Study of the Effects on Student Knowledge and Perceptions of Activities Related to Submetering the 6th Grade Wing of a Middle School, to Displaying the Carbon Footprint, and to Efforts to Reduce Energy Consumption and Greenhouse Gases

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July 12, 2009

***Abstract**: The **purpose** of the study was to determine the effects upon student knowledge and perceptions regarding greenhouse gas emissions as a result of an intervention relying upon the submetering the 6th grade wing of a Middle School, displaying the information regarding electrical consumption and carbon footprint, and reducing the electrical consumption of the wing. The **methodology** was to compare pre-test and post-test responses of 97 students to an instrument designed to assess knowledge and perceptions. All the students were residents of Loudoun County, Virginia, and of mixed ethnicity. The **results** demonstrated significant effects in the following areas: knowledge that CO_2 is a greenhouse gas, that the US, with 5% of world population, emits more than 20% of worldwide CO_2 emissions, and that about 1 kg of carbon dioxide is emitted for every 1 kWh of electricity produced. Perceptions also changed, the most significant being that students changed from perceiving themselves as ineffective (50% pre-test, 25% post-test), that they believed that they had reduced greenhouse gases, and that they no longer believed that relying on solar energy was the principal action to reduce greenhouse gases. **Conclusions**: Submetering the 6th grade wing of Seneca Ridge Middle School combined with collective actions of the students caused significant gains in learning and significant shifts in perceptions by students. **Recommendations**: That other schools consider submetering both to save energy and to increase student learning. That the Departments of Energy and Education consider implementing programs to encourage school design to include metering at discrete levels within a school. **Additional Data**: (Instrument for student completion)*

Background:

Seneca Ridge Middle School is a Loudoun County Public School in Sterling, Virginia. It opened its doors in 1977, and has had several physical modifications over the past thirty years. For 2008-'09, it had a total of 885 students in grades 6-8. The school had the following ethnicity in that year: 58% Caucasian, 20% Hispanic, 12% Asian, and 9% African-American. 19% of students were eligible to participate in the federally subsidized meals program. 7% of students received special education services. 298 students were in the 6th grade. About a third of the students were taught by the author of this study, in the "Panther" team, with 109 students enrolled in his classes in September. These students completed an instrument assessing perceptions and knowledge regarding climate change in September at the start of school, and in June near the end of the school year. The school was on the block schedule, with approximately 90 minute blocks. Three 6th grade science teachers taught science, and met at least once a week in Professional Learning Communities to discuss lessons, assessments, and approaches such as this project.

Grant:

The school received a grant of $5,000 in 2006 from the Dominion Power Foundation in order to install an electrical submeter in the 6th grade wing of the school, and to provide information to students so that they could participate in energy conservation while achieving learning gains under Virginia science Standards of Learning. The project manager under the grant was the author of this report. The grant was supplemented by $500 grants from the Loudoun Education Foundation, and from the law firm of Chamberlain Hrdlicka. The 6th grade teachers signed a statement of support for the project, and the Seneca Ridge Parent Teacher Organization committed to assist with funds. The students and other stakeholders in the project have expressed their gratitude to the Dominion Power Foundation for its vision, especially in understanding that the project took three years to complete, instead of the one year initially envisioned.

Intervention:

Initial plans to rewire every circuit feeding classrooms, offices, and common areas of the 6th grade wing proved too expensive to implement. Accordingly, an electrical distribution box in the six grade wing was identified as a point through which the majority of the electricity passed for the sixth grade wing. Three simple donut-shaped CTs (Current Transformers) were attached to the 3 phase lines entering the distribution box. The electrical pulses from the CTs were then fed to a computer containing energy management software. The advantage of this approach was simplicity of installation and low cost. The disadvantage was some loss of precision, and the introduction of confounding variables. The three meters did not capture all of the electrical usage of the 6th grade wing, and they measured some electrical consumption for the benefit of classrooms not in the 6th grade wing. Thus, four classrooms out of 24 in the 6th grade wing had their electricity for electrical outlets come from a non-metered distribution box. Further, the sixth grade distribution box provided power to rooftop blowers and compressors that serviced some classrooms not in the sixth grade wing. On the other hand, the distribution box did provide power to all of the lighting for the sixth grade wing, to include locker area, classrooms, hallways, offices, and restrooms. This was confirmed during installation of the CT meters to the distribution box, when the power to the distribution box was shut down. Accordingly, while the meters did not measure 100% of the electrical power consumed by the 6th grade wing, the consensus judgment of those involved with the project is that the CT meters measured approximately 90% of the 6th grade electrical consumption. This degree of precision was considered sufficient for the purposes of the project.

Power management software was acquired, with programming modifications made via independent contractors to reflect and display relevant data in a student friendly manner. This included the instantaneous kilowatt demand, updated every minute, the kilowatt hours consumed for the day, updated every minute, and the kilowatt hours consumed for the previous day. The carbon footprint for the minute was also displayed, as was the cumulative amount for the day. The basis of converting kilowatt hours to carbon dioxide was 1.1 kg per kilowatt hour. This information was displayed on a large

screen television monitor affixed high on a wall in the main locker area of the 6th grade wing. The display was also accessible to networked computers in any classroom inside the school, for display on the Promethean Boards in each classroom. Further, a link was provided on the school's web site so that anyone outside the school could access the information and display. A representative image of the display is attached. In addition, users of the system could build their own graphs of usage and carbon footprint.

Because science classes were not scheduled to study energy until April of the year, the energy information was not displayed until that time despite being active starting in late February of 2009. Alternate programming was put in place on the monitor once it became active. Using looped Power Point presentations, programming on the monitor included images of students in the locker area, images of the students during a fire drill, images of the students in class, images of students at each of three awards assemblies marking the end of the second term, images of an assembly where the Dean and Counselor were subjected to an "extreme makeover", conservation messages, weather information, especially when a winter storm threatened, and the cafeteria lunch menu for that day and the succeeding day. The objective of the programming were to get the students accustomed to seeing the monitor as a positive factor in school and to provide them with useful information and appealing images.

Each of the three teachers responsible for 6th grade science began their focus on energy and conservation around April 1. The exact lessons varied from teacher to teacher. Further, each of them had previously introduced energy concepts to their classes at varying times in the academic year before this time. Each of the science teachers also asked students to consider ways that energy could most readily be saved on a short term basis in the sixth grade wing. All suggestions were encouraged, and then they were discussed. While solar energy panels on the rooftops were common suggestions, the teachers observed that with flat roofs that had been known to leak in the past, it would be difficult to install solar panels, and even if the school could do so, it would be many months before they could become operational. Further, to provide electrical energy fo the 6th grade wing, the entire school would have to be covered by solar panels. Heating and air conditioning was also discussed, but due to the fact that these were centrally controlled, there was little to be done on a local basis. Several students noted that teachers often left computers on overnight, and that when some teachers went to lunch, they left lights in the classroom on. However, the consensus was that while there were occasional instances of teachers being careless with electrical consumption, in general the behavioral changes would probably have only a minimal effect. Some classes submitted suggestions to reduce carbon footprint, but the majority of classes held open discussions. The student consensus based on classroom discussions was that cutting back on lighting was the prime candidate for energy reduction, for the quickest reduction with the least disruption to all concerned.

In early April, all teachers with 6th grade homerooms were briefed on accessing the carbon footprint data from their classrooms and displaying that information on the Promethean Boards in the classrooms. Homeroom was normally dedicated to a "Drop Everything and Read" period of 20 minutes. At 8:35AM on Monday, April 13, with all the Promethean Boards signed on to the carbon footprint monitor, an announcement was made on the loudspeaker for all 6th grade homeroom teachers to "power up" by turning all lights and appliances on. Science teachers had previously distributed 550Watt hotplates to selected 6th grade classrooms to assure that maximum power was achieved. No action was taken requesting the central office to change HVAC settings. At 8:40 AM,

an announcement was made over the loudspeakers for all teachers of 6th grade homerooms to "power down", turning off all lights and appliances, but leaving the Promethean Board for last. Then, at 8:45, an announcement was made over the loudspeaker system for all teachers to restore power to normal conditions.

The result was a clear spike in minute-by-minute electrical consumption and carbon footprint followed by a brief drop in electrical consumption and carbon footprint. While a few teachers turned off the Promethean Boards prematurely, the science teachers were able to demonstrate this spike effect to all students during science classes on April 13 and 14.

A Town Hall meeting of all 6th grade students and their teachers was held on April 14 from 8:35 until 9AM. It was moderated by the three science teachers. Two questions were presented to the students. The first question was *should the 6th grade wing take active steps to reduce its carbon footprint?* The second question was *should the first step be cutting back on lighting in the locker area, the rest room, and the halls?* Each science teacher called for comments from a student on the science teacher's team, with the majority of comments being supportive. Then one of the school system's energy specialists spoke a few words in support of the innovative effort to engage students in reducing energy use. Before the voice votes were held, it was explained that in the event of an unclear voice vote, students would cast their votes in their science classes in the following two days. However, this was not necessary as the voice votes clearly demonstrated affirmative support for the two questions.

That afternoon, after students had been dismissed, the school's chief engineer and the project manager extracted 48 34-Watt fluorescent light bulbs from the main locker area and from the counselor's office. Further arrangements were made to keep the lights other than the security lights off all day in the two hallways of the wing plus the two restrooms for the girls and the boys. The total light bulbs thus disabled were 92, which resulted in a savings of 3,128 Watts. Since these lights had been energized for an average of 9 hours per day, the savings were 27 kilowatt hours. The range of kilowatt hours for the wing when school was in session was from 600 kWh to 1500 kWh, with outside temperature being the factor most affecting usage. Since the average usage was 900kWh, the extraction of light bulbs caused a saving of 3%.

The school's chief engineer and the project manager also affixed large plastic signs to the walls at several locations in the 6th grade wing. Signs at strategic locations proclaimed the following: *You are now entering the low carbon footprint area of House C; You are now leaving the low carbon footprint area of House C; Our lights are lowered to reduce our carbon footprint; Check our carbon footprint on this monitor;* and *10 100 Watt light bulbs for one hour = 1 kilowatt hour = 1.1 kilogram of carbon dioxide into the atmosphere.*

After over a week of experience with the reduced lighting, a second Town Hall meeting was held. The agenda included a review of actions taken, their effect, a voice vote whether to continue with the lighting reductions, and commentary plus a voice vote on a request to the central office to revise the set points for the air conditioning by one degree. The comments regarding continuing the effort to reduce energy usage were all positive, and the voice vote was clear, to continue the effort. However, the comments were mixed as to changing the set points for the air conditioning by one degree. The voice vote on a request to the central office to change the set points for the air conditioning by one degree upward was inconclusive, and the vote was deferred to a classroom setting. Discussion was held by the three science teachers with their classes,

and a vote was conducted, where the majority favored increasing the average temperature by one degree Fahrenheit. However, the discussions revealed that some teachers and a small number of students had strong concerns about temperatures in classrooms. They felt that some of their rooms were already hot, or were too hot at certain times of the day, and were already higher than the supposed set points. One student confessed that he would vote against changing the set points not because he personally opposed it but because his math teacher "would kill him" if he voted for it. So, it was clear that on HVAC there were some strong opinions. Further discussion with the assistant principal for facilities revealed that the set points were county wide, and that their establishment was designed to curtail the individual requests for temperature changes that had been common in the past. Further, it was noted that the rooftop units whose electricity was metered as part of the project served classrooms outside the 6th grade wing. Accordingly, no action was taken to request a change in air conditioning set points.

During the last week of school, the project manager compiled a list of lighting fixtures to be permanently replaced with acoustical tile. This list included all of the previously disabled fixtures except for two each in the restrooms. Additional lights were also selected to be permanently replaced by acoustical tile. It was noted that even after the lights were extracted the remaining wattage would be well in excess of the applicable standard of 1 watt/square foot.

As of this date, the signage remains up, and the disabled lights remain disabled. The expectation is that the lighting reduction for the 6th grade wing will prove to be a permanent change.

Measuring Shifts in Student Perceptions and Knowledge

The project manager applied the same measurement instrument to his students in September as he did in June. 109 students completed the pre-test instrument, and 97 completed the post-test instrument. There was a gain of two students and a loss of 3 students per the class rolls of the Panther team of students assigned to the project manager from June to September. Absences in the final week of school are the principal reason that the post-test instrument had reduced numbers. The responses were tallied and the percentages tabulated. These are shown on the following page as Table 1 on the following page.

Table 1 (109 responses pre-test and 97 post-test responses of Panther team students)

Question and possible responses	Pre-test	Post Test	Change
1. Global warming is real. Earth's average temperatures have been increasing in recent years			
True	85%	93%	8
The evidence is unclear	5%	4%	[1]
False	2%	0%	[2]
I don't know	8%	3%	[5]
2. Places on Earth most at risk to global warming are			
Deserts	4%	1%	[3]
Polar regions, such as the Arctic	81%	90%	9
Suburban regions, such as where we live	7%	4%	[3]
Cities	5%	1%	[4]
I don't know	4%	4%	0
3. The term *greenhouse gas* refers mainly to			
Ozone and other gases that trap ultraviolet radiation coming from the sun to Earth	59%	54%	[5]
Carbon dioxide and other gases that trap infrared radiation coming from the Earth	23%	41%	18
I don't know	18%	5%	[13]
4. The statement that *Human Activity is Causing Global Warming* is			
Not proven scientifically, but probably true	45%	38%	[7]
Proven scientifically	38%	49%	11
False	4%	1%	[3]
I don't know	14%	11%	[3]
5. The U.S., with about 5% of the world's population, contributes about what % of greenhouse gases to the atmosphere?			
Less than 5%	3%	5%	2
5%	8%	5%	[3]
Between 6% and 20%	34%	29%	[5]
Over 20%	13%	29%	16
I don't know	43%	31%	[12]

Question and possible responses	Pre	Post	Δ
6. Other than transportation (cars, trucks, airplanes) the major source of greenhouse emissions in the U.S. is			
Energy used to heat, cool, and light our buildings, including this school	56%	64%	8
Industrial use	33%	26%	[7]
The computer	0%	0%	0
I don't know	11%	10%	[1]
7. When I turn on the lights, a television, or a computer			
I simply don't think about how much electricity it uses, nor do I care	11%	10%	[1]
I don't think about how much electricity it uses, but I care	61%	60%	[1]
I am aware of how much electricity is used, and I care	28%	30%	2
8. Producing a kilowatt hour of electricity usually produces about how much CO_2?			
About a milligram	5%	1%	[4]
About a gram	13%	13%	0
About a kilogram	8%	55%	47
I don't know	75%	31%	[44]
9. When it comes to global warming and greenhouse gas emissions			
I have no desire to do anything about it	6%	8%	2
I would like to reduce greenhouse gases, but am too young to be effective	50%	25%	[25]
I am already doing everything I can	23%	15%	[8]
I have already helped reduce gases, and plan to do more in the future	22%	52%	30
10. The most important factor in reducing greenhouse gas emissions by people will be			
Relying on solar energy	38%	24%	[14]
Having individuals change their behavior as to the use of things that use energy	29%	37%	8
Having both new laws, new technology, and individual changes in behavior	16%	24%	8
I don't know	17%	14%	[3]
11. At home, when it comes to using lights and other devices using electricity			
I do a good job of conserving energy	45%	37%	[8]
I help others to conserve energy	10%	18%	8
I am neutral – I don't do much to either consume or use energy	37%	34%	[3]
I waste a lot of energy	8%	11%	3

Discussion:

The intention of the project was student learning through engagement in an experiment with measurable outcomes. Submetering the 6th grade wing of school enabled an experiment to be conducted where the independent variable was the behavior of the 6th graders and their teachers, and the dependent variables were the measured electrical consumption and associated carbon footprint.

Such an experiment was not and is not as educationally meaningful when conducted on either a larger basis, such as the entire school, or a smaller basis, such as a single appliance. The reasons are presented in the following paragraphs.

Conducting such an experiment on a large basis was impossible where the electrical consumption for the entire school was the only means of measurement. Not only were there two other grades, but the shop, the cafeteria, the library, the main office added many confounding variables. It was thus impossible to determine whether any change in behavior in the 6th grade wing resulted in a measurable difference in electrical usage or carbon footprint. Further, a meter tucked away in the boiler room was impossible for groups of students to read and understand. Accordingly, an experiment of this nature when conducted on a large basis was not meaningful due to the confounding variables that were present and to the difficulties in accessing clear information.

Conducting such an experiment on a small basis, while allowing for very accurate measurements of electrical consumption of a single appliance, was deeply flawed as to scale. Students can readily accept that a single appliance in a dwelling uses electrical energy, but they fail to connect that to the sum of all the appliances in a dwelling. Further, conducting an experiment on a single appliance does not allow collective action to be a variable. Only where there are electricity applications in a common area, such as the hallways, the locker area, and the restroom, can collective actions have a measurable effect. Changing greenhouse gas emissions requires both individual and collective action. The aspect of collective action and collective behaviors is not addressed by an experiment involving a solitary appliance.

For the reasons described above, submetering one wing was considered far better for educational outcomes than metering either the entire school or metering a single appliance. However, the display of the metered information was also considered important given the audience of 6th graders.

It was important to display the information regarding electrical consumption and carbon footprint in an area accessible to students and in a way they could understand. The energy specialists involved on the project recommended updating the data every 30 minutes to an hour, but the teachers involved considered this far too long for the average 6th grader. Accordingly, the project showed minute by minute data. This decision was validated during the *Power Up, Power Down* experiment. Because students saw the almost immediate effect of their actions as lights and hot plates were turned on throughout the wing, they could more readily associate cause and effect. This was considered absolutely crucial by the project manager. For the students to buy into making other collective behavioral changes, such as lighting, it was vital that they see the measurable effects of five minutes of concentrated electrical demand followed by five minutes of reduced electrical demand.

The data collected from students via the pre-test and post-test instrument indicate the following areas where the greatest and most statistically significant changes occurred in knowledge and perception:

- Carbon dioxide is a greenhouse gas. (23% pre-test vs. 41% post-test)
- The US contributes over 20% of worldwide greenhouse gas emissions despite having only 5% of the world's population. (13% pre-test vs. 29% post-test)
- Producing 1 kilowatt hour of electricity emits about 1 kilogram of CO_2. (8% knew this pre-test, vs. 55% post-test. Alternatively, 75% did not know the amount pre-test, vs. 31% post-test)
- Students felt ineffective in changing greenhouse gas emissions. (50% pre-test vs. 25% post-test.)
- Students believed that they had reduced greenhouse gas emissions in the past and planned to do more in the future. (22% pre-test vs. 52% post-test)
- Students believed that relying on solar energy was the most important factor in reducing greenhouse gas emissions. (38% pre-test vs. 24% post-test)

While the author of this report would have preferred greater gains in knowledge and a greater shift in perception, the results were considered favorable, and a justification for the project. The student engagement in the project and sense of control over the outcome is considered a reason for the favorable outcomes. Because the students could see the minute by minute spike in collective electrical demand and carbon footprint during the Power Up, Power Down experiment, they realized that actions in individual classrooms affected electrical use and carbon emissions. Then, when they voted in the Town Hall assemblies to cut back on the lights, they saw the very next day that their actions had direct and observable consequences. Thus, they were more than passive spectators in a process, but had some control over the outcome. One theory holds that as individuals gain a sense of control over their environment, to include their learning, they are more likely to learn (Rotter, 1966).

Summary:

Submetering the 6th grade wing of Seneca Ridge Middle School combined with collective actions of the students caused significant gains in learning and significant shifts in perceptions by students.

References:

Rotter, J. B. (1966). Generalized expectancies for internal versus external control of reinforcement. *Psychological Monographs, 80,* whole issue.

Exhibit 1: Instrument for student completion

Place a check mark next to the best response to the statements and questions below.
1. Global warming is real. Earth's average temperatures have been increasing in recent years
True
The evidence is unclear
False
I don't know
2. Places on Earth most at risk to global warming are
Deserts
Polar regions, such as the Arctic
Suburban regions, such as where we live
Cities
I don't know
3. The term *greenhouse gas* refers mainly to
Ozone and other gases that trap ultraviolet radiation coming from the sun to Earth
Carbon dioxide and other gases that trap infrared radiation coming from the Earth
I don't know
4. The statement that *Human Activity is Causing Global Warming* is
Not proven scientifically, but probably true
Proven scientifically
False
I don't know
5. The U.S., with about 5% of the world's population, contributes about what % of greenhouse gases to the atmosphere?
Less than 5%
5%
Between 6% and 20%
Over 20%
I don't know
6. Other than transportation (cars, trucks, airplanes) the major source of greenhouse emissions in the U.S. is
Energy used to heat, cool, and light our buildings, including this school
Industrial use
The computer
I don't know

7. When I turn on the lights, a television, or a computer
I simply don't think about how much electricity it uses, nor do I care
I don't think about how much electricity it uses, but I care
I am aware of how much electricity is used, and I care
8. Producing a kilowatt hour of electricity usually produces about how much CO_2?
About a milligram
About a gram
About a kilogram
I don't know
9. When it comes to global warming and greenhouse gas emissions
I have no desire to do anything about it
I would like to reduce greenhouse gases, but am too young to be effective
I am already doing everything I can
I have already helped reduce gases, and plan to do more in the future
10. The most important factor in reducing greenhouse gas emissions by people will be
Relying on solar energy
Having individuals change their behavior as to the use of things that use energy
Having both new laws, new technology, and individual changes in behavior
I don't know
11. At home, when it comes to using lights and other devices using electricity
I do a good job of conserving energy
I help others to conserve energy
I am neutral – I don't do much to either consume or use energy
I waste a lot of energy