Developing Photovoltaics Curriculum for Middle and Upper Grades: Using Solar to Engineer Our Energy Future (P12 Resource Exchange)

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Target Grades: 4th[th] through 12[th]

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Many of the most pressing issues facing the world today are fundamentally intertwined with global energy needs. Thus, a defining challenge of the 21st century is meeting the world's energy demand. We are on the edge of a transformative era of energy generation in which emerging technologies have the power to address local and global challenges. Solar energy solutions are likely to play a big part in meeting global energy demand in the near-term future by:

- increasing the use of PV on the electrical grid, thereby making it more robust, sustainable, economical, and decarbonizing the global economy;
- addressing global inequalities by providing the advantages of solar to broader populations and thereby decreasing energy poverty,
- and driving radically new applications, i.e., PV-on-everything.

But getting there requires an educated citizenry empowered to utilize and create sustainable energy solutions. To this end, QESST, an Engineering Research Center for Quantum Energy and Sustainable Solar Technologies sponsored by the National Science Foundation and the U.S. Department of Energy, program aims to advance PV science, technology and education through a Research Experience for Teachers (RET) program.

The QESST RET program is focused on furthering innovations in solar energy engineering by advancing PV science and technology. We are also committed to promoting solar energy education by (a) developing an extensive set of K-12 curriculum materials to promote solar energy and PV engineering education, (b) supporting teachers and outreach coordinators to implement lessons and modules on PV science and engineering, and (c) fostering teacher's confidence in developing PV engineering curriculum. To achieve these aims, the QESST program designed a summer research experience to provide classroom teachers opportunities to develop connections between PV engineering research labs and the classroom. Participants spend five weeks conducting use-inspired PV research, working with world-class PV scholars, and designing solar energy lessons for their classrooms, working with educational researchers and instructional designers.

The eleven teachers in the program split their time between learning about various socio-technical aspects of PV (visiting PV engineering labs, listening to PV expert presentations, and taking field trips to PV-related sites) and developing their PV engineering lessons. Participants were provided with resources to design, develop, and test solar curricula for K-12 students. In consultation with QESST graduate students specializing in PV-related fields, and drawing on educational research on project-based learning, they developed a set of interrelated lessons incorporating active, constructive, and interactive elements. Each lesson went through multiple design cycles to ensure its effectiveness. Lessons were iteratively improved through peer critique and field-testing during K-12 outreach events. Finally, RET participants were provided support to implement their new PV curricula in their own classrooms during the subsequent school year. All lessons have been field-tested multiple times by other teachers and by students.

Resulting lessons integrate STEM instruction to support 4th-12th grade students' understanding of how solar cells are made and how engineering research is improving the capacity of PV to address the most pressing energy challenges of the 21st century. QESST's eventual aim is to develop a sequenced learning progression of solar energy engineering concepts and skills. Here, we present example lessons designed for middle grade students, integrated in NGSS curriculum standards, disciplinary concepts, practices, and cross-cutting ideas:

Solar Farm (9^{th}-12^{th} grade, 2 hours): Students estimate the output of a 100-square mile solar farm, calculate the cost of building and running it, and compare the results to the energy needs of their state. Web links and worksheets included in lesson materials.

Plan Your Solar Home (9th-12th grade, 4 hours): In this math intensive lesson, students investigate their current home energy usage and cost. They conduct a DIY Energy Audit, then work in groups to identify ways to reduce electricity use. Students redesign their home to include photovoltaics, physical changes, and behavior changes.

The Solar Shuffle (6^{th}-12^{th} grade, 45 minutes): After learning how solar panels work, students are challenged to represent the process of how a solar panel works by collaboratively creating a physical demonstration of electrons moving through a circuit by creating a dance. PowerPoint of key PV concepts is included in lesson materials.

Solar City (6^{th}-8^{th} grade, 3 2-hour sessions): Students use (and improve) their geometry skills to build a scaled city/ neighborhood powered by photovoltaics that uses 2D and 3D, practicing plane and solid geometry, area and perimeter. Each group needs building materials such as cardboard, dowels, rulers and tape; a small solar panel and motor; 3D printer optional.

Solar Ship Transport (6th-8^{th} grade, 3 hours): Students collaborate in small groups to design a solar ship that is able to carry an additional payload of 10 grams while traveling a certain distance. Students will evaluate how well their design performs against other designs.

Solar Strengths and Weaknesses (5^{th}-6^{th} grade, 1 hour): Students explore energy concepts using mini solar panels to run a small motor with a propeller. They simulate different conditions including panel angle, clouds, and night-time to determine optimal conditions/limitations for generating electricity. This lesson serves as an introduction or entry point for students to build background knowledge about solar energy.

Solar Living Environment (4th-7th grade, 6 hours): This project-based learning unit challenges students to go "off the grid" and design a home completely powered by solar energy. Students will ask themselves: What is solar energy? How do we harness this energy? How much energy do I use in my home? How much energy will solar give me? Will I need to change my lifestyle to live in a solar environment? Students will experience engineering design and communication processes to explore applying solar technology in our society and daily lives.

Atmospheric Effects on Solar Panels (4^{th}-6^{th} grade, 3 hours): Students experiment with various materials that diffuse light in order to represent how the atmosphere above cities can hinder the efficiency of installed solar panels. Using common household materials, they create filters to represent atmospheric conditions in cities around the world. As each group researches a city and defends their representation, they improve their modeling abilities and solar knowledge.

Designing a Solar Scribbler ($4^{th-}5^{th}$ grade, 3 hours): Working in small groups, students create a solar scribbler and use the engineering design cycle to refine their STEAM design based on a hypothesis, test the hypothesis, (i.e. Build, Test, Reflect, Refine, Repeat).

For the entire set of lesson instructions and materials, please click here.

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