Improving Energy Literacy among Middle School Youth with Project-based Learning Pedagogies

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Abstract - **Energy literacy was measured among a sample of middle school students (n=865) before (pre) and after (post) their middle-level physical science course using a written quantitative questionnaire developed for this research. Overall, students demonstrated significant cognitive gains, with no significant change in their energy-related affect, self-efficacy, or behavior scores. A sub-set of students who participated in project-based energy curricula demonstrated greater cognitive gains, particularly on items that related to topics that were more practical and related to everyday life. One group of project-oriented students who were academically challenged demonstrated significant gains on every non-cognitive subscale score. Qualitative outcomes indicate that most project-oriented students thought more about their energy consumption and made a greater effort to conserve energy, after studying energy in school. They also reportedly talked more with their families about saving energy, felt more strongly about saving energy, developing and using renewable energy resources. The findings underscore the complex relationship between knowledge, affect, and behavior, confirming that energy-related behaviors are more strongly related to affect than to knowledge, and support the benefits of project-based instruction for improving students' broad energy literacy.**

Index Terms – Energy education, energy literacy, energy surveys.

INTRODUCTION AND BACKGROUND

Energy is inarguably one of the most hotly debated topics in today's world. As we move toward a future with dwindling fossil fuel reserves and worsening environmental conditions, our world is faced with defining new directions with respect to energy production, consumption, and energy independence. Meeting this challenge will require technological advances, policy changes, and consumer and behavioral adaptation at every level of society. Energy literacy, which includes broad, citizenship based knowledge of energy concepts as well as energy-related attitudes, values, and behaviors [1], will be a key component of our successful shift toward an energy-independent and sustainable future. A population that is energy literate is more likely to engage in the decision-making process and to embrace appropriate energy-related decisions and behaviors.

Unfortunately, a number of studies have shown that energy literacy in the U.S. is disparagingly low (e.g., [2-6]). For example, results from a 2009 survey study revealed high levels of concern about energy, but persistently low energy-related knowledge among a random sample of 1001 American adults [4]: 40% could not name a fossil fuel, and even more could not name a renewable resource; 66% overestimated U.S. dependence on Middle Eastern oil; and 56% incorrectly believed that nuclear energy contributes to global warming. More recent surveys indicate that consumers are becoming slightly more knowledgeable about renewable energy resources, but remain confused about many other issues such as how energy is produced and consumed within their homes and communities [6-9].

Effective school-based energy education programs that strive to impact students' energy literacy could improve this situation, since energy awareness and values are largely formulated during childhood [10-12]. Energy topics in K-12 education are typically housed within the science curriculum, where content is largely dictated by State and National Science Education Standards (e.g., [13, 14]) and the assessment programs with which they are aligned. While traditional education emphasizes student exposure to concept knowledge and the analysis of problems, environmental problem solving skill development and citizen participation are often neglected. Effective energy education should focus not only on the input and development of knowledge, but also on the exploration of attitudes and values, and the opportunity to use and develop decision-making skills [15]. According to Frances Lawrenz [16], the "ultimate goal of energy education is to develop a well-informed public with positive attitudes toward energy conservation." Indeed, modifying energy attitudes and directing values is a major challenge to educating students for the future [17], and the "information sharing" style of typical science classrooms falls short of achieving this goal. Hofman [18] argues that to "produce an energy literate society we must begin in the affective domain." The affective domain, including values and value systems, is the "gateway" to the learning process [19] and should be considered together with students' cognitive processes in the teaching-learning continuum [20].

RESEARCH OBJECTIVES

This paper describes the investigation of the broader impacts of project-based energy education for improving students' energy literacy, which includes a wide range of content knowledge as well as affective and behavioral characteristics. Specific research questions include:

- What are the energy-related cognitive, affective, and behavioral gains for students who participate in energy curricula that are enriched with hands-on activities, projects, and inquiry-based learning?
- Is there a difference in the broader impacts of project-oriented curricula, compared with those of traditional pedagogies?

Two case studies are presented, both describing student outcomes in project-oriented 8th grade science classrooms. One case study involves a heterogeneous group of students while the other involves a homogeneous group of academically challenged students. The study draws from educational research data that show the benefits of using project-based or inquiry-based approaches to improve student understanding and retention of content (e.g. [21-23]), as well as ideas from proponents of STS (Science-Technology-Society) education, who maintain that embedding scientific topics within a societal context helps students become engaged because they realize the relevance of the material to their own lives (e.g., [24-26]).

METHODOLOGY

Sample

Middle school teachers were solicited throughout New York State (NYS) for participation in a study that would require their students to complete a series of in-class surveys related to energy. In all, 13 physical science and 6 technology teachers and their students participated in the study. Students who completed questionnaires in their technology classes were simultaneously enrolled in an 8th grade physical science class. Participating teachers agreed to administer in-class questionnaires to their students on a voluntary basis. A total of 865 middle school students (51% male, 49% female) completed the pre/post questionnaires. The subjects attended a variety of public school types (11% urban, 59% suburban, 30% rural) that reported a fairly broad cross-section of ethnic backgrounds (80% of the students were white, with the remaining students distributed among ethnic groups encompassing Latino [7.5%], Asian [1.8%], African [10.5%], and Native American [0.3%]). The socioeconomic backgrounds also covered a wide range, as indicated by a school district census poverty index ranging from 1 to 39. Census poverty index is defined as the percentage of children 5-17 years of age in families below the poverty level, living within the school district boundaries.

Project-based Curricula and Classrooms

Two of the science teachers reported extensive use of projects and hands-on activities in their energy curricula. "Teacher A" worked with a mixed-ability group of 8th graders (n=35), using the project-based module, *Energy Systems and Solutions*, developed by Powers and DeWaters (http://www.clarkson.edu/highschool/k12/project/energysystems.html). This project-based curriculum brings students through the exploration of technical and societal-based issues surrounding energy production and consumption as they work their way through the solution of a real-world problem related to an energy issue. Standards-based science content is interwoven throughout the curriculum. An excerpt of the curriculum is described in Table I; the entire module was taught over a period of 4 weeks (20 school days) during students' regular 40-minute science class.

TABLE I
EXAMPLE CONTENT INCLUDED IN PROJECT-ORIENTED CLASSROOMS

"TEACHER A": *ENERGY IN OUR LIVES* CURRICULUM
Part 1: Understanding the Energy Problem Introduction – The Energy Problem (6-7 days) • "Energy Choices" board game • Graphing – Energy facts and statistics Problem Solving Approaches (1 day)
Part 2: Energy Background Energy Basics (4 days) • Work, power and energy Forms, States and Conversions (2 days) • Forms and conversions – everyday items Sources and Systems (7-8 days) • Energy sources research and diagrams of energy systems Efficiency (2 days) • Experimental measurement – efficiency of a system
Part 3: Solving the Problem Household Conservation and Efficiency (2-3 days) • Home energy audit Final project (4 days) • Students prepare posters, models, or displays to convey their results and recommendations
"TEACHER B": PROJECT-ENRICHED CURRICULUM
Multiple Circuits Activities Students categorize pictures of items that can/cannot be turned on with a circuit, and then play a game in which they use circuits, breakers, batteries and wires to light up a bulb. Students discuss the efficiency in their use of wires, number of bulbs, type of bulbs, and number of batteries needed.
Recycling Activity Students keep a log for one week to track their waste, and then they try to remain "trash free" for an entire day.
Wind Power students discuss pros and cons associated with wind power in their area. Students learn the mechanics of wind generated electricity and set up small wind wheels at various locations to determine the best location for a wind turbine.
Debate Day Students are given "energy dilemmas" and are required to find at least two facts that support, and two facts that oppose each situation. Students then hold small debates in class to discuss the pros and cons of each dilemma.

"Teacher B" worked with a small group of 8th grade students (17) who were below average academically, some with severe learning disabilities. Many students read at or below the level of a second grade student. This teacher also spent about 20 40-minute class periods on energy topics, using roughly three to four hands-on activities per week. A sampling of her activities is described in Table I. The activities are not strictly project-based, in that they are not aligned to focus on one specific "guiding question." Rather, Teacher B offered a series of hands-on activities and lessons that relate to various energy concepts and demonstrate the strong connections between energy and society. Students participated in class or small group discussions or debates, and evaluated the pros and cons related to energy resource development. Because of the hydroelectric dam across the road from the school, and wind turbines planned for development in the community, students frequently engaged in informal debates about these topics.

Data Collection and Analysis

Quantitative data were collected with a written instrument that was developed as part of this research. The Energy Literacy Questionnaire was developed according to established psychometric principles and methodologies in the sociological and educational sciences (e.g., [27-29]), and is described elsewhere in more detail [1, 30]. A variety of measures helped establish the instrument's construct and content validity. Our construct definition and measurement criteria were carefully developed through a review of prior energy education and knowledge/attitude/behavior research, and most survey items have been adapted and updated from existing energy- and environmental-surveys. The entire item/survey review process involved a diverse, six-member validity panel that represented a balance of secondary and college level educators and energy education specialists. Developmental age-progression comparisons, contrasted-group comparisons, and factor analyses were used to support construct validity and to explore the underlying dimensions of the new instrument. The internal consistency reliability of the survey subscales, as measured by Cronbach's alpha, range from 0.78 to 0.83, all satisfying generally accepted criteria for internal reliability, which can be as low as 0.6 for scales used in educational testing and assessment [29, 31].

The instrument contains three subscales that encompass energy-related affective (17 items), behavioral (10 items), and cognitive aspects (30 items), with four self-efficacy items embedded within the affective subscale. Affective and behavioral subscales use a 5-part Likert-type response scale with one neutral response; scores for each item range from one (least preferred response) to five (most preferred response). Items in the cognitive subscale use a 5-option multiple choice format, and were assigned one point for each correct answer and zero points for each incorrect or blank response. The cognitive subscale covers seven main topic areas that encompass basic scientific energy concepts as well as the "citizenship knowledge" of energy that is crucial to everyday life, in addition to cognitive skills such as critical thinking and analysis. The topic areas include: saving energy; energy forms, conversions, and units; home energy use; basic energy concepts; energy resources; critical analysis about renewable resources; and environmental impacts.

Responses to each of the three subscales were analyzed separately: student scores were summed across each subscale, with maximum scores of 30 on the cognitive; 85 on the affective; and 50 on the behavioral subscales. Total scores for each subscale were converted to percent correct (or percent of the maximum score, for Likert-type scales), established as a common metric to simplify comparison between the three subscales. Students were also assigned a "self-efficacy" score. Item mean responses (ranging from 1 to 5) were calculated for each individual Likert-type item, and percent correct was calculated for each cognitive item.

Pre/post differences in average student scores on each subscale were analyzed using a Wilcoxin signed rank test, a nonparametric statistical procedure equivalent to the paired-sample Students' t-test. The whole student sample was analyzed using the teacher as the unit of measure (n=19), in order to minimize potential problems resulting from the highly variable student/teacher ratio, which ranged from as low as 9:1 to as high as 94:1. Pre/post gains on individual items or topics within each of the three subscales were examined, using mean values by teacher for the whole group and individual students for each project-oriented group. Student gains on individual cognitive items within each project-oriented group were evaluated with a two-population proportion z-test. Potential differences between the performance of students in project-oriented classrooms and the rest of the student group were compared using a nonparametric fixed-effects analysis of covariance (ANCOVA), with student post score as the dependent variable, classroom teacher as the fixed factor, and student pre score as the covariate [32]. Statistical analyses were performed with Microsoft Excel, *Statistical Package for Social Sciences* (SPSS) Statistics Version 17 (SPSS Inc, 2008), and Minitab 15 (Minitab Inc., 2011).

Post-only qualitative data were collected from project-oriented groups after completing their energy modules. The qualitative methods were guided by a concern over how the course changed students' energy-related attitudes, values and behaviors, both on a personal and a global scale, and how the students viewed the effectiveness of their own actions toward making an impact on global and local energy issues. Data were collected with teacher interviews, student reflective essays, and written opinion surveys or questionnaires administered to students, teachers, and parents/guardians. The questionnaires used a combination of open-ended, yes/no, and 5-part Likert-type response items, which were designed to provide students the chance to openly and honestly respond about how the course influenced the way they think about and use energy in their own lives, and to gather information from the teachers' and parents' perspectives regarding the course's impact on the students' affect and behaviors.

Likert-type responses were tallied to determine the percent of responses at each of the five levels for each question. Scores were reported as "percent of students responding positively," which meant "definitely yes/yes" for items that ask a definitive "did you …" or "do you …" question, and "a lot/quite a bit" for items that ask "how much …". Responses from reflective essays and post-program free-response questionnaire data were reviewed for the presence of patterns revealed by the narratives [33, 34], which may expose inconsistencies or further explain the quantitative results. After identifying conceptual threads or patterns for each question, responses and comments were tallied for each particular thread. Other evidence in the form of vignettes or narratives from the reflective essay responses were used to provide more depth to the analysis.

RESULTS AND DISCUSSION

Overall Gains in Energy Literacy

The performance summaries for cognitive, affective, and behavioral subscales are provided in Table II, for the entire sample group as well as for students who worked with the two project-oriented teachers. Summaries for the four self-efficacy items that were embedded within the affective subscale are also included. Overall, students exhibited significant gains in energy-related knowledge (p=0.004), although scores were still discouragingly low (mean post score 46% correct). The percentage of students scoring above an 80% rose ten-fold, from 0.2% (pre) to 2.0% (post), while the 75th percentile score rose from 50% (pre) to 60% (post). In general, gains were most significant and post scores highest for topics that are contained in the standards-based curriculum, such as basic energy concepts; forms, conversions, and units of energy; and energy resources. Gains were less, and post scores lower, for categories of questions that had to do with the more practical- or consumer-oriented aspects of energy knowledge, such as energy conservation and home energy use. Similar trends in performance were found in earlier studies (e.g. [7, 35]).

TABLE II:
OVERALL PRE/POST SURVEY RESULTS

	Cognitive		Affective		Self-Efficacy		Behavior	
	Pre	**Post**	**Pre**	**Post**	**Pre**	**Post**	**Pre**	**Post**
Whole Student Group								
N (students)	730	730	865	865	865	865	860	860
Mean (%)	40.7	45.6	73.8	74.2	73.9	73.4	66.6	67.0
SD (%)	4.9	7.4	3.0	3.0	4.4	4.1	4.6	2.9
Probability[a]	**0.004**		0.67		0.38		0.60	
Project-oriented Teacher A								
N (students)	34	34	35	35	35	35	35	35
Mean (%)	43.3	53.8	71.5	71.1	67.9	67.1	66.3	64.8
SD (%)	13.8	14.5	11.2	11.6	17.4	17.0	14.3	15.3
Probability[a]	**<0.001**		0.81		0.71		0.34	
Project-oriented Teacher B								
N (students)	11	16	16	16	16	16	15	16
Mean (%)	36.9	37.1	73.4	78.2	72.5	80.3	55.8	66.4
SD (%)	14.0	17.0	12.0	12.0	14.0	15.9	20.5	14.9
Probability[a]	0.306		**0.011**		**0.019**		**0.038**	

[a]Probability of paired pre/post difference calculated with a Wilcoxin signed rank test. ***Bold*** *values are significant at α=0.01.*

Despite their knowledge gains, there were no significant pre/post changes in average energy-related affect, behavior, or self-efficacy scores. Relative to their scores on the cognitive subscale, however, the students exhibited generally positive energy-related attitudes and values, with behavioral tendencies that did not quite reflect these attitudes but were, indeed, indicative of a greater degree of conservation-mindedness than their cognitive scores might imply. These results are consistent with earlier findings [35] and demonstrate the lack of a clear connection between knowledge and behavior. In fact, despite greater energy-related knowledge, the students indicated on the post survey that they were *less* likely to save energy, even if they were provided with the knowledge and skills to do so.

Changes in Energy Literacy in a Project-based Classroom – Case I: Teacher A

The heterogeneous group of students who worked with Teacher A also demonstrated significant knowledge gains (p<0.001) with no accompanying change in energy-related affect or behavior. Yet the post-scores of Teacher A students were significantly higher than the rest of the group on the cognitive subscale (p<0.001). Table III summarizes post scores and pre/post gains on selected cognitive items, for Teacher A students as well as the whole student sample. The table includes average scores for each of the seven cognitive topics, with one example item within each topic; additional details are available in [36]. Significant values are bold – *% correct post* values mean the difference between Teacher A and the whole group is significant, while bold *pre/post gain* values are for each particular group of students.

Two general observations can be made based on the detailed findings presented in Table III. First, students in the project-oriented classrooms gained a higher level of proficiency with respect to energy-related knowledge and cognitive skills, relative to the whole student sample. This is evident from the overall differences in pre/post gains, as well as the higher post scores achieved on every category of knowledge questions. Second, the performance differences between project-oriented students and the rest of the student group were generally more pronounced for questions that related to practical energy knowledge. For example, the average post scores for questions in the Saving Energy and Home Energy Use categories were 13 and 12 percentage points higher, respectively, for Teacher A relative to the whole student group. In contrast, average post scores on questions related to Basic Energy Concepts were 9 percentage points higher for Teacher A. Within the category called Forms, Conversions, Units, there are two questions that are fairly practical in nature (units used to measure electricity, and how to determine the amount of electricity consumed by an electrical appliance), and two that are more strongly based on science concepts (energy forms and conversions). Comparing post score differences, project oriented students scored 48 percentage points higher than the whole group on the two practical items, and 33 percentage points higher on the two science-based questions.

Despite their cognitive gains, students who worked with Teacher A did not show appreciable gains in their energy-related affect, self-efficacy, or behavior scores (Table II). There were a few interesting differences in post-survey responses to specific items, however. For example, relative to the rest of the sample group, Teacher A students agreed more strongly that saving energy is important, were more willing to pay extra for energy produced from renewable energy resources, and felt more strongly that laws protecting the natural environment should be relaxed so that more energy can be produced. They also reported a higher tendency to turn off lights and to purchase (and encourage their families to purchase) energy efficient light bulbs.

TABLE III.
COMPARISON OF POST SCORES AND PRE/POST GAINS, COGNITIVE ITEMS

	Teacher A		Whole Group	
Topic	**% Correct Post**	**Pre/post Gain**	**% Correct Post**	**Pre/post Gain**
Saving Energy				
topic mean:	55.3	6.1	48.2	-0.6
Q. If a person commuted alone to work 30 miles every day and wanted to save gasoline, which one of the following options would save the MOST gasoline? ***Carpooling to and from work with one other person.***				
	54.5	3.0	41.5	-3.1
Forms, Conversions, Units				
topic mean:	**63.6*****	**25.8*****	44.8	**5.0***
Q. The amount of ELECTRICAL ENERGY (ELECTRICITY) we use is measured in units called … ***Kilowatt-hours (kWh).***				
	33.3***	**27.3****	12.0	**2.9**
Home Energy Use				
topic mean:	**40.4***	6.1	28.8	**5.2****
Q. Which of the following items uses the <u>MOST ELECTRICITY</u> in the average American home in one year? ***Refrigerator***				
	60.6**	12.1	32.9	**6.5***
Basic Energy Concepts				
topic mean:	**67.2****	**21.2*****	58.1	**8.9****
Q. What does it mean if an electric power plant is 35% efficient? ***For every 100 units of energy that go into the plant, 35 units are converted into electrical energy***				
	57.6	15.2	41.6	-1.1
Energy Resources				
topic mean:	**49.2***	**11.7****	40.9	**6.9*****
Q. Most of the <u>ELECTRICITY</u> produced in the United States comes from … ***Burning coal.***				
	54.5**	**39.4*****	30.5	**10.5****
Critical Analysis about Renewable Resources				
topic mean:	49.0	-5.5	44.1	2.0
Q. Some people think that if we run out of fossil fuels we can just switch over to electric cars. What is wrong with this idea? ***Most electricity is currently produced from fossil fuels (coal, oil, natural gas)***				
	63.6	-3.0	51.0	-1.0
Environmental Impacts				
topic mean:	47.6	-10.0	44.6	-0.2
Q. Which of the following energy-related activities is <u>LEAST</u> harmful to human health and the environment? ***Generating electricity with photovoltaic (solar) cells***				
	46.9	1.4	37.1	-3.4

***Bold** values are significant at:*α=0.05; **α=0.01; ***α= 0.001.*

Case II: Teacher B

Results for Teacher B students were opposite from those for the rest of the group – pre/post gains on the cognitive subscale were negligible, while non-cognitive gains were all significant (Table II). The low cognitive subscale scores relative to the rest of the student sample are not unexpected, given the nature of this academically challenged group. Yet Teacher B has, through the extensive use of projects and hands-on activities, engaged her students in such a way that they have demonstrated significant pre/post gains on the energy-related affect, self-efficacy, and behavioral portions of the Energy Questionnaire. No other single group of students in the study exhibited such gains.

Although their knowledge gains were significantly less than the whole student sample, Teacher B students did perform equivalent or better relative to the whole group on some of the items related to practical energy knowledge (see [36] for details). For example, like the other students, 36% of Teacher B students correctly identified space heating and cooling as the major energy consumer in the home, and more of them correctly identified the unit used to measure electricity. They also did quite well on questions related to energy resources, such as quantifying the contribution of hydropower to the pool of renewable energy resources in the U.S. (54% correct, vs. 25% for the whole group); and defining and identifying renewable energy resources (50% vs. 62% correct). In contrast, Teacher B students scored much lower than the whole group on some of the science-oriented questions, for example the definition of efficiency (27% vs. 51% correct).

Significant pre/post changes to a few specific affective and behavioral items are shown in Table IV, along with the responses of all other students to these same items. Significant values are in bold – bolded *mean response post* values mean the differences between Teacher B and the whole group are significant, while bold *pre/post gain* values are significant for each particular group of students.

TABLE IV.
COMPARISON OF POST SCORES AND PRE/POST GAINS, NON-COGNITIVE ITEMS

	Teacher B		Whole Group	
Affective items	**Mean response post**	**Pre/post Gain**	**Mean response post**	**Pre/post Gain**
I would do more to save energy if I knew how.				
	3.94	**0.31***	3.60	**-0.16***
I don't need to worry about turning the lights off in the classroom, because the school pays for the electricity.[a]				
	4.25*	0.31	3.48	-0.07
I believe that I can contribute to solving the energy problems by making appropriate energy-related choices and actions.				
	4.25	0.50	3.88	-0.09
I believe that I can contribute to solving energy problems by working with others.				
	4.00	**0.69***	3.81	-0.03
Behavioral items				
I walk or bike to go short distances, instead of asking for a ride in the car.				
	3.75	**0.55****	3.64	-0.07
Many of my everyday decisions are affected by my thoughts on energy use.				
	2.75	0.75	2.61	-0.03
I am willing to buy fewer things in order to save energy.				
	3.19	**0.76***	2.83	0.04

Likert-type (non-cognitive) responses range from 1 to 5.
[a]Negatively-worded items have been reverse-scored for analysis.
*Red values indicate a negative pre/post change. **Bold** values are significant at: *α=0.05; **α=0.01; ***α= 0.001.*

Significant gains on two affective items, both of which relate to their feelings of self-efficacy and desire to work toward positive change, are in contrast to negative trends observed among the rest of the sample group. In fact, Teacher B students' post mean scores were higher than the rest of the student responses for almost every affective item. Teacher B students also showed a positive trend in their agreement that environmental protection laws should be relaxed to enable more wind farms to be developed, in contrast to the rest of the student sample who demonstrated a negative trend in agreement with this item. Teacher B described that this class held regular mini-debates on current events that impact their local community, including wind farm development. The responses of these students seem to reflect the political discussions surrounding this topic, which demonstrates that they have become engaged in that discussion and have evaluated some different options.

Similarly, these students demonstrated consistently greater pre/post gains on behavioral items relative to the other students. They also reported that they made more of an effort to conserve energy, they talked more with their families at home about saving energy, and they were more willing to contribute toward energy savings by making fewer purchases. These results align with the positive pre/post changes in self-efficacy responses.

Qualitative Outcomes

Student responses to qualitative survey questions provided a deeper understanding of their energy-related attitudes, values, and behaviors. Earlier studies have shown that the "moderator variable" associated with self-reported measures among school children can produce unreliable data, because of discrepancies between what people "say" and what people "do" [37, 38]. Hines et al. [39] found that subjects tend to under-report their behaviors on these types of measures. In fact, while our qualitative findings confirm the positive energy-related affect and behaviors among Teacher B students, even relative to the other project-oriented students, they also demonstrate that affective and behavioral outcomes for Teacher A students are more positive than what is shown by the quantitative results in Table II.

In general, qualitative findings indicate that the energy curricula had a positive influence on the attitudes, values, and behaviors of project-oriented students. Over half of the students (54% Teacher A; 66% Teacher B) reported that their energy studies influenced the way they think about their energy use and their energy consumption behaviors. "[The course] influenced the way I use energy because now I know how much energy I actually use." Nearly 60% (Teacher A) and 70% (Teacher B) reported that they felt their actions can help solve our energy problems, suggesting an increase in feelings of self-efficacy, despite the negative trend noted in the quantitative survey for Teacher A students. Many students (40% Teacher A; 63% Teacher B) described specific actions or behaviors they had adopted to save energy, including turning off lights and appliances, unplugging electronics, taking shorter showers, washing larger loads of laundry, and building a compost pile. 53% of the parent respondents from Teacher A students indicated that their son/daughter displayed an increased awareness toward energy-related issues, and 65% reported that their son/daughter discussed saving energy at home.

CONCLUSIONS, IMPLICATIONS

Results of this study demonstrate that a project-based learning approach tends to be very effective at improving students' overall understanding of practical or "citizenship" energy knowledge, even for students who are academically challenged or suffer from learning disabilities. Engaging students in projects where they were required to evaluate pros and cons related to energy issues, play with circuits to explore efficiency, track their own energy consumption and use equipment to measure electricity consumption of various electronic appliances provided them with greater opportunities to develop a deeper understanding of these topics. We also found that students who were taught with project-based pedagogies developed a better understanding of basic energy concepts, a finding that is consistent with earlier research [40].

This study also illustrates the complex relationship between knowledge, beliefs, attitudes, values, and behaviors [39]. The results presented here corroborate earlier findings that self-efficacy is more strongly correlated to behavior than knowledge and adds another potential factor for influencing student affect and behavior, which is the *type* of knowledge – practical or informal "citizenship" understanding of energy, vs. technical or formal "science" content knowledge. Students who participated in educational experiences that demonstrated the relevance of what they were learning in school to their everyday lives were more apt to share the information with their families at home, and to adopt attitudes and behaviors that reflected what they had learned. In general, the results tend to verify the ideas of Hofman [18] and Solomon [25], that a *practical* understanding of energy issues will equip students to make appropriate energy-related decisions and actions.

The ultimate goal of energy education is to foster critical thinking and effective decision making, in order to empower students to become actively engaged in behaviors and actions that will help move us toward a sustainable energy future [15]. Our results demonstrate the importance of providing students with educational experiences that expose them to *broad* content knowledge as well as opportunities that directly foster positive energy-related attitudes and values [17-20, 41], and provide opportunities to learn effective decision making, critical analysis, and action strategies [15, 42]. Wider implementation of project-based energy curricula may serve to move us one step further toward developing a more energy-literate population.

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