The fifth webinar delved into the process of Life Cycle Assessment with a presentation by the research team responsible for investigating the overall environmental impacts of the proposed wood-based biojet fuel (Figure 3). The researchers described the process of doing an assessment, and their preliminary findings.

The sixth webinar featured researchers who are looking at ways to use some of the lignin and other "leftover" material from the process of making wood-based biojet fuel to make co-products that can help to offset the cost of the fuel much in the same way that plastics offset the cost of petroleum-based fuels. Beyond this, these researchers hope to develop products that increase the overall positive environmental impact of the whole enterprise (e.g. lignin products can be used in activated carbon products that can act as "scrubbers" to clean up coal-fired power plant emissions, or as biochar that is a soil amendment).

The seventh, and last webinar, was a final check-in before the Imagine Tomorrow competition. We asked teachers to have their student groups upload videos of their presentations using a private YouTube channel (password protected and not shared in any way publicly to avoid issues with minors and privacy). Workshop facilitators and other coaches were given the opportunity to comment on each team's presentation. Comments largely came from workshop facilitators.

**Format Two: Intensive four-day workshop delivered onsite with an online cohort "following along"**

In the second workshop format, we invited a cohort of teachers to come to our field campus in McCall, Idaho, for a hands-on problem-based workshop exploring many of the same concepts addressed in the webinar series. As with the webinar series, the intensive workshop was grounded in problem-based learning, place-based pedagogies and used the NARA project as a case study.

Within this context, we explored two overarching essential questions:
1) **Is this a good idea?** How do we define "good" when we ask if this is a good idea? By what criteria should we evaluate if this is a "good" idea?
2) **How do we know?** By what measures do we know if something is "good"? What data do we have to use in our evaluation? How are these data generated?

And these additional guiding questions:

1) How much wood waste is out there? (and how do we know?) (measurement)
2) How does wood become jet fuel? (conversion)
3) What do we do with the other stuff that doesn't turn into fuel? (co-products)
4) What are the potential social, economic, and environmental considerations in these processes? (LCA and techno-economic analysis)
5) What are some of the unintended consequences of this choice?

*Participants*

A total of 37 teachers participated in this intensive workshop; 17 teachers participated on site and 20 teachers participated online. The online version was created throughout the one-week workshop by workshop facilitators and the onsite teachers through a "blog" format. Teachers were divided into four teams, each responsible for two blog posts over the course of the week. Three total posts were prepared per day, two by workshop participants and one by workshop facilitators. A total of 15 blog updates were posted through the course of the week.

**Figure 4 Root beer made by class**

*Content*

Throughout the course of the week, we had in-person presentations from two members of the NARA research team, and pre-recorded lectures and webinars from four other researchers. We used several content resources that are specific to the NARA case study: newsletters prepared by the communications team, a "knowledge base" that has original research articles related to woody biomass-based bioenergy, and the Energy Literacy Matrix.

Day one started with an overview of the project and an introduction to our "big questions." We made root beer from scratch and asked the question, "how is making root beer like making biofuel?" In other words, if you were investigating the possibility of starting a root beer business in your community, what things would you consider? This prompted great considerations about the available raw materials (feedstock), how to get it to where you'd be making the root beer (transportation), if your community has the necessary skills (workforce), if there is a demand for the product, and if it would make sense from an economic standpoint. Some ventured into questions about the environmental impact of making the product. This activity was a great introduction to many of the considerations and concerns being addressed by the NARA team in assessing the feasibility of woody biomass-based biofuels and associated co-products. We identified three main areas of interest in this process – economic, social and environmental advantages and concerns. These became the basis for three teams that worked together all week to gather additional information to make arguments for and against creating a woody biomass biofuel industry in the Pacific Northwest based on economic, social and environmental considerations.

**Figure 5 Measuring the carbon sequestered in a tree**

On day two, we explored issues on the feedstock end of the supply chain. The feedstock in the NARA case study is largely forest residues from logging operations. These are the tree-tops, limbs, needles and stumps that are currently not valuable for producing wood products and are typically burned on site. However, due to the high cost of collecting, processing, and transporting this low value material, its use as a viable energy or fuel source can be limited (Long and Boston, 2014). Furthermore, "managers hoping to use this material as fuel will need to efficiently manage the logging residue supply chain if they want to generate competitive energy rates. Thus, the first step that is needed for efficient management of the supply chain is to accurately measure the supply to plan the most efficient operations for the collection, processing, and transportation of this matter" (p. 200). In other words, managers need to know "how much logging residue is out there?" A graduate student presented on his work using a terrestrial laser scanner to quantify the volume of slash piles. The teachers were given the task of measuring a slash pile by hand, using any methods they thought appropriate. They compared the volumes that they quantified with the volume determined by the terrestrial laser scanner. This activity was based on research published by Long and Boston in the February 2014 issue of *Forest Science*. After comparing methods, we discussed the tradeoffs of each approach (accuracy, time needed to set up the laser equipment, cost).

**Figure 6 Using LiDAR to measure the volume of a slash pile**

**Figure 7 Using sugar cubes and peanut butter to teach a concept about converting biomass into fuel**

We also completed an activity that estimates the carbon that can be stored in a tree versus the amount of fuel that could be created from the residuals of that tree, and the number of air miles that could be flown in a Boeing 747 with that fuel (Schon et al, 2014). This led to a great discussion of the benefits of carbon sequestration, the potential for avoided impacts of CO2 emissions by using the slash for jet fuel instead of burning it onsite, and a great math lesson where we calculated and compared the "seat miles per gallon" of a Boeing 747 to an average passenger auto. We also discussed the need to understand impacts on soil

productivity and nutrient cycling and the activities researchers are undertaking to understand these impacts.

Finally, the teachers participated in an "Adventure Race" designed to simulate all the parts of the supply chain from trucking it out of the forest to the refinery to the end user. We used this very physical and fun "race" as a platform to discuss the logistical considerations and the economic, social and environmental impacts that have to be considered within the supply chain. This was followed by our first researcher presentation. A bioregional planner discussed with us how the project team is evaluating potential site locations and means of transporting slash to conversion sites.

Day three focused on the process of converting woody biomass into jet fuel. We led the teachers in an activity that simulates the challenge of separating lignin from cellulose and hemicellulose by having them remove peanut butter from sugar cubes using various processes. The sugar cubes were then put into hot water. The clearer the water, the better job the teachers did of separating out the "lignin." The teachers were then challenged to find uses for the leftover peanut butter. This activity led into a pre-recorded presentation from two researchers who explained the conversion and co-products processes. In particular, they discussed activated carbon as a co-product and its potential uses.

After the presentation, teachers explored uses for activated carbon. We provided them with various tools (activated carbon, various "contaminants", tools for measuring soil moisture, nitrate levels, etc.) and we gave them the task of creating their own mini-research projects to determine some uses for the products. This was a largely open inquiry with some guidance from workshop facilitators when groups were "stuck."

On day four, we considered the big picture, with a focus on Life Cycle Assessment (LCA). According to the Environmental Protection Agency (EPA), "LCA is a technique to assess the environmental aspects and potential impacts associated with a product, process, or service, by:

- Compiling an inventory of relevant energy and material inputs and environmental releases
- Evaluating the potential environmental impacts associated with identified inputs and releases
- Interpreting the results to help you make a more informed decision"

The morning lesson had teachers examine the life cycle impacts of their morning cup of coffee. This provided a good scaffold for the teachers to think about the kinds of impacts that might be measured with a wood-based biofuel. We followed this lesson with several lessons from *Fueling Our Future*. Specifically, the teachers explored benefits and tradeoffs of various fuel types and their overall environmental impacts (positive and negative). This prepared the teachers to listen to a presentation from NARA researchers who are looking at the Life Cycle Analysis of biojet. The goal with this biofuel is to reduce greenhouse gas emissions by 60% compared to a fossil-fuel scenario. The team looking at Life

**Figure 8 Stakeholder meeting**

Cycle Assessment is responsible for evaluating the potential of this fuel to meet that target. The teachers also participated in a mock stakeholder meeting that had them looking at the issue from various perspectives that are realistically present within the broad biofuel discussion.

On the last day of the workshop, the three groups presented their final presentations that explored the environmental, economic and social implications of the wood-based biofuels case study. They were asked to make a judgment about the project, telling us their conclusions to our "big questions" of: Is this a good idea? How do we know? What do you think? What evidence have you found? Through discussion, they came up with three principles for consideration. Principle 1: just because we can doesn't mean we should. In other words, having the technological sophistication or economic incentives to bring this process to scale are not sufficient considerations. The whole picture needs to be analyzed critically, especially with respect to unknown environmental impacts. Principle 2: there is strength in diversity, and the related Principle 3: don't expect one right answer. In other words, the "solution" to the nation's energy challenges is not one single solution, but rather a complex mix of technological advances, behavioral changes, multiple sources of energy and willingness at the individual and societal scale to reduce our consumption. The group decided that on this process overall they would recommend "proceeding, with caution." There were unanswered questions about environmental impacts, particularly with respect to soil and nutrient cycling; these are on the "watch list" as they would recommend that the group move forward with the process.


Figure 9 Screen shot of the last blog post

## Evaluation Questions

We asked several questions in our evaluation of these two programs, including:

i) What are the comparative strengths and limitations of each approach relative to best practices identified in the literature?
ii) How do teachers benefit by participating in these experiences?
iii) How do scientists benefit by participating in these experiences?
iv) How does this interaction contribute to teachers' abilities to facilitate the investigation of complex problems?
v) How compatible are online and hybrid online / onsite formats for supporting place-based sustainability and problem-based education?

In this paper, we focus on the first evaluation question: What are the comparative strengths and limitations of each approach relative to best practices identified in the literature? Other papers, in development, will report on our findings for questions 2 – 5.

**Analysis**

Using criteria identified by DeWaters and Powers (2011), Fischoff (2013), and Buxton (2010) related to place-based pedagogy, public science outreach and social problem solving through science respectively, we reflected on each workshop format. Table 1 summarizes our reflections on each approach with respect to its ability to address various criterion areas. In the following discussion, we will elaborate on these reflections.

| Criterion | Webinar Format | | Intensive Workshop Format | |
|---|---|---|---|---|
| | Strengths | Limitations | Strengths | Limitations |
| **DeWaters and Powers (2011)** | | | | |
| Interdisciplinary holistic approach. | Presenters came from a variety of backgrounds. | Science, social science and engineering were better represented than humanities perspectives. | An interdisciplinary and holistic approach was used to teach the concepts. | |
| Improved flow of information between researchers and educators. | Provided direct contact between researchers and teachers, with follow-up opportunities. | Technology made it difficult to make contact two-way. | Provided direct contact between researchers and teachers, with follow-up opportunities. | Desired more in-person presentations. |
| Inclusion of global perspectives and the relationship between global decisions and local impacts. | Curriculum focused on a global issue with local impacts especially the LCA presentation. | | Curriculum focused on a global issue with local impacts highlighted across the curriculum. | |
| Curriculum that is hands on, inquiry-based, experiential and grounded in problem-solving. | Workshop was a problem-based framework grounded in inquiry and experiential methods. | Online format did not easily allow for this, though it is conceivable that it could. | Grounded in a strong essential question, very experiential and inquiry-based and situated in a problem-solving pedagogy. | |
| Use of relevant projects and case studies. | The NARA project served as a case study focused on the feasibility and wisdom of using woody biomass to create biojet fuel. | | As with the webinar series, The NARA project served as a case study focused on the feasibility and wisdom of using woody biomass to create biojet fuel. | |
| Use the local community as a learning lab. | Imagine Tomorrow projects often take place in the community. | | | This could be addressed more effectively in helping teachers to find local resources for their study once they return to their communities. |

| | Webinar Format | | Intensive Workshop Format | |
|---|---|---|---|---|
| Criterion | Strengths | Limitations | Strengths | Limitations |
| **Fischoff (2013)** | | | | |
| Explicit goals that include understanding about the audience. | The webinar series overall had explicit goals, and each session had its own goals. | More effort could have gone into understanding the audience's goals. For example, teachers would have liked more information about the IT competition so they could better prepare their students for the experience. | The intensive workshop had explicit goals; each presenter understood how their presentation fit into the bigger picture. Given the intimate nature of the workshop, it was easier to understand the audience's needs and goals. | |
| Consider the values, attitudes and beliefs that the audience may hold and an effort to connect learning to personal meaning for participants. | | Not always easy to get participants' feedback to presenters so they knew if they connected with the participants; not always possible to provide the researchers with details about the participants in advance of their presentation. | Participants answered the question "is this a good idea" based on their own evaluation of the process, and through the lenses of various values they hold. | |
| Activities that support the overall learning goals. | Activities were well connected to learning goals. | | Activities were well connected to learning goals. | |
| Efforts to gather assessment and evaluation information to understand if goals were met. | Multiple forms of evaluation and assessment were used including a pre- and post- program survey, focus group, and interviews with the presenters. | | Multiple forms of evaluation and assessment were used including a pre- and post- program survey, focus group, and interviews with the presenters. | |

| Criterion | Webinar Format | | Intensive Workshop Format | |
|---|---|---|---|---|
| | Strengths | Limitations | Strengths | Limitations |
| **Buxton (2010)** | | | | |
| Recognize how "ways of thinking" associated with our dominant culture have led to some of the nation's environmental challenges. | | This question was not explicitly addressed, though it is embedded in some of the curriculum presented in the workshop (e.g. Fueling Our Future) | The "triple bottom line" of economic, social and environmental sustainability was clear throughout the workshop. | |
| Understand ways to make decisions that better support living in harmony with ecological systems. | The Life Cycle Assessment presentation addressed this question explicitly. | The case itself has this as an embedded question, but it was not always at the forefront of discussion. | This was an emphasis throughout the workshop, though the economic and social perspectives balanced it. | |
| Connect these understandings to concepts mandated by the science standards that teachers need to address. | These concepts easily connected with Common Core and Next Generation Science Standards. | | These concepts easily connected with Common Core and Next Generation Science Standards. | |

## Discussion

In interviews with teachers and researchers involved in these professional development experiences, it is clear that both educators and researchers benefitted in some capacity from both workshop formats. For educators, they gained content knowledge, more sophisticated ways of thinking about energy, and pedagogical examples for the classroom. For researchers, they gained the satisfaction that more people understand the importance of their work with respect to large-scale problem solving and a better understanding of some of the perspectives and values that "the public" will bring to understanding the science they are engaged in. They also clearly benefit from learning to communicate about their science to a broader audience because it not only helps them to get the message out, but also helps them to refine their thinking and define new questions that may be of greater importance on a broad public scale. These findings will be discussed in detail in a manuscript currently in preparation.

Both formats afforded opportunities to learn. The webinar series attracted the broader geographic participation and connected more specifically with problem-based learning within their communities (though not all projects would have explicitly addressed concerns related to place). The intensive workshop allowed for more in-depth exploration of the content and an explicit example of problem-based learning that teachers could bring back to their classroom with or without the specific bioenergy content.

### *Interdisciplinary holistic approach*

Both formats took an interdisciplinary approach that explored questions from social scientific, economic, scientific and political lenses. This was done through presentations, reading, the hands-on exploration of concepts, and discussion. Presenters were selected from various fields including social science, engineering, chemistry and an economics; the latter, for a notable example, is an economist who studies the environmental impacts of supply chains. Many of these collaborators were met and recruited in NARA workshops or meetings, and selected for capacities in communicating science. Because the NARA project itself uses an interdisciplinary approach of looking at the "triple bottom line" of economic, social and environmental impacts, it was natural to see this cross-disciplinary cross-pollination in the educational experiences using this project as a case study.

### *Improved flow of information between researchers and educators*

An important part of this process was the direct connection between researchers and educators, though each format placed limitations on this connection. The webinar format made direct interaction between the researcher and the teacher difficult because of technology issues arising from the format itself. For example, participants often needed to type their questions into a chat box rather being able to ask the question directly. This challenge was due to both technical challenges with the software and the challenge of managing audio inputs with a large group (e.g. if the audiences' audio input was not muted, audio feedback became an issue). In the intensive workshop, face-to-face interaction proved to be mutually beneficial and engaging. However, it was not always possible to get people there face to face and in some cases we relied on previously recorded material. Still, in both cases the participants had access to scientific

understandings that are just emerging. This flow of information, though imperfect, is an improvement over waiting for research to become part of a textbook.

*Inclusion of global perspectives and the relationship between global decisions and local impacts; use of relevant projects and case studies*

Both formats were used to create case studies focused on making biojet fuel from wood waste. The premise of each is that a new fuel source can help to alleviate some global impacts from carbon emissions, increase national energy security, and benefit local economies. The Life Cycle Assessment portion of the content is particularly well-suited for discussions of global perspectives and of the relationship between global decisions and local impacts.

Because both approaches were grounded in well-funded emerging research as case studies, we had access to a lot of primary research texts and researcher presentations that had been recorded and posted online. From these texts and presentations, participants had access to a lot of data. It is important to note here that our teachers have the advantage of a direct connection to a large-scale research project that is generating many articles, videos, presentations and publications. These are available online but not all teachers immediately know where to access this wealth of information. Part of our strategy is to compile these resources into more accessible formats and to take the primary research and turn it into lesson plans that can be shared more broadly.

*Curriculum that is hands on, inquiry-based, experiential and grounded in problem-solving*

The webinar format makes hands-on and experiential curricula more challenging, though the whole workshop was situated within a problem-based framework grounded in inquiry and experiential methods for the Imagine Tomorrow student teams. We introduced the Facing the Future curriculum called *Fueling Our Future* early in the project, and this provided teachers an opportunity to engage their students in a curriculum that is built on these principles.

The intensive workshop format was better suited to provide hands-on, experiential and inquiry-based curriculum because of the face-to-face format and the extended time together. We were able to conduct field experiments connected to work being done by the research team, and we used hands-on demonstrations to explain some of the chemistry.

Both formats were grounded in problem-solving pedagogies. The intensive workshop allowed teachers to conduct a problem-based inquiry in small teams; the webinar series supported teachers in working with their own students to engage in problem-solving. One of the most frequently discussed outcomes of both workshops was being able to transfer learning and pedagogy to their own classrooms.

*Use the local community as a learning lab*

The webinar series may have been more successful in helping participants think of ways to use the local community as a learning lab because the focus of their learning were student problem-solving teams often working on place-based problems; however, not all teams had this focus. This was a topic explored through early webinars. Participants asked within the online forum: what makes a good IT project? Veteran participants responded that local projects using local knowledge were more successful.

In the intensive workshop, effort was made to connect learning to place but more could be done to specifically explore local impacts of this region-wide process that is connected to global issues. For example, participants researched potential local-scale economic and environmental impacts of the supply chain but they did not investigating these impacts specifically in their own communities.

*Explicit goals that include understanding about the audience; activities that support the overall learning goals*

Both formats did have explicit goals that to different degrees incorporated understanding about the audience. Activities were designed to support the overall learning goals in both formats, and we gathered assessment and evaluation information to understand if goals were met. There could have been more effort in understanding the goals of the audience in the webinar format. For example, teachers were really interested in having more information about the competition itself so that they could better prepare their students for what the experience might entail. In future years, we will spend more time in this area while still providing a good amount of content material. Because of the intimate nature of the workshop, it was easier to develop an understanding of the particular needs and goals of the audience. This may be a strength of intensive workshops generally in comparison to webinars.

*Consider the values, attitudes and beliefs that the audience may hold and an effort to connect learning to personal meaning for participants*

Within the webinar framework, it was not always easy to get feedback from participants that would help presenters to understand if they were able to connect with the participants, and it was not always possible to provide the researchers with a lot of information about the participants in advance of their presentation. This limited our consideration of the values, attitudes and beliefs that the audience held. Each presenter was asked to think of ways that their work might connect with student audiences. For example, we asked each presenter to provide examples of projects that students could do to address questions similar to those the researchers were investigating. This led to some good interactions between the participants and researchers. Additionally, through the "chat" feature of the webinar, we were able to hear participants' concerns and questions so that the presenters could address these in the question and answer section if not directly in the presentation.

In contrast, the intensive workshop format proved to be a natural place for this to happen, so it was in this format that we saw the most effort to connect learning to personal meaning for participants.

*Efforts to gather assessment and evaluation information to understand if goals were met*

Multiple forms of evaluation and assessment were used including a pre- and post-program survey, focus group, and interviews with the presenters. The results of these assessments and evaluation will be reported in various other outlets. Note that this review of the program design and curriculum in relation to principles identified in the literature is also a part of our evaluation strategy.

*Recognize how "ways of thinking" associated with the dominant Western culture have led to some of our environmental challenges and understand ways to make decisions that better support living in harmony with ecological systems*

The webinar format was less well suited for this specific criterion, but the Life Cycle Assessment presentation did allow participants to explore ways to consider an environmental bottom line in addition to the more traditionally considered economic goals of a project. This framework provides a way of thinking about living more in harmony with ecological systems. The intensive format allowed for more in-depth consideration of the "ways of thinking" of our dominant Western culture and more holistic decision-making. The idea of the "triple bottom line" of economic, social and environmental sustainability is a different way of thinking compared to common business strategies and this case study lent itself particularly well to promoting the consideration of these other lenses.

*Connect these understandings to concepts mandated by the science standards that teachers need to address.*

Finally, we understand that if teachers are going to incorporate this learning and these concepts into their classrooms, we know that it needs to be connected to the Common Core and Next Generation Science Standards. Both workshop formats were designed with these standards in mind.

## Conclusion

We found both formats to be successful in helping to build energy literacy and to effectively address complex environmental challenges. Each approach had some benefits and tradeoffs in comparison to the other, and in comparison to the principles derived from the literature. We would recommend that with either approach efforts are made to connect the content more explicitly to what is happening in participants' own communities, and that more space is provided to consider the individual goals and values of participants. In spite of these limitations, we found both approaches to be valuable for learning and for advancing energy literacy in teachers and in their ability to bring energy literacy to their students.

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