Energy Inquiry: Hands-on, Inquiry Learning Methods to Enhance STEM Learning by Engaging Students in Renewable Energy Solutions (Research to Practice)

Leslie Wilkins, Maui Economic Development Board

Leslie Wilkins has served as the Vice President of the Maui Economic Development Board since 1999. She was hired to design, launch and direct the Women in Technology Project with a mission to engage girls/women and underrepresented populations into the Science, Technology, Engineering and Math (STEM) pipeline. In its 13th year, the program serves annually more than 14,000 students, educators and industry members throughout the state of Hawaii from elementary school to job placement.

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Graham DeVey is a Project Manager with the Maui Economic Development Board’s Women in Technology Program. He directs the statewide program Island Energy Inquiry™, a place-based, inquiry learning curriculum for STEM teachers in grades 5-12. He holds a Master of Arts in Teaching degree (Physics) and a Bachelor of Science in Mechanical Engineering and Aeronautical Science, with 18 years of experience in engineering management and 19 years as an educator, curriculum developer, and professional development specialist.
K-12 engineering education in the United States faces various challenges, from a seeming lack of interest in the field within American students to ongoing uncertainty among educators regarding how to develop and implement relevant curriculum standards. Despite these existing obstacles, Island Energy Inquiry™ (IEI), in existence since 2009, has introduced engineering concepts to more than 286 elementary, middle, and high school teachers and over 45,000 students across the state of Hawaii through a specially designed ad hoc science, technology, engineering, and math (STEM) integration approach as termed in The Status and Nature of K-12 Engineering Education in the United States. IEI is a place-based, culturally competent Professional Development (PD) program that educates K-12 teachers and their students on renewable energy solutions—a highly relevant issue in the state—and builds STEM skills and methods through student-focused inquiry learning.

Current uncertainties of K-12 engineering education in the United States

STEM education and technological literacy are fundamental in the digital era. In recent years, educators and policy makers have reached a consensus that the teaching of STEM subjects in U.S. schools must be improved. The focus on STEM topics is closely related to concerns about U.S. competitiveness in the global economy and about the development of a workforce with the knowledge and skills to address technical and technological issues. Several national trends are driving the advancement of engineering education within the United States. These trends include a declining interest among U.S.-born students in engineering, a decrease in national achievement in mathematics and sciences at pre-college levels, and a lack of technological literacy for all Americans. There are also predictions that there will not be a younger generation of U.S. citizens ready to replace science and engineering professionals nearing retirement age within the U.S. government. In addition, students who do pursue engineering degrees do not reflect the diversity of students in the United States, a pattern of enrollment that is likely to have a number of negative consequences, both for the successful practice of engineering and for the resolution of broader societal issues. Concerns about the lack of engineering exposure for all children and ensuring a larger, more reliable supply of future engineers have been accompanied by the realization that we have not yet determined the best way to inform children of engineering skills and concepts.

There is also continued debate on whether national standards should be developed and implemented for K-12 engineering education. A 2010 report by the National Academy of Sciences Committee on Standards for K-12 Engineering Education concluded that “...Although it is theoretically possible to develop standards for K-12 engineering education, it would be extremely difficult to ensure their usefulness and effective implementation.” Alternately, several
states currently implement their own standards for K-12 engineering education. More states are expressing interest in this approach.\textsuperscript{5}

United States educators at the classroom level also have mixed opinions regarding the status and potential of engineering education. A 2004 analysis by the ASEE Engineering K12 Center found that “…Overall, K-12 teachers have a positive attitude toward engineering.”\textsuperscript{6} However, when asked “How many of your students could succeed as engineers?” only 2.9\% of responding teachers replied “all.” As stated in the analysis, “Teachers are overwhelmingly positive about engineering in the abstract, extolling the virtues of an engineering education and career. However, when it comes down to their students, they believe that many—and especially females and minorities—cannot succeed in the engineering world.”\textsuperscript{6} Considering that female and minority groups will be dominating the U.S. workforce in the near-future,\textsuperscript{3} this is a concerning attitude for educators to possess.

Despite the potential shortages in the future U.S. engineering workforce, lack of consensus regarding standards, and disparate attitudes held by educators about engineering education, there are a growing number of programs across the United States that incorporate engineering education into the classroom. Although these programs vary in their approach and context, they are making much-needed attempts to integrate essential engineering concepts in K-12 education. IEI falls within this cadre, providing a contextual foundation that innately connects engineering design to STEM activities by focusing on clean energy solutions, a topic that is highly relevant to the state of Hawaii and of interest to its students.

Responding to clean energy needs and regional workforce demands

Hawaii is more dependent than any other state in the nation on the importation of fossil fuel, currently importing 90\% of its energy. Energy sustainability for this remote island chain will require reducing reliance on imported fossil fuels and a significant increase in reliance on renewable energy sources in the islands, such as wind, solar, geothermal, and wave energy.\textsuperscript{7} In 2008, Hawaii made a public commitment to achieve 70\% clean energy by 2030. An estimated thirty percent of this increase is expected to result from increases in energy efficiency. Hawaii’s clean energy target is one of the most ambitious in the nation, and, if achieved, could serve as an example for the United States and the world.\textsuperscript{8}

In order to meet the need for a talented clean energy workforce in Hawaii, local students must pursue educational and career pathways in the high-growth, high-paying STEM sector. Over the past 10 years, growth in STEM jobs [in the United States] was three times as fast as growth in non-STEM jobs.\textsuperscript{9} STEM employment is expected to grow 17\% between 2008 and 2018, outpacing the 10\% growth projected for overall employment.\textsuperscript{9} Also, the average annual wage for all STEM occupations was $77,880 in May 2009, significantly above the U.S. average of $43,460 for non-STEM occupations.\textsuperscript{9} In the United States demand for STEM workers is unmet. In the STEM occupations, job postings outnumbered unemployed people by 1.9 to one.\textsuperscript{9} These national workforce trends are also reflected in Hawaii, where projections indicate that there will be 29,000 STEM-related jobs to be filled by 2018.\textsuperscript{10}

Despite the high demand for STEM workers and the incentive of well-paying careers, the United States still struggles to sufficiently educate its students in these fields. Only one in five STEM college students felt that their K-12 education prepared them extremely well for their
college courses in STEM. Fewer than 40 percent of students who enter college intending to major in a STEM field complete a STEM degree. A persistent gap continues between women and men pursuing STEM education and careers. A National Science Foundation survey found that in 2006, 15.1% of American female first-year college students majored in the STEM field, versus 29.3% of American male first year college students. The gender disparity in plans to major is even more significant when the biological sciences are not included. Just over one-fifth of male freshmen planned to major in engineering, computer science, or the physical sciences, compared to only about 5% of female freshmen. However, there is hope to improve the numbers of females and underrepresented minorities in STEM fields, including engineering. Researchers believe that engaging, context-based engineering activities at the K-12 level could significantly increase the diversity of students who participate in STEM classes and ultimately pursue careers in these areas. IEI uses inquiry methodology, applicable examples of engineering in industry, and inclusive kinesthetic activities to encourage students of all backgrounds to engage in engineering and experience its connections to STEM learning.

Island Energy Inquiry model: Renewable energy education via inquiry and design-based learning

Although there is a number of natural connections between engineering and other STEM subjects, existing curricula in K-12 engineering education do not fully explore them. Building an education-to-workforce technical skills pipeline is critical to attaining clean energy goals both in Hawaii and the Asia Pacific region. The need for a regional renewable energy workforce with appropriate STEM skills presents a unique opportunity. IEI begins the process of preparing a local workforce that is knowledgeable in clean energy issues as well as STEM concepts through PD coursework that:

1. Utilizes inquiry learning to interest students in STEM.
2. Provides teachers with information on renewable energy progress in Hawaii.

IEI is a product of the Women in Technology Project (WIT), a workforce development program under the auspices of the Maui Economic Development Board. WIT has been building education programs in STEM for K-12 schools statewide for over ten years. In particular, WIT builds programs to engage underrepresented populations in STEM fields, including girls, women, and indigenous populations seeking to increase equity for all. IEI grew out of an annual Inquiry Science PD event for middle and high school science teachers. Recognizing the need for developing skills in energy science and connected STEM concepts, WIT developed the state’s first renewable energy PD model which was initially piloted on Maui and then soon expanded to reach teachers statewide.

The IEI model addresses the issue of the shrinking United States engineering workforce through the following elements:

1. Highlights the three guiding principles of K-12 engineering education.
2. Implements ad hoc and STEM integration approaches through flexible curriculum.
3. Builds engineering education competence and shifts attitudes regarding STEM in teachers through professional development workshops, evaluation, reflection, resources, and ongoing program support.
4. Increases STEM interest among females and underrepresented minorities through place-based application and local industry partnerships.
1. \textit{Highlights the three guiding principles of K-12 engineering education:}^{4}

\textbf{A. Emphasizes engineering design.}

The engineering design process should be highly iterative and open-ended: promoting recognition that a problem may have many possible solutions; providing a meaningful context for learning scientific, mathematical, and technological concepts; and serving as a stimulus to systems thinking, modeling, and analysis.\textsuperscript{4} An example within IEI’s state-wide implementation illustrates the emphasis of engineering design in a unique environment—art class. Studio art teacher Janice Miyoshi-Vitarelli of Kalani High School on Oahu introduced the project “Celebrating Wind Energy,” directly based on IEI lesson 8.4, “Wind Turbine Design Inquiry.”\textsuperscript{13} The goal of her project was to combine art and science in project-based learning. Although part of an art class, Miyoshi-Vitarelli’s lesson was a clear example of engineering design and problem-solving methods.

In this instance, students were challenged to design, test, and redesign wind turbine blades, defining variables and measuring performance. Their goal was to optimize performance through design iterations, creating “functional design that adds beauty,” and basing form on the function of the blades themselves. Students were also required to model their design in stages, first sketching the blades and doing a design review with the teacher before earning approval for the next steps—sketching onto balsa, cutting and prepping unpainted blades, testing, modifying, and finally painting blades. This adheres closely to the guidelines of the Next Generation Science Standards (NGSS) Appendix F, Science and Engineering Practices in the NGSS:

“In engineering, models may be used to analyze a system to see where or under what conditions flaws might develop, or to test possible solutions to a problem. Models can also be used to visualize and refine a design, to communicate a design’s features to others, and as prototypes for testing design performance.” Practice 2: Developing and Using Models.\textsuperscript{14}

This example also addresses NGSS standard ETS1C: Optimizing the design solution.\textsuperscript{15} In “Celebrating Wind Energy,” the teacher notes that the design, test, and redesign phase of the project enhanced the critical thinking and problem solving skills of her students. She also points out that following the design process empowered students as self-directed learners. And, at the project’s conclusion, students were asked to reflect on their learning, to analyze their results and draw meaningful conclusions—individually and as part of two-person design teams.

\textbf{B. Incorporates important and developmentally appropriate mathematics, science, and technology knowledge and skills.}

Some science concepts, and some methods of scientific inquiry, can support the engineering design process. Some mathematical concepts and computational methods can also support engineering design, especially in the areas of analysis and modeling. Technology and technology concepts can illustrate the outcomes of engineering design, provide opportunities for “reverse engineering,” and encourage the consideration of social, environmental, and other impacts of engineering design decisions.\textsuperscript{4} IEI teachers and their students are trained to use tablet technology to enhance their STEM knowledge and skills with the Hawaii Clean Energy iPad App, which was developed as part of the program. Students model a series of renewable energies including wind, solar, geothermal, biomass, and hydroelectric. In each model there are more than
one variable. For example, the wind farm activity enables the user to select number of turbines, individual turbine rated size, or wind speed to explore the system output in megawatts of electric power. Students are first challenged to ask questions, such as “What’s happened to output at low wind speeds?” or, “Is it ‘better’ to have more turbines, or larger turbines?” The app can be manipulated to explore these and other questions in maximizing and optimizing wind farm design.

Using iPads to explore engineering questions through Clean Energy App simulations appeals to modern students. With basic guidance from their teacher, students can soon find the value—and absolute importance—of selecting a single independent variable at a time in the quest to best develop a solution to their problem. This combination of rigor and discipline within a largely self-taught and self-directed simulation model is critical in helping students recognize the paths that engineers follow in pursuing the answers to infrastructural, environmental, and societal problems.

C. Promotes engineering habits of mind.

Inquiry science, as adapted by IEI and WIT, pursues the following process:

1. Has or obtains background information
2. States a problem and/or asks a question
3. Develops a testable hypothesis
4. Develops methods to test (establishes variables) and then tests
5. Analyzes results and makes conclusions

These five steps follow a cyclical pattern as new questions arise from conducted experiments. IEI’s inquiry process gives rise to engineering “habits of mind,” which include systems thinking, creativity, optimism, collaboration, communication, and ethical considerations.

An example of this approach is IEI lesson 5.3, Solar Hot Water Heating. In this activity, students are challenged to optimize a heat exchanger design, using solar energy to heat water. They coil a fixed length of clear plastic tubing within a black frame which has a single transparent surface. The pattern for tubing layout is left completely to the student team. During the first lab session, the exchanger is prepared and then connected to a small electric water pump which is itself driven by a photovoltaic panel. This gives students an opportunity to be sure their system is working and to make preliminary observations of the water heating effect.

As the initial system is observed and proven to be functional, student groups are asked to discuss possible variables affecting performance, and select a variable to test during the follow-on lab the next day. This team discussion is critical in understanding how engineers really develop their own investigations. From NGSS Appendix F - Science and Engineering Practices in the NGSS:

“In laboratory experiments, students are expected to decide which variables should be treated as results or outputs, which should be treated as inputs and intentionally varied from trial to trial, and which should be controlled, or kept the same across trials. In the case of field observations, planning involves deciding how to collect different samples of data under different
conditions, even though not all conditions are under the direct control of the investigator. Planning and carrying out investigations may include elements of all of the other practices.”

Practice 3, Planning and Carrying Out Investigations.¹⁴

It is not enough that students merely know their solar hot water system works, although that is certainly important. They learn how the sun is heating water by providing energy to the photovoltaic panel, thereby powering the water pump electrically. But the true significance of this entire lab—the engineering practice they use and reinforce—is the ability to identify and control variables in a way that maximizes the effectiveness of their mechanical and thermodynamic system. It is these practices, skills, and abilities, developed under the teacher’s watchful eye, that help prepare our students for meaningful STEM careers. Inquiry learning goes beyond the transfer of scientific or engineering information and knowledge by empowering students to develop their own confidence in using the methods of working professionals.

2. Implements ad hoc and STEM integration approaches through flexible curriculum.¹

As termed in The Status and Nature of K-12 Engineering Education in the United States, ad hoc infusion, or introduction, of engineering ideas and activities (i.e., design projects) into existing science, mathematics, and technology curricula is the most direct and least complicated option [for engineering education], because implementation requires no significant changes in school structure. The ad hoc option is probably most useful for providing an introductory exposure to engineering ideas rather than a deep understanding of engineering principles and skills.¹ IEI closely aligns with the ad hoc approach because of its concept introduction to teachers who have little or no previous exposure to engineering education. On a smaller scale, IEI follows the STEM education integration approach, using engineering concepts and skills to leverage the natural connections between STEM subjects¹ through its scientific inquiry foundation and connections to multiple facets of STEM. IEI promotes the scientific inquiry process throughout its curriculum, gives teachers and students the opportunity to simulate various clean energy systems and hone their technology skills with the Clean Energy iPad App, utilizes engineering design concepts by building different clean energy apparatuses, and prompts students to use mathematical formulas to calculate data they collect in experiments. IEI only serves a minor role in this overall approach, however, because its intensive implementation, which includes “changes in school structures and practices”¹ is beyond the scope of the program.

The IEI curriculum is a vehicle for teachers across the state to teach students STEM concepts while incorporating highly relevant information about renewable energy data, design, and resources. It maintains a place-based foundation, providing examples that are relevant to Hawaii’s geography, climate, and culture. IEI encourages students to use critical thinking skills to solve problems, to ask relevant questions about the subject matter they are learning, and to successfully apply theoretical concepts to real-world challenges through hands-on educational activities.

IEI educators play a key role in facilitating the curriculum’s inquiry process, guiding students through its steps and supporting classroom discussions that occur. It has been found that the IEI curriculum allows flexible modification and implementation for participating teachers from a variety of backgrounds. Teachers not only come from STEM subject areas, but also language arts, fine art, social studies, and career and technical education.
3. Builds engineering education competence and shifts attitudes regarding STEM in teachers through professional development workshops, evaluation, reflection, resources, and ongoing program support. The delivery of IEI extends beyond the experience of the training workshop itself. To earn credit as an implementer, each teacher must reflect on lessons learned in the classroom and share with peers. Some teachers report that this is the most valuable step in learning to use IEI—taking the time for meaningful reflection, and developing conclusions from their own teaching that represent value to other teachers pursuing inquiry learning techniques:

“Overall, this course has become much more beneficial to me as a teaching practitioner over the past few days in reflection than I would have imagined. The workshop was hands-on and informative, the presentations and feedback sessions brought more “realness” to the application and the learning process of the inquiry activities, and the reflections especially, have forced me to dig deep to find the relevance and meaning to this workshop in accordance to my personal and professional life.”

Kellie Takamori, Grade 7 Math, Kalakaua Middle School, Oahu, January 2014

4. Increases STEM interest in females and underrepresented minorities through place-based application and local industry partnerships.

IEI provides gender equity training and focuses on the inclusion of underrepresented minorities to achieve the overarching goals of gender parity and increased diversity in the STEM field. This includes take-home reading assignments and allocated time for group discussion among IEI participants about concrete strategies for pursuing parity in STEM success.

Since IEI’s beginning, local industry professionals from wind, solar, geothermal, ocean thermal energy conversion, biofuel, and energy conservation have presented at IEI’s workshops, providing highly accessible evidence of the local renewable energy industry and showcasing Hawaii as a premier clean energy test bed.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Renewable Energy IEI Workshop Presentations by Island, November 2012-October 2013</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maui</td>
<td>Oahu</td>
</tr>
<tr>
<td>Wind Turbine Basics (Auwahi Wind Farm, June 2013)</td>
<td>Algal Biofuels (Blue Planet Project, January, March, May, October 2013)</td>
</tr>
<tr>
<td>Kauai</td>
<td>Hawaii Island</td>
</tr>
<tr>
<td>Energy on Kauai (Kauai Island Utility Cooperative, January 2013)</td>
<td>Geothermal Energy (Puna Geothermal Venture, January 2013)</td>
</tr>
<tr>
<td>Solar Energy Resources (Kauai Community College, January 2013)</td>
<td>Biodiesel Fuel (Pacific Biodiesel, January 2013)</td>
</tr>
</tbody>
</table>
The local industry professionals who present at IEI workshops are mainly from engineering, science, and agriculture technology backgrounds. Educators take resources from these presenters and inform their own students about current renewable energy trends in Hawaii. This method provides a high-impact expansion of statewide knowledge in renewable energy, offers local industry leaders the opportunity to improve or maintain their organization’s public image, and provides the essential connection between education and industry that shows students the emerging career possibilities in renewable energy and STEM.

Applicability and expansion

Since IEI’s five pilot workshops in 2009, the program has significantly expanded its reach. From November 2012 to October 2013, 125 STEM teachers from eight two-day IEI workshops experienced an 85% success rate in launching and sharing results from curriculum-based labs and activities. In this eleven month period, 43.7% of the total 286 IEI participants were trained.

As part of its ongoing evaluation process, IEI administers pre- and post-workshop participant assessments, utilizing audience response systems technology to instantly record and save results. Assessments are designed by IEI WIT staff in consultation with a retained external project evaluator. The IEI workshop pre-assessment mainly focuses on the enrolled educator’s demographic information and intentions regarding attending the workshop. Key results of the pre-assessment of 120 educators that participated in the IEI workshops from November 2012 through October 2013 are presented below.

<table>
<thead>
<tr>
<th>Island in which IEI Participant Resides:</th>
<th>Maui, Molokai, Lanai</th>
<th>Oahu</th>
<th>Kauai</th>
<th>Hawaii Island</th>
</tr>
</thead>
<tbody>
<tr>
<td>26.7%</td>
<td>60.8%</td>
<td>3.3%</td>
<td>9.2%</td>
<td></td>
</tr>
</tbody>
</table>

The majority of IEI participants reside on Oahu, which is to be expected because it is the island with, by far, the highest population in the state. Demand for IEI workshops was also the highest from Oahu educators, with four of the eight IEI workshops occurring on the island.

75.4% IEI workshop teacher participants were women and 24.6% were men. The classroom gender mix among IEI student participants was teacher reported as follows: 87.3% “fairly even mix of boys and girls,” 11.9% “all or mostly boys,” and 0.8% “all or mostly girls.”
The IEI curriculum’s units focus on educational benchmarks for grades 5-8. This is reflected in IEI student demographics with 59.5% of participants teaching grades 5-8. Although the IEI curriculum was originally created for intermediate-level students, there is frequent implementation of the lessons and concepts by higher-level educators, with 34.5% of IEI participants teaching grades 9-12. One of IEI’s strengths is its applicability to various grade levels and subject areas. Because of the diverse backgrounds of the IEI participant teachers, students across disciplines are introduced to engineering design concepts and scientific inquiry methodology through IEI activities, such as wind turbine building, energy auditing, and solar power system design.

Finally, 61.8% of IEI participants stated their reason for attending the workshop was because they were “interested in energy on our islands.” This demonstrates the demand for information and resources about renewable energy in the region. Providing educator resources, training, and tools meets that need and increases the future workforce’s capacity in energy and STEM through lesson implementation.

IEI post-assessments focused on how participants’ capacity improved in inquiry learning methodology, clean energy knowledge, and understanding gender influence in classroom education. Out of 105 participants who attended the two-day workshops and completed the post-assessment, the following results were found:

**Table 3**

<table>
<thead>
<tr>
<th>IEI Participant Grades Taught:</th>
<th>Grade 1-2</th>
<th>Grade 3-4</th>
<th>Grade 5-6</th>
<th>Grade 7-8</th>
<th>Grade 9-10</th>
<th>Grade 11-12</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0.9%</td>
<td>5.2%</td>
<td>27.6%</td>
<td>31.9%</td>
<td>19.0%</td>
<td>15.5%</td>
</tr>
</tbody>
</table>

**Table 4**

“I have improved my ability to implement inquiry-based science.”

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Not Sure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>45.2%</td>
<td>54.8%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

**Table 5**

“I have a clearer understanding of energy sources and uses in Hawaii.”

<table>
<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
<th>Not Sure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>73.3%</td>
<td>26.7%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>

**Table 6**

“Energy education in Hawaii’s science classes is:”

<table>
<thead>
<tr>
<th></th>
<th>Very Important</th>
<th>Somewhat Important</th>
<th>Mostly Unimportant</th>
<th>Unimportant</th>
<th>Not Sure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>89.5%</td>
<td>10.5%</td>
<td>0.0%</td>
<td>0.0%</td>
<td>0.0%</td>
</tr>
</tbody>
</table>
100% of respondents strongly agreed or agreed that they had “improved [their] ability to implement inquiry-based science.” 100% of respondents strongly agreed or agreed with the statement, “I have a clearer understanding of energy sources and uses in Hawaii.” 100% of respondents also replied that “energy education in Hawaii’s science classes is” very important or important. 91.4% of participants strongly agreed or agreed that they “have a clearer understanding of gender influences on science learning in the classroom,” and 87.7% of respondents strongly agreed or agreed with the statement that they are “more confident in [their] methods to involve girls and under-represented groups in science learning. Finally, 98.1% of respondents strongly agreed or agreed that they “would recommend this course to other Hawaii-based teachers in [their] field.”

Qualitative data also resulted from teacher responses in their Hawaii DOE Learning Results Portfolios (LRPs), which include the following elements:

- Lesson Plan 1
- Six Student Reflections, Lesson 1
- Teacher Reflection, Lesson 1
- Lesson Plan 2
- Six Student Reflections, Lesson 2
- Teacher Reflection, Lesson 2
- Teacher Culminating Reflection (impacts of course implementation on teacher methods)
- Teacher pre- and post-course surveys

The following is a sample of quotes from LRP teacher reflections:

“The Island Energy Inquiry workshop and lessons were so amazing. I plan on doing these lessons and expanding on them every year…I will add more inquiry-based activities to my lessons knowing that students learn so much because of the high motivation generated by these concrete activities.”

Carolyne Bush, Grade 4, Kamalii Elementary School, Maui, November 2013
“After attending the workshop this summer, I returned to school with renewed motivation to teach science...I found the focus on Hawaiian energy issues to be the most beneficial...When students see the relevance of the science they are learning about in their own home, community and state, their enthusiasm for learning increases dramatically.”

Robert Tenison, Grade 11 Chemistry, King Kekaulike High School, Maui, October 2013

“The activities were attention-grabbing and the students became determined to finish and focus on completing the work. Independently, they were able to generate an inquiry and more importantly, complete the inquiry as self-directed learners.”

Harvey Llantero, Grade 8 Science, Washington Middle School, Oahu, November 2013

“For my female students, this was one of their first experiences with electronics and tools. Watching them build circuits and feel comfortable with tools such as wire strippers and motors was empowering to me...This course reminded me of the type of teacher I wanted to be when I first entered this profession. Having the ability and resources to guide students through labs that demonstrate real-life physics and science concepts strengthens my own practice.”

Joanna Kobayashi, Grade 9 Basic Physics, Moanalua High School, Oahu, April 2013

“Our student discussions were anything but boring...Having the IEI training has enlightened me to more of my own potential of being able to run project-based-learning. Having the IEI lesson plans makes it very doable, very practical to teach math through inquiry learning.”

Cynthia Van Kleef, Grade 7 Math, Iao Intermediate School, Maui, September 2013

These results display the effectiveness of IEI in its capacity to augment inquiry-based teaching skills in educators that teach a variety of subject areas while highlighting current placed-based clean energy issues and resources.

Addressing educational standards

In addition to increased implementation rates and overall reach since 2009, IEI’s dynamism is evidenced by its integration of institutional education standards. Furthermore, IEI’s structure naturally integrates engineering concepts within these existing standards, allowing teachers greater capacity for implementation. As a Hawaii DOE PD course, IEI has addressed the Hawaii Content and Performance Standards (HCPS III) in Science as part of its implementation process. More recently, IEI has adopted the Common Core State Standards Initiative (CCSS) as well as the NGSS, based on the framework for K-12 Science Education and developed by the National Research Council.

Each IEI curriculum unit addresses HCPS III for Science. An example of this is displayed in Table 9, in which wind energy is used as a platform topic for HCPS III benchmarks.13

<table>
<thead>
<tr>
<th>Lesson</th>
<th>Title</th>
<th>Essential Question</th>
<th>HCPS III Benchmarks for Science</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Wind Power Basics</td>
<td>How does wind energy turn a simple turbine?</td>
<td>SC.8.1.1</td>
</tr>
<tr>
<td>Lesson</td>
<td>Title</td>
<td>Essential Question</td>
<td>HCPS III Benchmarks for Science</td>
</tr>
<tr>
<td>--------</td>
<td>--------------------------------------</td>
<td>-------------------------------------------------------------------------------------</td>
<td>---------------------------------</td>
</tr>
<tr>
<td>2</td>
<td>The Earth’s Wind Patterns</td>
<td>Why does the Earth have wind patterns?</td>
<td>SC.8.8.3, SC.8.8.4, SC8.8.6</td>
</tr>
<tr>
<td>3</td>
<td>Wind Projects for Hawaii</td>
<td>How are wind farms in Hawaii currently producing energy for the state?</td>
<td>SC.8.2.1</td>
</tr>
<tr>
<td>4</td>
<td>Wind Turbine Design Inquiry</td>
<td>What are the most efficient turbine designs?</td>
<td>SC.8.1.1, SC.8.1.2</td>
</tr>
<tr>
<td>5</td>
<td>Energy Sustainability for Hawaii</td>
<td>How can harnessing wind energy impact the future energy sustainability of Hawaii?</td>
<td>SC.8.2.1</td>
</tr>
</tbody>
</table>

- SC.8.1.1: Determine the link(s) between evidence and the conclusion(s) of an investigation
- SC.8.1.2: Communicate the significant components of the experimental design and results of a scientific investigation
- SC.8.8.3: Describe how the Earth’s motions and tilt on its axis affect the seasons and weather patterns
- SC.8.8.4: Explain how the sun is the major source of energy influencing climate and weather on Earth
- SC8.8.6: Explain the relationship between density of convection currents in the ocean and atmosphere
- SC.8.2.1: Describe significant relationships among society, science, and technology and how one impacts the other

IEI also offers interdisciplinary HCPS III benchmarks as resources for teachers in Math (MA), Language Arts (LA), and Technical and Career Education (CTE). These include but are not limited to:

- MA.8.11.2: Judge the validity of data based on the data collection method
- MA.8.14.1: Judge the validity of conjectures that are based on experiments or simulations
- LA.8.1.2: Use a variety of grade-appropriate print and online sources to research an inquiry question
- LA.7.7.3: Use precise vocabulary suited to topic and audience
- CTE.8.1.1: Assess the overall effectiveness of a product design or solution

IEI will be selecting benchmarks from among the CCSS for Reading and Math and applying them to the next edition of IEI Curriculum Guide. An IEI pilot module that has been tested in local schools addresses the CCSS Writing Standards, Text Types, and Purposes: Write arguments to support claims in an analysis of substantive topics or texts, using valid reasoning and relevant and sufficient evidence. Students must critically analyze literature and media.
regarding controversies in smart grid technology, an issue that is highly relevant to the Maui community.

Although Hawaii is only in the preparation process of adopting the NGSS, several benchmarks will be included in the next edition of the IEI curriculum:

**NGSS Physical Science—**

- PS1A: Structure and properties of matter
- PS2A: Forces and motion
- PS3A: Definitions of energy
- PS3B: Conservation of energy and energy transfer
- PS3C: Relationship between energy and forces
- PS4B: Electromagnetic radiation
- PS4C: Information technologies and instrumentation

**NGSS Engineering, Technology, and Applications of Science—**

- ETS1A: Defining and delimiting an engineering problem
- ETS1B: Develop possible solutions
- ETS1C: Optimizing the design solution

IEI’s ability to adopt new and evolving educational standards offers teachers a curriculum that incorporates engineering education concepts while providing progressive pedagogy and necessary benchmarks that appropriately measure student and institutional progress.

**Conclusion**

IEI successfully awakens the natural engineer in students, showing them and their teachers that everyone can appreciate the methods and achievements of career engineers. The curriculum’s ad hoc, STEM integration approach makes engineering and STEM a more accessible topic for all students by including gender equity discussion and a culturally-relevant context. IEI teachers use the techniques of inquiry learning, inspiring young people to ask their own questions, develop, revise and optimize designs, and seek solutions individually and in teams—the essence of engineering design. The hands-on nature and variety of materials used in IEI to model renewable energies can show students how to apply mathematics while also helping them understand that technology is much wider in scope than computers and cell phones. Because energy is particularly expensive in their locale, IEI students motivate towards lab activities that emphasize renewable energy and energy efficiency, linking classroom learning to the needs in their home community.

A well-educated and prepared future STEM workforce is essential to meet Hawaii’s goals of 70% clean energy by 2030. Simultaneously, there is a serious current and projected shortfall in the STEM education pipeline, especially among women and minorities in the engineering field. Teachers find that the techniques IEI employs to reach young females and underrepresented groups can boost motivation and enjoyment for all their students. Tying learning to both culture and place makes classwork meaningful and relevant. Even as standards and national teaching methods are being explored, IEI gives K-12 educators a dynamic and proven teaching
model in showing the value of STEM careers to our next generation of young scientists and engineers.

References


