David W. Goodman. (2015). Effects of an Informal Energy Exhibit on Knowledge and Attitudes of Fourth Grade Students. *Journal of Education and Learning.* Vol.9 (2) pp. 145-157.

Effects of an Informal Energy Exhibit on Knowledge and Attitudes of Fourth Grade Students

David W. Goodman*
Indiana University-Purdue University Indianapolis (IUPUI)

Abstract
The public has limited knowledge of renewable energy technologies. An increase in energy literacy can potentially lead to desired energy-related behavioral changes in the future. One potential solution is to increase the public's access to renewable energy information by placing informal energy education exhibits in libraries, community centers, and parks. After calibrating the exhibit based on observations of children's interactions at a children's museum, the exhibit was displayed at a university, a private school, and a community center. The opinion surveys and interviews both showed that participants enjoyed and learned from the exhibit. Students showed no significant statistical improvement between the pretests and posttests, but interviews showed that they could recall facts, explain processes, and make inferences from the exhibit. Fourth-grade students can benefit from interacting with an informal energy exhibit in order to increase their knowledge of energy topics and technologies.

Keywords*: Informal; Energy; Education; Elementary; K-12; Energy Education; Informal Education; Science Education; Environmental Education; Knowledge; Attitudes; Exhibit; Museum*

*David W. Goodman, Assistant Professor, Engineering and Technology Department, Indiana University-Purdue University Indianapolis (IUPUI), Indianapolis, Indiana, Unites States of America.
E-mail: *dwgoodma@iupui.edu*

Introduction

Energy security requirements and the desire to create a safe, sustainable environment necessitate a gradual transition from fossil fuels to new and emerging energy solutions. An important component of addressing future global energy challenges will be public understanding and acceptance of clean energy technologies as safe and reliable sources of transportation fuels, energy storage, and power generation. Creating a highly educated workforce that will strive to overcome energy challenges and increase public awareness of challenges and opportunities are essential in bringing about this transition (Rosentrater & Al-Kalaani, 2006). Informal science education can be used to promote energy literacy at all levels by providing opportunities for the public to interact with energy technologies in a community setting (Falk, 1997). Educating youth through informal channels strengthens formal school learning and provides early exposure to concepts and applications (Cox-Petersen, 2003).

For children, opportunities to engage in informal science learning can include books, community activities, Internet sites, and television programs (Korpan, et al., 1997). Conversations with peers and parents can also become learning experiences which may include explanations which help them gain understanding (Crowley & Siegler, 1999). Ash conducted studies investigating the interaction of parents and children during multiple museum visits. Observations revealed that parents gave explanations, modeled inquiry skills, developed scaffolding, and activated prior knowledge, allowing their children to reach a new zone of proximal development (Ash, 2003, 2004). Because museums and community centers are inherently social environments, children's interactions with their peers also play an important role in their learning. This social negotiation of meaning involves collaborative groups putting knowledge together and constructing understanding (Cole & Wertsch, 1996).

The goal of the proposed research was to expand efforts in new and emerging sustainable energy education. Informal science education methods were applied to the energy discipline to provide public exposure to the high-profile concept of hydrogen and fuel cell technology. Specifically, a museum-style exhibit exposed children to energy concepts before they learned of these in a formal setting in the hope that the early exposure will motivate them to take an active role in future energy solutions.

This preliminary research was the first step in a large-scale, informal energy education program covering multiple energy technology areas (e.g., solar, wind, bio-energy). The vision is to develop several permanent energy exhibits throughout a local university and the community to promote overall energy literacy. This type of setting bears resemblance to the natural world, where the opportunity for informal education is everywhere (Ramey-Gassert, 1997).

Methodology

This study utilized a mixed method design, which can yield richer, more valid, and more reliable findings than quantitative or qualitative designs alone (Berkowitz, 1996). The qualitative portion had a larger role and included observations and interviews. Observation data was obtained at a children's museum in a medium-sized city while two fourth-grade classes visited the museum for two hours each. Both observations and interviews were conducted when students visited the exhibit for up to 30 minutes at a public university, a Christian school, and a community center. Interviews at the university and community center took place directly after participants finished interacting with the exhibit; interviews at the school occurred 4 to 28 hours after interaction. The interviews were conducted in groups of two or three and were recorded on digital audio recorders for later transcription and analysis.

Table 1. Research Protocol

Participants	Context	Methods	Data	Analysis
2 - 4th grade classes (n=47)	Museum	Observation	Field Notes	Reflection
4th graders (n=2)	University	Observation, Interview, Knowledge Assessment, Opinion Survey	Field Notes, Transcriptions, Pre/posttest, Survey	Reflection, Open Coding, Statistical
2 - 4th grade classes (n=34)	School	Observation, Interview, Knowledge Assessment, Opinion Survey	Field Notes, Transcriptions, Pre/posttest, Survey	Reflection, Open Coding, Statistical
4th graders (n=7)	Community Center	Observation, Interview	Field Notes, Transcriptions	Reflection, Open Coding

The quantitative portion of the study was conducted in conjunction with the interviews. Although the researcher attempted to randomize the pretest groups, they will be considered nonequivalent due to the stratification and reliance on volunteers. Cognitive and affective change of the groups were compared within and across groups using a multiple choice and open-ended survey for knowledge change and a three-point Likert scale survey for attitude change assessments. The pretest was given to a small, randomly selected subset of students at the school two hours before the participants visited the exhibit, and the posttest was given in conjunction with the interviews. The research methods are shown for both qualitative and quantitative protocols in Table 1.

Population and Sample

The participants were fourth-graders belonging to one of three categories: 1) students on a field trip with their teacher, 2) students on a field trip with their parent, and 3) students in small groups without adults. Those observed at the museum were from a rural area or adjacent small town (population less than 2,000). The participants at the university and elementary school were from a private, Christian school in a medium-size city (population around 150,000). The participants at the community center were from home school associations in the same city. The population for the study included those that volunteered for either written assessments of knowledge and attitude or both the written assessments and interviews.

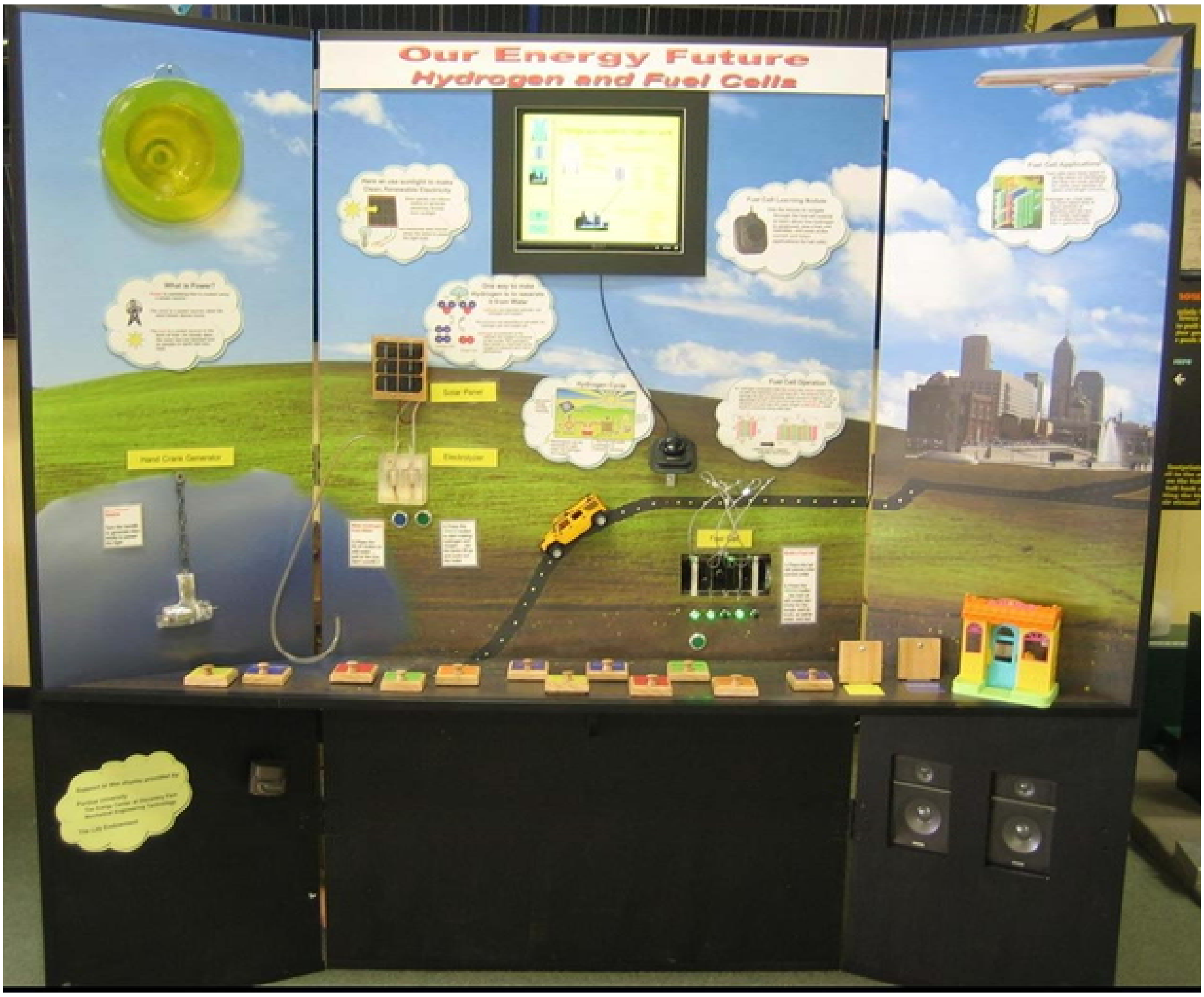

Figure 1. Energy exhibit arranged in four learning zones and two experience levels.

Exhibit

The exhibit, shown in Figure 1, was separated into four learning zones and two experience levels. The first zone covers general energy topics and provides information about what energy is, gives examples of various sources of energy, and is located in the first two feet width of the exhibit. The second zone provides information on the process of electrolysis and how hydrogen fuel is created and stored. The third zone provides information about fuel cells and how it uses hydrogen, and the fourth zone provides information about the applications of fuel cell technology. All of the information is also conveyed in an interactive PowerPoint™ presentation displayed on a monitor in the center of the exhibit. The more interactive elements—hand crank generator, electrolyzer, flip questions, and fuel cell puzzle, displayed in Figure 2—and simple descriptions are placed at a lower height level to target participants with a lower developmental level. More complicated diagrams, informational signs, instructions, and the interactive PowerPoint™ slides are at a higher height level to target adult experience level learners.

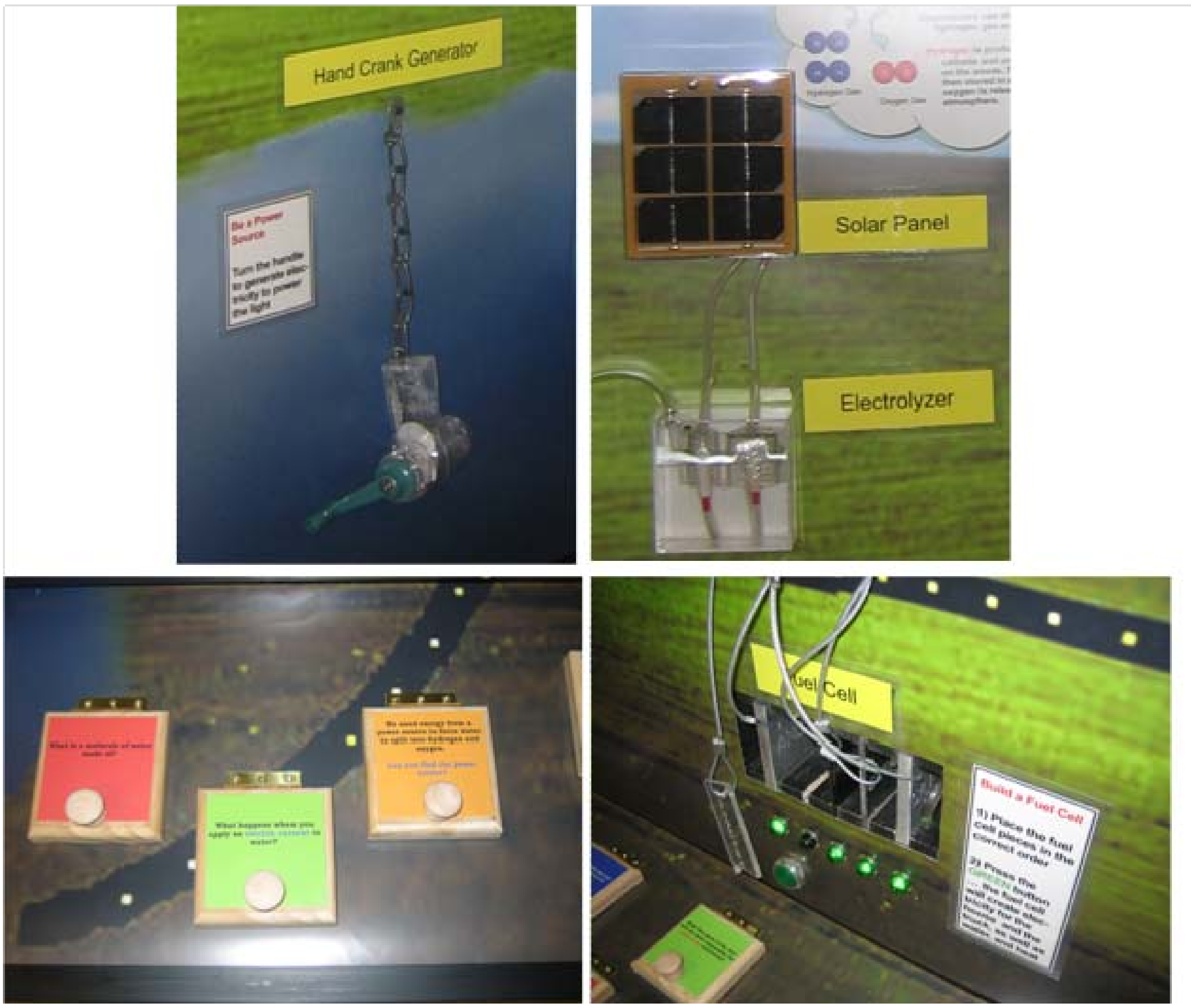

Figure 2. Interactive elements of the energy exhibit, clockwise from top left: hand crank generator, solar panel and electrolyzer, fuel cell puzzle, and flip questions.

Falk found that labeling an exhibit with a concept title significantly improved the understanding of the visitors (1997). Therefore, the initial design of the fuel cell exhibit was altered to include the title “Our Energy Future: Hydrogen and Fuel Cells” as well as labels on the various elements, which provides a foundation for storing and retrieving information. Inkpen, et al. showed that children tend to play in groups and that groups have a significant impact on learning compared to individual learning (1995). Thus, the exhibit concepts were separated into four areas to allow visitors to naturally gather around a concept and share their ideas within their group. The exhibit was also designed from a social constructivist viewpoint allowing group interaction, active involvement, purposeful manipulation of objects, and inter-group discussion, which were identified as important factors in learning by Falk (Cox-Petersen, 2003).

Instrumentation

Three instruments were used—a knowledge assessment (see Appendix A), attitude assessment (see Appendix B), and personal interviews. The knowledge assessment was a multiple choice, open-ended survey developed from a subset of the National Energy Education Development Project (NEED) assessment dealing with the specific target concepts of the energy exhibit, along with questions taken directly from the exhibit signage (2008). A Likert scale modified from the original Scientific Attitude Inventory (SAI) survey was used to assess attitude (Moore, 1997). Questions from both assessments and research questions, acted as a semi-structured guide for the interviews, though not every question was asked of each participant.

Data Collection

This study included three distinct phases of data collection. Observation data and field notes were taken at the children's museum. The data recorded how children interacted with the exhibit, how long and how often they visited a topic area, and if there were any physical barriers to learning. The second phase includes results from a pilot group at the university which suggested no changes. The final phase included observation, interview, and written assessment data from the school and community center.

The qualitative portions of data collection utilized in-depth, open-ended interviews and direct observation. Direct observation allowed the researcher to collect the subjects' experiences, by recording body language, patterns of interaction, and other insights. The interviews were used to collect an individual's own words about how he or she interpreted the experience or what the experience meant.

For the interviews the researcher utilized an interview guide approach: the interview was conducted from a list of topics and issues, not specific questions with exact wording asked in a set order. This method allowed the collection of more comprehensive data and the ability to fill in gaps with relevant follow-up questions.

Results & Discussion

Children's Museum

The researcher acted as a non-participant, remote observer at the children's museum over a two hour period with two fourth-grade classes. The researcher focused on determining how children and adults interacted with the exhibit, what they touched and read, how much time they spent in each zone, and what physical barriers to learning may have been present. Observations revealed that students tended to interact with the exhibit multiple times, usually for less than one minute each time, before moving on to other exhibits. During early visits the children would manipulate the interactive elements, such as flipping the questions, pressing the buttons, and touching the car. Between the third and fifth visit they would typically spend more time at the exhibit, especially in the hand-crank generator and electrolysis zones which were easy to manipulate without reading or scaffolding. Few children took the time to figure out the fuel cell puzzle, which when properly aligned starts the car wheel spinning and turns on the house lights, but after a few provided scaffolding to others it became very popular. Less than five percent of the children figured out how to use the PowerPoint™ display, and even after watching others, less than ten percent continued interacting with it for more than 15 seconds due to difficulties with the optical mouse.

Very few (less than five percent) participants seemed to read the signs, which was interpreted based on the tilt of the head because their eyes could not be seen. Most children changed zones or exhibits if their interaction did not provide a visual or auditory response within ten seconds. The fuel cell puzzle was an exception that required interaction 3 to 12 times longer but became very popular after the conditions required for a response became known.

Initially, an optical mouse was utilized to engage with the PowerPoint™ display, but as a result of the observed operational difficulty, the optical mouse was replaced with a mouse designed by the researcher utilizing video arcade controls. The researcher was also concerned that flip questions and interactive elements may have been too high for the target audience, but observation revealed that no changes were required.

Elementary School

The bulk of the data was collected at the elementary school. The breakdown of participants by location and assessment instrument are shown in Table 2. Due to the number of participants, mathematical analysis was only conducted on data from the school location knowledge tests and opinion surveys, though interviews were analysed from all locations.

Table 2. Student Participation

Location	Population	Knowledge Test	Opinion Survey	Interview
University	-	2	2	2
School	34	34	34	20
Community Center	-	7	7	1

Knowledge Test

The raw test data were entered into a Microsoft Excel™ spreadsheet. Each question was assigned a (C) for a correct response or (I) for an incorrect response. A correct response for questions with multiple answers was determined by adding positive and negative replies into an overall response, considering a net positive response correct and a net zero or negative response incorrect. For example, question H states "What does a fuel cell produce?" Per the exhibit, the most correct response is "electricity, heat, and water," which is a net positive of three and would be graded as correct. A correct grade could also be received by stating only one of the three desired answers. However, if the student responded "heat and fire" or "hydrogen and oxygen", then the question would be graded as incorrect due to a net zero and a net negative two response, respectively. Table 3 shows the pretest and posttest performance data analyzed by question. Questions A, B, and J through R were taken from the NEED material and were designed to determine prior general energy knowledge. The remaining questions were taken directly from the exhibit and designed to determine specific renewable energy and fuel cell knowledge.

Mathematically, the student performance on the general energy questions improved slightly compared to the pretest but declined for the specific renewable energy and fuel cell questions. The questions addressed on the exhibit by the flip questions fared much better than those addressed by the interactive PowerPoint™.

Table 3. Pre/Posttest Performance

Question A		Question B		Question C		Question D		Question E	
Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
20%	24%	40%	47%	0%	15%	0%	3%	0%	3%
Points Difference		Points Difference		Points Difference		Points Difference		Points Difference	
4		7		15		3		3	
Question F		**Question G**		**Question H**		**Question I**		**Question J**	
Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
0%	0%	0%	6%	0%	26%	0%	18%	80%	62%
Points Difference		Points Difference		Points Difference		Points Difference		Points Difference	
0		6		26		18		-18	
Question K		**Question L**		**Question M**		**Question N**		**Question O**	
Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
60%	44%	0%	29%	40%	56%	60%	74%	20%	26%
Points Difference		Points Difference		Points Difference		Points Difference		Points Difference	
-16		29		16		14		6	
Question P		**Question Q**		**Question R**		**Question S**		**Question T**	
Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest
60%	59%	60%	74%	60%	62%	0%	3%	40%	12%
-1		14		2		3		-28	
Points Difference		Points Difference		Points Difference		Points Difference		Points Difference	
Question U		**Question V**		**Question W**		**Question X**			
Pretest	Posttest	Pretest	Posttest	Pretest	Posttest	Pretest	Posttest		
60%	35%	20%	35%	80%	44%	100%	62%		
Points Difference		Points Difference		Points Difference		Points Difference			
-25		15		-36		-38			

Opinion Survey

The raw opinion data were entered into a Microsoft Excel™ spreadsheet. The first section titled "Public Understanding" included five questions taken directly from the SAI assessment. The second section titled "Energy" included 11 questions, which were modified from the SAI assessment by changing the word 'science' to 'energy'. Both sections utilized positively and negatively worded questions. Positively worded questions such as, "Every person should understand energy," were given a numerical value of three for an agree response, two for a not sure response, and one for a disagree response. Negatively worded questions like, "Most people are not able to understand energy," were given the opposite numerical value—a score of three for disagree, two for not sure, and one for agree. The questions in the third section, "Predisposition," asked participants about their self-perceived ability in math and science, and the questions in the fourth section, "Energy," asked participants if they enjoyed the exhibit and believed they learned from it. Tables 6 and 7 illustrate the raw data. Because the ordinal scale does not give any indication of the magnitude of the differences between the ranks, the highest measurement of central tendency that could be performed with this scale is the median operation (Sekaran, 2003).

Interviews

Participants' understanding of energy topics related to the exhibit, as well as their methods of constructing their understanding, were queried during the interview process. Several questions were asked about participants' understanding related to research question 1: What do fourth-grade students know about hydrogen and fuel cells? Responses about their prior knowledge of energy, hydrogen, and fuel cells mostly indicated that they had not encountered these topics in a structured educational environment, but they anticipated seeing these topics in future school years.

Several questions were also asked about participants' understanding related to research question 2: How do fourth-grade students construct knowledge about hydrogen, fuel cells, and energy at an informal exhibit? First asked about whether they believed they learned from the exhibit, responses included, "I don't remember anything, but the questions where the flap goes up were interesting. I think I learned stuff from that," and, "Definitely, a lot about science. I learned a lot about how to use electricity."

Asked whether they enjoyed the exhibit or were interested or motivated by it, students responded that they enjoyed the hands-on nature and found it preferable to simply reading about the topics. Participants were also asked about the ways they constructed knowledge about the exhibit topics or perceived barriers to learning, giving responses indicating their use of experimentation and scaffolding, as well as a potential barrier in the use of scientific jargon.

Several questions were asked about participants' understanding related to research question 3: What parts of the exhibit contribute most to students' knowledge or attitudes, if any? Bamberger and Tal found that when learners activate prior experience during informal exhibits they label the experience as learning, but if they do not connect to prior experience, they label the experience as fun (2006). Students cited the various hands-on features of the exhibit as being the parts they learned from most, with responses like, "The best part was when you had to figure out how to make electricity [with the fuel cell puzzle]. Yeah, it didn't stay in there its own way, so I just pushed it with one hand and pressed the button. It was hard."

Summary

Observations at the museum revealed how children without adult assistance interacted with an energy exhibit. The children tended to visit the exhibit multiple times with each revisit resulting in deeper interaction. Children that were more interested spent more time and became knowledgeable enough to help scaffold other children into using more complex portions of the exhibit. However, very few ever figured out how to use the optical mouse, and thus the interactive PowerPoint™; therefore, the mouse was replaced before the exhibit was taken to other locations.

The next location for data collection was the university, which acted as a pilot of all three instruments before starting phase 3. Students interacted with the exhibit and provided feedback on the knowledge test, opinion survey, and interview process. The participants recommended no changes to the instruments.

Participants at the private, Christian school interacted with the exhibit next and provided data that revealed slight improvement in the knowledge test scores. However, the interview process revealed that participants had considerably more knowledge about the exhibit than was revealed by the knowledge test scores. The vast majority of participants stated on the opinion survey that they enjoyed the exhibit and that they learned from the exhibit. However, the interview process revealed far fewer participants could elaborate about how they learned. Finally, the exhibit was taken to a community center but poor participation did not warrant separate analysis, and the interviews were analyzed with the school data.

Conclusions

Quantitative Assessments

When the pretest and posttest performance data were compiled, the Microsoft Excel™ Data Analysis Tool Pack was used to calculate the basic descriptive statistics for each data set. These statistics consist of values for mean, standard error, median, mode, standard deviation, sample variance, kurtosis number, skewness, range, minimum, maximum, sum, and count. This analysis was performed on the pretest and posttest data sets and between the posttest data sets. Table 4 shows the basic descriptive statistics for the pretest and posttest data sets and revealed a positive reduction in error and deviation.

Table 4. Basic Descriptive Statistics

Operation	Pretest	Posttest
Mean	33.333333	34.06863
Standard Error	8.0147434	1.754505
Median	41.666667	35.41667
Mode	#N/A	37.5
Standard Deviation	17.921511	10.23044
Sample Variance	321.18056	104.6618
Kurtosis	-1.681519	-0.279147
Skewness	-0.754039	-0.464424
Range	41.666667	41.66667
Minimum	8.3333333	8.333333
Maximum	50	50
Sum	166.66667	1158.333
Count	5	34

There was a small increase in mean scores from pretest to posttest; however, in order to determine if the difference was significant a paired t-test was performed on the data sets. The paired t-test null hypothesis stated that the posttest was equal to the pretest, and the alternative hypothesis stated that the posttest was greater than the pretest on the 95% significance level (Ho:U1=U2,Ha:U1>U2-95% significance level). The test calculated the sample size, mean, standard deviation, t-stat, degrees of freedom (df), P-value, and a final analysis of the data set. It was determined that if the P-value was less than or equal to 0.05 (95% significance level), the null hypothesis was rejected; if the P-value was greater than 0.05, the alternative hypothesis was rejected. Table 5 shows the paired t-test for the pretest vs. posttest and shows that there was no significant difference between knowledge test scores due to exposure to the exhibit at the 95% significance level.

Table 5. Pretest vs. Posttest Paired t-Test

$H_o: U_1 = U_2, H_a: U_1 > U_2$ – 95% Significance Level								
Data Set		Sample Size	Mean	Standard Deviation	t-stat	df	P-value	Final Analysis
U_2	Pretest	5	33.33	17.92	-0.487	4	0.3145	Reject Alternative Hypothesis
U_1	Posttest	34	34.07	10.23		33		$CI_{95\%}$ (t=-0.487, df=35, P<=0.3145)

Qualitative Conclusions

The student opinion surveys, as shown in Table 6, indicate that they believe that the public can and should understand energy topics, yielding a median score of 3.0 on a 3.0 scale. The results also show that they feel capable of tackling energy issues and are favorable toward the field but unwilling to personally commit, yielding median scores of 2.5 for predisposition and 2.0 for energy respectively. They were also very favorable toward the exhibit with a median score of 3.0. Large majorities also indicated, as shown in Table 7, that they learned from and enjoyed the exhibit, with median scores of 3.0.

Table 6. 4th Grade Student Opinion Survey Performance Results

	Public Understanding						Energy						Predisposition						Exhibit					
Posttest	1’s	1.5’s	2’s	2.5’s	3’s	n=	1’s	1.5’s	2’s	2.5’s	3’s	n=	1’s	1.5’s	2’s	2.5’s	3’s	n=	1’s	1.5’s	2’s	2.5’s	3’s	n=
	5	0	9	1	19	34	5	0	16	2	11	34	2	3	8	7	13	3	1	2	1	6	24	34
	Median						Median						Median						Median					
	3.0						2.0						2.5						3.0					

Table 7. Opinion Survey Performance Results by Individual Exhibit Questions

Enjoyed Exhibit				Learned from Exhibit			
1's	2's	3's	n =	1's	2's	3's	n =
2	3	28	33	3	5	26	34
Median				Median			
3.0				3.0			

Assertions

In this study, the researcher asked questions about what children knew about renewable energy topics, what they learned from the exhibit, and their attitudes toward science, energy, and the exhibit. The findings are presented in the form of three assertions developed from the data.

Assertion 1: Fourth graders have limited prior knowledge of energy topics.

For this assertion the researcher defined limited as fewer than 60%—which corresponds to a failing grade in most school assessments—of the participants expressed an understanding of exhibit topics such as energy, hydrogen, fuel cells, or renewable energy. In this context, knowledge means that participants were able to identify renewable energy sources, define energy, and be aware of at least some of the various energy technologies. Each child goes through some form of formal education which prepares them to function in the world around them. Although most children may not need to concern themselves with energy issues in their elementary years, a good foundation may help them make wiser decisions in the future.

When participants in this study were asked about hydrogen and fuel cell technology, they had no comments. Asked to define energy, all but one student had no comment. When asked about energy sources, 8 of 37 (22%) responded with one or two of the following: wind, solar, water, coal, gas, oil, animal, and ethanol. However, when asked whether they used energy, nearly all gave several examples such as physical activity, lights, TV, and video games. Based on the responses, the researcher concluded that participants have little depth of understanding about exhibit topics and that their understanding may be compartmentalized rather than part of a cohesive concept map.

State standards in the study area do not require study of renewable energy topics until sixth grade, but some topics are discussed earlier in general science lessons (IDoE, 2004). The prevalence of adult discussion about energy, the availability of internet information, and informal/formal field trips to museums and learning centers have also contributed to some understanding of energy topics. Exposure to these topics was limited, however, and without better exposure, there is little chance that students will develop knowledge and attitudes that lead to 'citizenship behavior' (Hungerford and Volk, 1990). Therefore, the exhibit used in this study, others like it, and other energy outreach education methods are necessary and should continue to be researched, refined, and implemented.

Assertion 2: Fourth graders have positive attitudes toward science, energy, and the exhibit.

For this assertion the researcher defined positive attitudes through the terms used by participants. Terms such as fun, cool, and interesting were considered positive, and terms such as hard or boring were considered negative. Per the opinion survey, 87% of the participants stated they enjoyed the exhibit, and 45% of the participants believed science was important. With respect to energy, working on energy issues, and choosing an energy career, participants had 13 favorable responses versus 5 negative responses. Though the energy portion of the survey was based on the standard SAI instrument, two interview comments support that the section may be skewed; two of the questions directly ask children whether they want to work in energy-related fields, which would force a negative response from anyone who had already chosen a career path.

All interview participants had positive responses about the exhibit. When asked about energy, fuel cells, or hydrogen only 2 of 37 had mixed or negative responses; one participant stated "Complicated, [but] fun to learn. It's a fun way to do it." Another student stated:

Well, it is flammable, so I would have to say that it is very dangerous to, um, use with if you like, if you mess with fire, you know. If a kid, um, would have bottle [sic], and he's playing with that hydrogen, and then he think [sic] that he could put out fire or just by just dropping it in [inaudible] people could lose homes, valuables.

Though complicated generally has a negative connotation, with the remainder of the statement it was counted as a positive attitude. Similarly flammable could be considered simply factual, but based on field note comments it was counted as the lone negative response. Based on the survey and interview responses, the participants clearly had very positive attitudes toward the exhibit, implying that participants have positive attitudes toward energy, as well.

Assertion 3: Fourth graders increased their knowledge of energy and renewable energy due to interacting with the energy exhibit.

For this assertion the researcher defined increase in knowledge as any recalled fact, description, or explanations related to hydrogen, electrolysis, or fuel cells because based on assertion 1 they had no prior knowledge in these specific areas. Based solely on the statistical evidence, this assertion would be rejected, but the interviews provide many rich descriptions and facts that contradict the knowledge assessment scores.

Per the survey, 74% of participants claim they learned from the exhibit. Per the interviews, 97% stated that they learned from the exhibit, though many did not cite specific examples. Asked about their knowledge of hydrogen, electrolysis, and fuel cells based on their experience with the exhibit, students recalled facts about the various technologies displayed in the exhibit and described how those technologies work. Despite the analysis showing no statistical improvement in knowledge, the qualitative data clearly shows that participants could recall information, explain processes, and make inferences from the exhibit.

Summary Conclusion

The results of this study suggest that fourth-grade students can benefit from interacting with an informal energy exhibit. The participants learned facts about energy and showed positive attitudes toward both the exhibit and energy topics, which are a necessary step toward desired future 'citizen behavior' (Hungerford and Volk, 1990). Although many factors will influence future behavior, each opportunity to positively interact with energy topics may also increase the potential for desired future behaviors, and thus similar energy exhibits should be made available to the public. Informal energy education is a relatively unexplored area that could also benefit from research into reliable, validated knowledge and attitude test instruments, as well as a better understanding of barriers to learning and how exhibit designs can counter those barriers to help participants develop a more cohesive concept of energy across various topics and technologies.

References

Ash, D. (2003). Dialogic inquiry in life science conversations of family groups in a museum. *Journal of Research in Science Teaching*, 40, 138-162.

Ash, D. (2004). Reflective scientific sense-making dialogue in two languages: The science in the dialogue and the dialogue in the science. *Science Educatio*n, 88, 855-884.

Bamberger, Y. & Tal, T. (2006). Learning in a Personal Context: Levels of Choice in a Free Choice Learning Environment in Science and Natural History Museums. *Science Education*, 91, 75-95.

Berkowitz, S. (1996). *Using Qualitative and Mixed Method Approaches*. R. Reviere, S. Berkowitz, C.C. Carter, and C. Graves-Ferguson, Eds. Washington: Taylor & Francis Publishers.

Cole, M., & Wertsch, J. V. (1996). Beyond the individual-social antinomy in discussions of Piaget and Vygotsky. *Human Development*, 39, 250-256.

Cox-Petersen, A. M., Marsh, D.D., Kisiel, J., & Melber, L. M. (2003). Investigation of guided tours, student learning, and science reform. *Journal of Research in Science Teaching*, 40(2), 200-218.

Crowley, K., & Siegler, R. S. (1999). Explanation and generalization in young children's strategy learning. *Child Development*, 70, 304-316.

Falk, J. H. (1997). Testing a museum exhibition design assumption: Effect of explicit labeling of exhibit clusters on visitor concept development. *Science Education*, 81(6) 679-687.

Hungerford H.R. and T. Volk. (1990). Changing learner behavior through environmental education. J*ournal of Environmental Education*. 21(3): 8-21.

Indiana Department of Education (IDoE). (2004). *Indiana science standards grade 4-5*. Retrieved from http://www.doe.state.in.us/standards/Docs-2004/English/.

Inkpen, K., Booth, K.S., Klawe, M., & Upitis, R. (1995). Playing together beats playing apart, especially for girls. Proceedings of *Computer Supported Collaborative Learning (CSCL) '95*. Lawrence Erlbaum Associates, 177-181. Retrieved from http://www.cs.sfu.ca/people/Faculty/inkpen/Papers/CSCL95/cscl95.html.

Korpan, C. A., Bisanz, G.L., Bisanz, J., & Henderson, J. (1997). Assessing literacy in science: Evaluation of scientific news briefs. *Science Education*, 81, 515-532.

Moore, R. W., Hill Foy, R. L. (1997). The Scientific Attitude Inventory: A Revision (SAI II). *Journal Of Research In Science Teaching*, 34(4), 327–336.

National Energy Education Development Project. (2008). Energy Polls. Retrieved from http://www.need.org/educators/.

Ramey-Gassert, L. (1997). Learning science beyond the classroom. *The Elementary School Journal*, 97(4) 433-450.

Rosentrater, K. A. & Al-Kalaani, Y. (2006). Renewable energy alternatives – a growing opportunity for engineering and technology education. *The Technology Interface*, 6(1), Spring 2006. Retrieved from http://technologyinterface.nmsu.edu/Spring06/.

Sekaran, U. (2003). *Research Methods for Business, a Skill Building Approach*. (4th ed). John Wiley & Sons, Inc.

Appendices

Appendix A: Knowledge Assessment

Question									
A)	The sun and wind are two power sources that can be used to create energy. Can you think of others?								
B)	What is a molecule of water made of?	A)	Hydrogen	B)	Oxygen & Carbon	C)	Nitrogen	D)	Hydrogen & Oxygen
C)	What happens when you apply an electric current to water?								
D)	What is a fuel cell?								
E)	What are the four main parts of a fuel cell?								
F)	What part of the fuel cell causes the hydrogen to split?								
G)	What part of the fuel cell allows only the positive hydrogen ions to pass through?								
H)	What does a fuel cell produce?								
I)	How much pollution does a fuel cell produce?								
					Fossil Fuel		Renewable		
J)	Are the following sources considered fossil fuels or renewable sources?		Oil		____		____		
K)			Solar		____		____		
L)			Geothermal		____		____		
M)			Natural Gas		____		____		
N)			Water		____		____		
O)			Hydrogen		____		____		
P)			Wind		____		____		
Q)			Coal		____		____		
R)			Gasoline		____		____		
S)	What are fuel cells used for?	A)	Storage of energy	B)	Conversion of energy	C)	A source of fuel	D)	All of the above
T)	What process splits water into hydrogen gas and oxygen gas?	A)	Electrolysis	B)	Solar	C)	Catalyst	D)	Electricity
U)	What does a solar panel (photovoltaic) produce?	A)	Pollution	B)	Water	C)	Electricity	D)	Heat
V)	What may limit the use of fuel cells in airplanes?	A)	Size	B)	Weight	C)	Shape	D)	Electricity
W)	A hydrogen tank requires ____ space than a gasoline tank for the same amount of energy storage.	A)	More	B)	Less				
X)	Hydrogen is as safe as gasoline or diesel fuel when handled properly?	A)	True	B)	False				

Appendix B: Opinion Survey

Question		Disagree	Not Sure	Agree
1)	Most people can understand energy.	o	o	o
2)	People must understand energy because it affects their lives.	o	o	o
3)	Every person should understand energy.	o	o	o
4)	Only highly trained scientists can understand energy.	o	o	o
5)	Most people are not able to understand energy.	o	o	o
6)	Work on energy is useful only to scientists.	o	o	o
7)	I would enjoy studying energy.	o	o	o
8)	I would like to work with other scientists, engineers, and technicians to solve energy problems.	o	o	o
9)	I may not make great discoveries, but working in energy would be fun.	o	o	o
10)	I would like to be an energy scientist, engineer, or technician.	o	o	o
11)	Working on energy problems would be fun.	o	o	o
12)	The search for energy knowledge would be boring.	o	o	o
13)	Energy work would be too hard for me.	o	o	o
14)	I do not want to be an energy scientist, engineer, or technician.	o	o	o
15)	Energy scientists, engineers, and technicians do not have enough time for their families or for fun.	o	o	o
16)	Energy scientists, engineers, and technicians have to study too much.	o	o	o
17)	I usually do well in Math.	o	o	o
18)	I usually do well in Science.	o	o	o
19)	I enjoyed the energy exhibit.	o	o	o
20)	I learned from the energy exhibit.	o	o	o