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Energy Sustainability and Engineering Education for K-8 Teachers

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Abstract:

In August 2014, twenty-nine K-8 teachers from eleven Vermont schools engaged in the science, engineering and pedagogical practices of sustainable energy education. This week long workshop was organized by the Vermont Science Initiative (VSI), with an engineering and science instructor each from Norwich University and Lyndon State College respectively, and in partnership with the Vermont Energy Education Program (VEEP).

Teachers defined energy in terms of work, differentiated between transfers and transformations occurring across different energy forms, and gained a deeper conceptual understanding of renewable and nonrenewable energy sources. Opportunities for inquiry ranged from wind turbines, to electrical circuits, to light and Photovoltaic (PV) cells, and an energy bike. These, in combination with scientist meetings and a field trip to a nearby solar PV farm solidified their scientific literacy in the sustainable energy context. The teachers were also led through the Engineering Design Process (EDP) including concepts of design criteria and constraints to learn about sustainably engineering the energy components of systems. Teachers worked in groups to build an Archimedes Screw pump and determined the efficiency of a micro-hydro-generator. By the end of the week, post assessment test results revealed that the teachers had a 37% improvement in understanding various content areas.

By engaging elementary and middle school teachers in fun, hands-on exploration of sustainable energy we hope to bring this form of literacy to our youngest citizens, and future leaders and decision makers. The opportunity to continue engagement throughout the year with three follow-up sessions, and a forum to share the units they developed and best practices through the VT Agency of Education website will serve as a model for other stakeholders interested in implementing a similar program.

Keywords: energy education, sustainability, engineering, K-12, STEM, VSI, VEEP

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Introduction

The American conservation movement of the late eighteenth through early twentieth centuries was comprised of resource efficiency advocates, transcendentalists, and industry groups. It influenced ideas of environmental conservation and protection with a view to promoting social well being while also being mindful of the profit margins for businesses in the United States long before the term “sustainability” was coined (Theis and Tomkin, 2012). The Brundtland Report helped bring back these ideals to the fore, challenging the world to look toward the year 2000 and beyond by identifying and addressing global problems collectively, and by developing “sustainably” (United Nations, 1987).

Hammond (2007) identifies energy systems as being central to the principles of sustainable development. He juxtaposes the ability of energy systems to provide us with warm homes, workplaces, and incredible technological advancements with global environmental and related risks associated with production and consumption of energy. Even as our growing population seeks easily accessible and affordable sources of energy, in the form of energy services (including flows, transfers, and transformations), the impact from such consumption has increased concerns (Haas et. al., 2008). Emission of carbon dioxide and other green house gases as well as excessive water withdrawals and production of hazardous wastes in the production, manufacturing and consumption of electricity and electronic products had led to many debates over the science, policy, and governance of sustainable energy. McCollum et. al., (2011) argue for an integration of air pollution and climate change considerations with any policies related to securing a continuous and safe supply of energy sources to meet our many energy demands. A recognition of the contribution of energy production and use toward increasing greenhouse gases, led the United Nations General Assembly to designate 2012 as the International Year of Sustainability for all (Mohamed, 2014).

In the United States, President Obama’s “All of the Above” energy strategy seeks to make America more energy independent (The White House, 2012). In his State of the Union Address, the President emphasized his commitment to clean energy by doubling the share of electricity from clean energy sources by 2035, among other things. A number of states have already legislated Renewable Portfolio Standards that require 20% of the state electricity generation to be renewable by 2020.

In order to meet these global challenges and answer the calls of the international community leaders, it is imperative that we have a generation that is scientifically literate in issues pertaining to all aspects of energy and well trained in implementing innovative solutions. Batterman et. al. (2011) emphasize the prominent role of energy in sustainable development, highlighting its presence in practically every sector and our increasing dependence on both the renewable and nonrenewable sources of energy. They further go on to evaluate the course offerings related to energy sustainability in over 20 universities and find a lack of comprehensive curricula to train students in higher education programs in this important discipline. Their research led to the development of a model with prioritized competencies of a scaled and cross-disciplinary nature to promote an integrated energy-sustainability education.

Education in the form of both sustainability literacy or energy literacy and ideally both is believed to be the solution that has the potential to create deep and long-lasting change. We believe that core energy sustainability education needs to start much earlier. Programs aimed at educating the general public are resourceful and have varying degrees of success. However, bringing the message to our K-12 classrooms may hold the key to making a real difference. The K-12 classrooms serve as the ideal places to begin engaging young children in discussions, and activities pertaining to energy sustainability.

A number of federal, state, and local agencies support early energy sustainability literacy initiatives. For example, the US Department of Energy's *Energy Literacy: Essential Principles and Fundamental Concepts for Energy Education* provides a framework to assist with the development of curriculum that includes consideration of economic, political, environmental, and societal factors that influence our current and future energy use. The National Energy Education Development (NEED) Project and KidWind offer curricula and materials for purchase that help students investigate renewable energy resources such as hydropower, wind, solar, and biomass. Vermont Energy Education Program (VEEP) provides curricula and week-long training at no cost to Vermont Schools to engage students in understanding how renewable resources can be harnessed to provide energy more sustainably than when using non-renewable fossil fuels.

It is imperative however, that any content delivered to our K-12 audiences, be scientifically sound and mathematically accurate, while being engaging, hands-on and fun at the same time. It's not easy to take a curriculum package and translate that to sound instructional practice in the classroom that meets the needs of all student learners to master the Next Generation Science Standards (NGSS) surrounding the complex topic of energy. This is where the Vermont Science Initiative (VSI) has been instrumental in bringing quality education and training to elementary and middle school teachers in Vermont.

Project background

Vermont Science Initiative

Now in its thirteenth year, the VSI is a grant-funded, statewide system of programs that involves K-8 teachers in training and support that directly impact their content knowledge, their ability to deliver content through sound instructional practices, and their capacity for science leadership. VSI works in partnership with teachers, school administrators, scientists, engineers, and educators at institutions of higher education to produce outstanding science educators through a range of in-depth professional development programs. In the past, VSI featured a master's degree program that graduated four cohorts and now offers intensive professional development programs for in-service teachers.

One such program, the VSI Science and Engineering Academy, is a year-long professional development program targeted for teachers in grades K-8 that features a residential summer institute, follow up sessions during the school year, on-site Professional Learning Community (PLC) sessions, and additional content through the National Science Teacher Association (NSTA) Learning Center. The program is team-taught by an engineering professor, science professor, and pedagogy specialists to help teachers learn science and engineering content and pedagogy by engaging them as adult learners through best practice. The most recent Academy focused on energy and engineering and involved seven early elementary (K-2), ten upper elementary (3-5), and twelve middle school teachers (6-8). As states begin implementing the NGSS, energy is uniquely positioned, appearing as both a disciplinary core idea but also as one of the seven big ideas (crosscutting concepts) that crosses life, earth, and physical science domains throughout K-12.

Next Generation Science Standards

The NGSS have recognized the need for sustainable energy education and developed grade specific standards to promote energy literacy with and without the integration of sustainability. The third physical science standard in NGSS is devoted to energy, including definitions of energy, conservation of energy and energy transfer, the relationship between energy and forces, and energy in chemical processes and everyday life (NGSS Lead States, 2013). Understanding builds from K-12 through instruction that encourages students to investigate increasingly complex core ideas using the practices that scientists and engineers use to learn about unknown phenomena and design solutions to human needs. Table 1 outlines a sample progression of NGSS core ideas about energy and natural resources.

Table 1. Sample NGSS Progression of Core Ideas About Energy and Natural Resources

	K – 2nd Grade	**3rd-5th Grade**	**6th-8th Grade**
PS3.A Definitions of Energy **PS3.B Conservation of Energy and Energy Transfer**	N/A	Energy can be moved from place to place by moving objects or through sound, light, or electrical currents. Energy can be converted from one form to another.	Kinetic energy can be distinguished from the various forms of potential energy. Energy changes to and from each type can be tracked through physical or chemical interactions.
ESS3.A Natural Resources	Humans use natural resources for everything they do.	Energy and fuel that humans use are derived from natural resources and their use affects the environment. Some resources are renewable over time. Others are not.	Humans depend on earth's land, ocean, atmosphere and biosphere, many of which are limited or not renewable. Resources are distributed unevenly around the planet as a result of past geologic processes.

More specifically, one fourth grade energy performance expectation in NGSS, 4-PS3-4, states that, after instruction, students who demonstrate understanding can apply scientific ideas to design, test, and refine a device that converts energy from one form to another. When NGSS is enacted in the classroom, through quality instruction, students build knowledge of disciplinary core ideas and crosscutting concepts of 4-PS3 through engaging in the science and engineering practices outlined below to meet the performance expectations of 4-PS3: Energy (Text Box 1).

Text Box 1. Sample of NGSS Addressed in the Institute (4-PS3)

Disciplinary Core Ideas:

PS3.A Definitions of Energy

- Energy can be moved from place to place by moving objects or through sound, light or electrical currents.

PS3.B Conservation of Energy and Energy Transfer

- Energy is present whenever there are moving objects, sound, light, or heat. When objects collide, energy can be transferred from one object to another, thereby changing their motion. In such collisions, some energy is typically also transferred to the surrounding air; as a result, the air gets heated and sound is produced.
- Light also transfers energy from place to place.
- Energy can also be transferred from place to place by electrical currents, which can then be used locally to produce motion, sound, heat, or light. The currents may have been produced to begin with by transforming the energy of motion into electrical energy.

PS3.D Energy in Chemical Processes and Everyday Life

- The expression "produce energy" typically refers to the conversion of stored energy into a desirable form for practical use.

Crosscutting Concept

Energy and Matter

- Energy can be transferred in various ways and between objects.

Science and Engineering Practices

- Asking Questions (for science) and Defining Problems (for engineering)
- Developing and Using Models
- Planning and Carrying Out Investigations
- Analyzing and Interpreting Data
- Using Mathematics and Computational Thinking
- Constructing Explanations (for science) and Designing Solutions (for engineering)
- Engaging in Argument from Evidence
- Obtaining, Evaluating, and Communicating Information

As this fourth-grade NGSS performance expectation demonstrates, the NGSS emphasizes an integration of the engineering design process and problem solving pedagogies as the standards are being taught and practiced across states. In grades 3-5, for example, NGSS states "engineering design engages students in more formalized problem solving. Students define a problem using criteria for success and constraints or limits of possible solutions. Students research and consider multiple possible solutions to a given problem. Generating and testing solutions also becomes more rigorous as students learn to optimize solutions by revising them several times to obtain the best possible design." (NGSS Lead States, 2013).

Approach and Methodology

The overarching question "How do we sustainably capture, store, and use energy from renewable resources?" was used to focus the content of the Academy. This was designed to help deepen teacher understanding of how energy is transferred and transformed in systems as well as tackle engineering design challenges that use renewable energy resources to solve human problems. The participants experienced first-hand how energy moves through systems and how the Engineering Design Process (EDP) works in the classroom. Teachers then developed a related engineering design task and science unit for implementation in their own classrooms.

For this energy engineering academy, VSI partnered with the Vermont Energy Education Program (VEEP), a non-profit organization that helps K-12 students and teachers understand energy and make energy choices that result in a sustainable and vital economy. VEEP has created inquiry- and engineering-focused energy activities and loans their materials and educators to schools throughout Vermont. The partnership between VSI and VEEP helped provide content and related curricular materials that could be brought back to participating teachers' classrooms after the summer training.

Pre-planning

As seen in Figure 1, the Academy had three central goals to help the team plan the content: increase content understanding related to energy; increase understanding of the engineering design process; and improve pedagogical practice. The team worked to plan the summer institute and refine the goals to allow for in-depth investigation of a limited amount of concepts that was delivered by modeling the best instructional practices we hoped to foster. As a result, with our overarching question in mind, additional essential questions were developed to guide the summer institute:

- How is energy transferred, transformed, and conserved?
- How do engineers solve problems?
- How do science, engineering, and the technologies that result from them, affect the ways in which people live?
- How do we engage students in the practices of science and engineering in order to make meaning of the natural and human-made world?
- What does engineering look like in a K-8 science classroom?

Figure 1. Central Goals of the VSI 2014 Science and Engineering Academy on Sustainable Energy

Workshop Structure:

The Institute provided opportunities to identify energy transfers and transformations within systems such as wind turbines and PV cells through activities such as an interactive "inquiry circus" (Text Box 2), an introduction to some energy basics, and exploring PV systems as a vehicle for exploring how electricity is generated, properties of waves and light, and how we can capture, store and use energy from the sun.

Text Box 2: Pedagogical Models

Inquiry "Circus" - Teachers are provided with materials, and suggestions for activity around a particular concept and focus question, working at their own pace to gather evidence. For example, one inquiry circus asked participants to engage with a variety of systems (e.g. wind turbine, solar PV, etc.) and identify how energy is transferred and transformed in each system. Another asked participants to gather evidence about the properties of light.
Whole group discussions - Teachers engaged in several "scientist meetings" where they were encouraged to make meaning by discussing as a group, with the instructors acting as facilitators.
Writing to make meaning - Teachers used ideas from the discussion and direct instruction to write scientific conclusions and explored how to scaffold the process with students.
Anchoring Event - A complex phenomena is presented and participants are asked to create an initial explanation, which is revisited after instruction (Windschitl, 2013).

Participants were introduced to the EDP in the context of energy and renewable and nonrenewable sources of energy beginning with wind energy. Teachers then engaged in the engineering design process related to pumps and the movement of water, which ultimately led to a micro-hydro-generator design challenge designed to maximize the power output. Whole group discussions, writing to make meaning, and model based inquiry were modeled and utilized throughout the institute (Text Box 2). Throughout the week, participants received support in identifying a standards based, grade appropriate science and engineering unit where the ideas from the week could be applied. Each of the seventeen units developed include an energy related engineering design task and outline the science and engineering lessons that will scaffold the task.

The Engineering Component

The engineering content of the workshop was broadly divided into the following components:

1. An introduction to technology

A classic Engineering is Elementary (EiE) "tech in a bag" exercise was included early on to dispel any misconceptions that technology is limited to the electric and electronic devices alone (Museum of Science, 2008).

2. An introduction to the EDP

This session defined engineering, differentiated between the work of scientists and engineers and allowed groups to come up with their own version of an EDP. Other EDP visuals were shared, as well as video clips that emphasized the steps in the process. An evening session deepened this concept, by allowing teachers to work on an activity from the Museum of Science, Boston's Engineering is Elementary (EiE) module on windmills. The activity had participants go through each step of the EDP (see Figure 2 for the museum's version of the EDP) in words and action by imagining their designs, testing materials, experimenting with various configurations based on these tests, and assessing their designs to improve and iterate the process, until the objective was met.

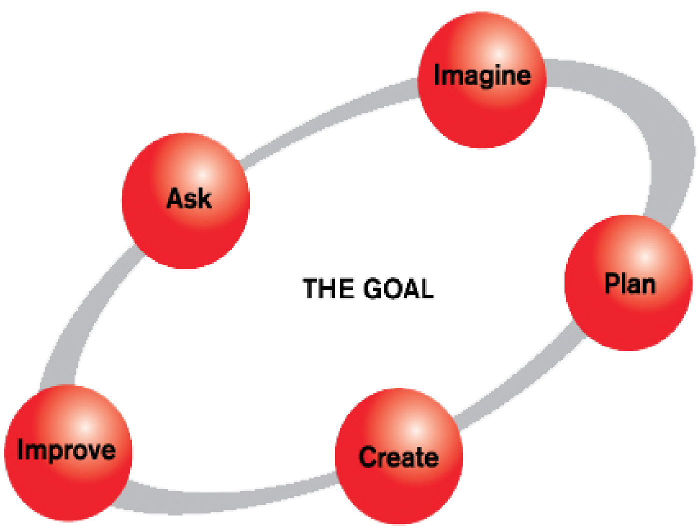

Figure 2. Engineering Design Process (EDP) from the Museum of Science, Boston

3. A review of the renewable and nonrenewable sources from an engineering and sustainability perspective.

After an initial explanation of the differences between the renewable and nonrenewable energy sources, participants were each handed the name of an energy source, which they classified into the two categories, and discussed the engineering involved in using these energy sources to produce electricity. These sources ranged from oil, coal, and natural gas, to solar, wind, biomass, and hydraulic fracturing. The discussions also included some of the controversies that challenge the sustainability of some of these energy sources.

4. An introduction to pumps and turbines as critical engineering components of most energy systems

This was done with a hands-on activity, in which participants built an Archimedes screw. A very simple set up requiring only a section of a two-inch PVC pipe and a stretch of clear rubber tubing, and tape were used to build the pump. The activity was set up as an engineering design mini-challenge, where PVC sections of different lengths were offered, and participants had to build the pump to produce a specific flow rate.

5. *A hands on activity to design and engineer a micro-hydro-generator, with a view to understand energy efficiency and losses.*

This was a more involved engineering design challenge, where water from a bucket at a certain height (head) was sprayed on a turbine (provided by VEEP) using a hose and nozzle and used to generate electricity. Participants had to design the turbine blades to produce the highest efficiency. All calculations relating to potential and kinetic energy were discussed, along with conversions from one energy form to another, and among units, along with discussions on the losses involved (and hence energy conservation).

Photograph 1. Building an Archimedes Screw pump

The Science Component

The science component of the workshop focused on definitions of energy and the energy transfers and transformations involved in generating electricity using renewable and non-renewable resources. We also considered the ways we then transform electricity into other forms to power our homes and offices. Throughout, we considered ways that we could generate the electricity we need, most sustainably and locally, reduce our use, and use electricity more efficiently.

1. Energy Overview

To begin, participants learned through direct instruction that, simply put, energy is the ability to do work and that all of the potential energy that exists in our world originates from just three unseen fields -- gravitational fields, electromagnetic fields, and the strong and weak forces within the nucleus of an atom. Through modeling, participants explored transfers and transformations of energy from potential to kinetic with electricity as the central focus. They also learned that efficiency involves doing the same amount of work with less energy input.

2. Basic Electric Circuitry

Participants created and tested circuits with simple materials and used multimeters to measure current and voltage within the circuits and explore how to increase these measurements. They then replaced all batteries (potential chemical energy source) with small photovoltaic cells, to convert renewable sunlight (electromagnetic radiation) into electrical energy. Using large LED lamps and taking their circuits outside into the sun, participants experimented to determine the many factors that affected the PV panel's voltage output including angle of incident light, distance from the light source, and percentage of panel exposed to incoming radiation. Some of the participants also replaced the battery with desktop wind generators and explored factors that affect voltage output. Using fans to simulate wind, and a variable number of turbine blades whose angles could be adjusted, participants tinkered with altering the wind generator set up and gathered data, constructing arguments to support claims based on the evidence they gathered about factors that affect electrical outputs using wind generators.

3. Tracing Energy Transformations: Energy Chains

Throughout the above explorations, instructors and participants traced energy transformations that led up to the flow of electricity in wires within generators. We emphasized how dependent we are on electricity in our designed world because our society has benefitted from the fact that it can be transferred long distances and transformed to perform many different types of work, including heat, light, sound, and movement. For example, burning of fossil fuels (chemical potential energy) in a far-away state to generate steam (which possesses thermal energy and under pressure) to turn a turbine (mechanical energy) that generates electricity that can then be transferred long distances and transformed to do everyday household work such as lighting and heating our homes and cooking our food. This long energy chain begins with a non-renewable resource and a great deal of energy is transformed to unused forms along the way (heat, sound, etc.). We touched on ways to more locally or sustainably create the electricity we use through renewable resources as we traced the energy transformations that occur using solar cells as well as those taking place using wind generators.

4. Understanding more localized production of electricity through photovoltaics

Through direct instruction and modeling, participants learned that sunlight is composed of waves of electromagnetic radiation that have both wave and particle-like properties. Teachers learned how PV cells work and created models of PV cells, which they then applied to their growing knowledge of how solar panels can be arranged to function most optimally to power a home. Following this, participants went up close to a grid-tied photovoltaic array to learn about how solar cells are combined to generate adequate voltage and current to power homes.

The culminating engineering activity, designing a micro-hydro-generator, described above, provided a rich opportunity to tie together science concepts built through the workshop.

Results

All participants in the workshop took a pre-assessment test on the first day of the workshop. They answered 11 questions and took a few minutes to discuss these questions in small groups, after turning in their tests, with no input from any of the instructors. These questions ranged from general engineering design process, modeling, and technology related questions to the energy specific questions on defining energy, differentiating between transfers and transformations of energy, explaining energy conservation and light properties and their role in solar panels.

Later, on the last day of the workshop, all participants also completed a post-assessment test. The results of these tests are shown below. As seen in Figure 3, participants were already comfortable differentiating between the roles of scientists and engineers and there was only an 18% improvement in the pre and post results on this question. There was however, a marked improvement in the understanding of an EDP as an iterative approach that seeks continual improvement based on researching, testing, and implementing sound scientific principles, rather than a trial and error method. There was also a 48% improvement in participant understanding of the criteria and constraints in an engineering design task. These were emphasized in multiple activities throughout the workshop, including the EiE windmills activity, the mini-engineering design challenge of building an Archimedes Screw and the bigger challenge of iterative design to improve the efficiency of a micro hydro generator.

Participants also developed a deeper understanding of energy as the ability to do work (53% improvement). Answers relating to energy transformations progressed beyond providing examples to a clearer articulation of why, when, and how such transformations occur (43% improvement). There was also a greatly improved appreciation for light energy and its role in solar panels. Most people already knew that light is a form of energy. 44% of participants showed some increased awareness of either the photon or electromagnetic wave pictures of light, but only a few mentioned both, and some others showed no improvement.

With regards to PV panels, some participants showed marked improvement (50%) in understanding that only shorter wavelengths of sunlight can be converted. Some people showed no improvement, while others described something more general about how solar panels worked.

The 44% and 50% improvement in these responses reflect the numerous activities and discussions that continued throughout the week, through the inquiry circus, scientist meeting, hands on material testing, and visit to a PV array on campus, all which helped participants continue to engage in asking and answering questions.

A number of participants used the more common interpretation of energy conservation as “saving electricity” by turning off lights when not in use, or using less energy, to answer the question on conservation of energy. This view held in the post assessment (20% improvement) in some cases despite an emphasis on the scientific idea of energy conservation. A few participants were able to articulate this, but this has been tagged as an area for greater emphasis in future offerings of this curriculum or during follow up sessions.

In addition, informal feedback was sought from participants toward the middle of the workshop period, where they wrote a few short sentences on their experience so far in the workshop, indicating what they had gained so far, and included their suggestions for improvement. This was instrumental for informing changes as we continued with the workshop to address specific concerns and reinforce missed concepts.

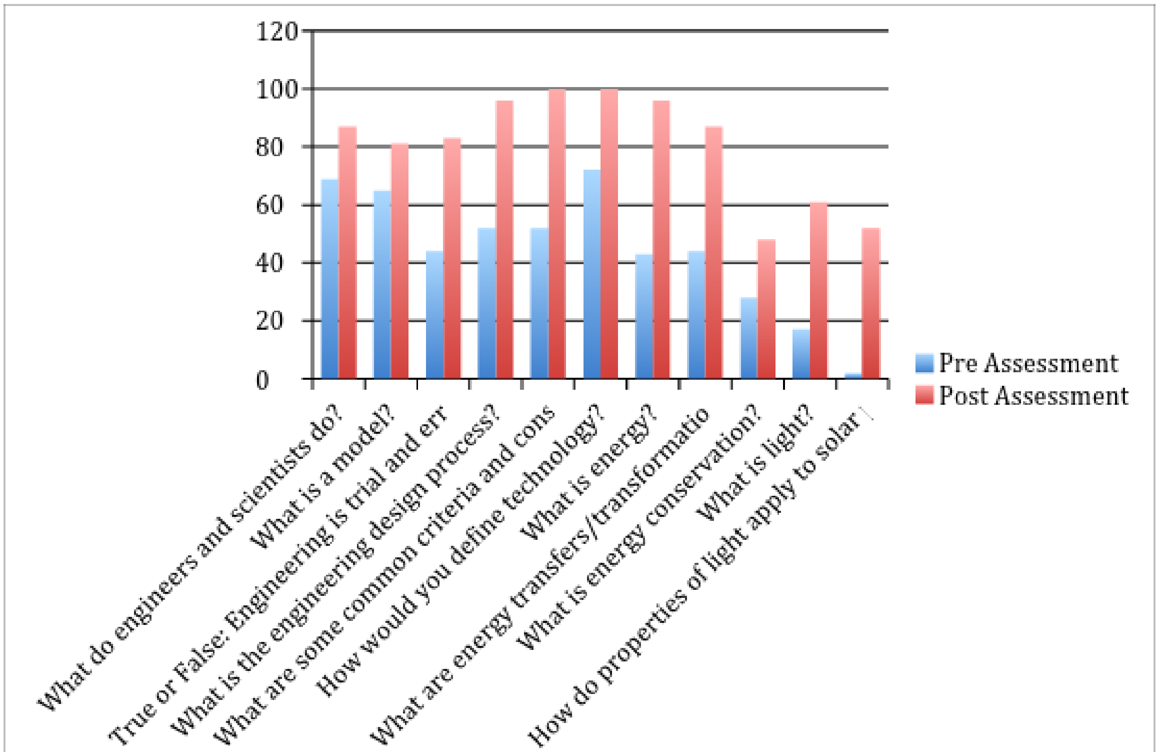

Figure 3. Pre and post assessment test results from the workshop (in percentage).

Discussion

Overall the pre-assessment grade totaled 44%, indicating that participants as a whole, answered 44% of the eleven questions correctly. The post assessment results were at 81%, indicating that the responses had improved by 37% . As teachers develop their units and delve deeper into the content, and as more of their questions are answered during follow up sessions, we hope to see the improvement percentages increase even more.

In addition to the pre and post assessment responses, based on informal feedback from participants (open ended feedback forms completed by participants), conversations with participants between sessions, and at lunch, as well as our own observations as instructors, we noted that despite the range of grade levels represented in the workshop, all teachers were committed to learn as much as they could and bring that knowledge in bite sized pieces to their classrooms. There was an initial sense of being overwhelmed by some of the technical content. However, as theory gave way to experiments, design, and building, and as they engaged through questions and discussions, most participants were able to see how everything fit in a pedagogical framework, propped by the relevant NGSS.

In each session, in addition to the opportunity for participants to ask questions, the instructor team sought specific feedback on that lesson or the workshop so far from the participants. This resulted in additional insights such as the fact that the, early elementary teachers did not feel the necessity to learn about the nuances of efficiency calculations or the more elaborate units and conversions. They did however appreciate discussions involving scaling down or modifying the theory and activities for their classrooms. Moreover, middle school teachers were especially encouraged by the additional tools this workshop offered, to help them teach the complex subject of sustainable energy. Teachers frequently reiterated that the integration of science, math, reading, and writing using the various experimental resources from the inquiry circus, EiE kits, engineering design challenges, physical and virtual tours of related technologies, and pedagogies modeled allowed for a tremendous increase in confidence in teaching this content in a fun and engaging manner. There was a strong consensus, based on discussions within sessions that different participants could use one or more pieces of the variety of activities presented throughout the workshop for their individual classroom and grade level needs.

Instructors reinforced the idea that the theoretical content was designed to deepen the teachers' own understanding as adult learners beyond the level of concepts they had to teach their students. This content along with the featured inquiry investigations and pedagogical practices served as tools to help them develop their units on sustainable energy. The correlation to the NGSS throughout the week's activities was intended to help arm teachers with the resources they needed to have a classroom ready unit. The deeper conceptual understanding of the different forms of energy, transfers and transformations, and conservation, with a view to sustainably managing our energy resources, was designed to add to their comfort in teaching and answering questions related to sustainable energy, including the numbers and the controversies.

Conclusion

Broad concepts of energy within the context of sustainability are identified as key components of science instruction in the NGSS. K-12 classrooms serve as the ideal places to begin engaging young children in discussions and activities pertaining to energy sustainability. This requires teachers who possess strong content knowledge and effective instructional practices. Engineering design, which is new to many teachers, lends itself to these energy concepts and provides a perfect place for students to apply their understanding to something real and connected to their everyday lives. However, teachers need support in translating these ideas back to their classrooms across the grade levels. It is our hope that programs like the Science and Engineering Academy will provide the in-depth support, connections to experts, and resources that can directly impact student learning. The year-long nature of the program will allow us to support and follow participants as they implement their energy units. Having access to the engineering and science professors as well as on-going pedagogical support will hopefully result in greater fidelity of implementation.

As our participants build their engineering (and science) units and these become available on the Vermont Agency of Education website, the core content and its many applications at various grade levels will be accessible for all teachers to use and improve. This workshop has multiple aspects that should be of interest to teachers and program administrators across the nation. First, the core science and engineering content was developed by university level academics, to be scientifically sound, and mathematically accurate, while also offering sufficient flexibility to be accessible to a range of K-8 teachers and their students. The pedagogical team went to great lengths to design the entire workshop curriculum to be a reflection of the NGSS requirements and practices. The partnership with VEEP offered an opportunity to add greatly to the initial smaller set of hands on activities and experiments. The integration of resources such as the EiE kits and requiring teacher participants to upload their units to the Agency of Education website, continued with the theme of ensuring that the workshop content could be accessible for any teacher who is interested in developing and implementing similar units, anywhere in the country or abroad.

As teachers across grade levels use the uploaded units and modify them for use in their classrooms, the core curriculum should find applications across grade levels. For example, early elementary students could work to understand the idea that sunlight warms the earth through investigations and an engineering design challenge of creating a shade structure to prevent a water bottle from getting hot in the sun. This idea of solar energy can be extended in the upper grades to include properties of light, heat transfer, and how solar energy can be transferred and transformed leading to engineering design challenges such as creating a solar collector or solar cooker. The overall model structure of instructor team pre-planning, a week long residential style workshop, and multiple follow-up sessions through the school year, should also work well for a high school only or K-12 audience, or any combination thereof. The content itself may vary accordingly, but the format should easily be scaled to other grade levels. Given the complex nature of the topic of energy, its sources, inter-relationships, societal consequences, and sustainability related concerns, we strongly recommend a workshop that is at least a week long to cover as much of the core content as possible.

As programs like these are made available to a larger audience and multiple schools in a myriad of states are able to bring energy education into as many classrooms as possible, the potential for deeper and long-lasting change will become more evident. As teachers implement their lesson plans, and an increasing generation of students starting right from elementary grade levels apply their lessons, our collective journey toward better energy literacy and a sustainable form of energy independence is achievable.

We envision students in these classrooms bringing their lessons into their homes and communities, presenting their evolved ideas at science fairs and debate competitions, and integrating their learning into art, music, and theatre to create a domino effect of sustainable energy literacy.

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