The Effect of the “Ohio Schools Going Solar” Project on Student Perceptions of the Quality of Learning in Middle School Science

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Abstract

In an era of continuing developments in science and technology, teachers are faced with an increasingly challenging task of helping K–12 students become and remain scientifically literate. Effective science instruction involves activation of prior knowledge, hands-on learning, and continuous reflection. Technology has the potential to play a supporting role, and the Ohio Schools Going Solar project (OSGS) is one example of what is available. This study examines the effect of the OSGS project on student perceptions of the quality of science learning as defined by Newmann’s framework of authentic intellectual work. Results indicate a positive effect in the areas of disciplined inquiry and construction of knowledge. (Keywords: alternative energy, solar energy, student perceptions, middle school science.)

INTRODUCTION

New developments in science and technology are manifold at the beginning of the 21st century. Phenomena such as human cloning or wireless Internet access that were foreign to us twenty years ago are now part of our everyday language. Much of the new scientific knowledge is complex, highly technical, and often difficult to understand for the average person, yet it is important because of its effects on how we live and the environment we live in. Consequently, teaching K–12 students to become and remain scientifically literate has become increasingly challenging, especially when considering that the most effective ways to learn science include a wide variety of learner-centered and hands-on knowledge-building processes. The research presented here investigates how technology can play a supporting role within this context, by studying the effect of the Ohio Schools Going Solar project on student perceptions toward learning in middle school science classrooms.

Research literature on science education describes methods and models that are useful for science educators who favor this type of approach to learning science. For example, Glynn and Duit (1995) describe learning science as a process in which pre-existing knowledge is activated and related to educational experiences, intrinsic motivation to learn new information is developed, and new knowledge is constructed, applied, evaluated, and revised. Edelson (2001) proposes a similar model called Learning-for-Use. His model takes students through phases of motivation to acquire new and needed knowledge, knowledge construction, and knowledge refinement. The project-based science model (e.g., Krajcik, Czerniak, & Berger, 1999) asks students to “find solutions to real problems by asking and refining questions, designing and conducting investigations, gathering and analyzing information and data, making interpretations, drawing conclusions, and reporting findings" (Schneider, Krajcik, Marx, & Soloway, 2002, p. 411).

As their authors admit, these models are by no means new or revolutionary. In fact, there is a long line of research in science learning that forms the foundation for the recent emphasis on knowledge construction in science standards (AAAS, 1993; NRC, 1996), including theories such as discovery learning (Bruner, 1960), constructivism (e.g., Brooks & Brooks, 1993), and problem-based learning (e.g., Torp & Sage, 1998). In fact, most of the models share aspects of learning processes that are considered to be essential for students to become and remain scientifically literate. For one, the models emphasize the importance of linking learning of new scientific knowledge to pre-existing knowledge to provide a "hook" to grab and reel in new information (e.g., Bransford, Brown, & Cocking, 2000; Newmann & Associates, 1996). In addition, active student involvement in knowledge construction is seen as essential (e.g., Brooks & Brooks, 1993; Newmann & Associates, 1996; Yager, 1995). Finally, reflection on knowledge construction is often described as a tool to help students come to a deep understanding of the structure of their knowledge, including both old and new information (e.g., Khishfe & Abd-El-Khalick, 2002; Novak & Gowin, 1984; Schön, 1983).

Technology can be helpful in this type of learning process because of its potential to "support and amplify" (Jonassen, 2000b, p. 24) activities such as data collection and visualization, meaningful thinking, problem solving, and reflection (e.g., Cajas, 2001; Jonassen, 2000a, 2000b; Kozma, 2000; Salomon, Perkins, & Globerson, 1991). Examples of supporting tools include simulation software such as SimCalc (Roschelle, Kaput, & Stroup, 2000) or Cooties (Curtis, Williams, Norris, O'Leary, & Soloway, 2003), science instruments that are remotely controlled through the Internet such as Bugscope (Thakkar et al., 2000), and software tools such as DataStudio, MicroWorlds, and Inspiration, which among other things can be used for data visualization (e.g., Jonassen, 2000a).

This study focuses on another example of supporting tools, specifically solar panel technology at a middle school in Northeast Ohio. The tools available to learners for the study of alternative energy forms and how they affect their lives include two large solar arrays located directly outside their building and connected to a desktop computer inside a seventh-grade science classroom, providing students with continuous real-time data from the arrays. In addition, students have access to seven classroom computers for Internet research, communication, and productivity purposes, and a variety of smaller solar panels, motors, and electrical components, as well as tools and building materials to experiment with and solve problems related to solar and other alternative energy sources such as wind and biomass. Finally, the classroom houses a presentation system including a laptop, document camera, and VCR/DVD player that are all connected to a projector.

To investigate student perceptions of teaching and learning in environments such as the one under study, where problem solving and inquiry are emphasized and technology is used to enhance these processes, Newmann's framework on authentic intellectual work is useful, because it fits in well with models of science teaching that favor an active and hands-on approach. The framework was originally proposed by Archbald and Newmann (1988) to guide educators in designing meaningful learning experiences (as opposed to the learning of routine facts and procedures) that better prepare students for more complex intellectual tasks such as collaborative problem-solving often required of skilled adults, and defined by Archbald and Newmann as authentic intellectual work. The framework is composed of three components (Newmann & Associates, 1996; Newmann, Bryk, & Nagaoka, 2001):

Disciplined Inquiry can be defined as the investigation into the details of a particular problem. It requires the use of one's prior knowledge, which can be used to frame a problem and what steps to take to solve it; in-depth understanding of the problem by thoroughly researching it; and elaborated communication of ideas and findings—i.e., oral or written communication that is coherent and provides both original arguments/conclusions supported by substantial evidence. Even though it is not a part of the framework, technology is helpful here because it provides student access to literally a world of information and channels of communication, as well as productivity tools (e.g., word processors and multimedia authoring tools) with which to communicate.

Construction of Knowledge involves the original application of knowledge and skills rather than just routine use of facts and procedures. Consequently, students are required to use higher-level thinking and problem-solving skills such as analysis, synthesis, and evaluation. Technology is an aid in this process in that it provides the tools to do the basic jobs more efficiently, creating time for more complex tasks.

Application Beyond the Classroom means that learning results in a product or presentation that is authentic in that it has meaning or value beyond success in school—i.e., a good grade. A simple example would be doing a presentation to a community group using a multimedia presentation tool such as PowerPoint, or providing a solution for a community problem or issue.

For purposes of the current study, student perceptions toward science learning were operationally defined as consisting of the three factors described above: (1) *disciplined inquiry*, (2) *construction of meaning*, and (3) *application beyond the classroom*.

PROBLEM/RATIONALE

Ample research is available that documents the effect of traditional uses of technology in classrooms (i.e., to learn discrete skills and facts of curriculum). James Kulik (1994), for example, did a meta-analysis of more than 500 such studies and found "motivation, on task behavior, and high levels of content acquisition" (p. 30) to be common when technology is used for classroom instruction. Although we recognize that schools must directly teach knowledge and skills, we also know that it is more important than ever for students to be taught to apply those skills to tasks they will encounter beyond school, especially in science (Newmann et al., 2001). In contrast, large-scale research is still somewhat limited when it comes to the role of technology in student-centered learning models focused on skills such as problem solving, inquiry, and authentic tasks—skills commonly identified as necessary in the digital age (U.S. Department of Labor, 1992). Some of the meta-analyses of this type of research are confident with regards to the effects of technology on higher-level learning (e.g., Sivin-Kachelo & Bialo, 1996; Valdez et al., 1999). Authors of a more recent study calculated effect sizes from 42 studies and concluded that teaching and learning with technology had a small positive effect on student outcomes (Waxman, Lin, & Michko, 2003). However, the authors point out that the results are based on a limited number of research articles, most of which lacked a randomized, experimental design and enough details to perform a thorough analysis, or were based on technology nearly a decade old. All in all though, the authors are cautiously optimistic in their findings in that they yielded effect sizes roughly twice the size of similar recent meta-analyses (.41 and .21, respectively).

Some of the smaller available research projects have focused on narrowly defined groups of students, such as disadvantaged students (D'Agostino, 1996; Knapp, Shields, & Turnbull, 1992; Lee, Smith, & Newmann, 2000), students in first, second, and eighth grade mathematics (Cobb et al., 1991; Silver & Lane, 1995), first through third grade reading, (Tharp, 1982), and high school math and science (Lee, Smith, & Croninger, 1997). In a nutshell, this research shows that students who are exposed to higher-level learning, which includes elements such as higher-order thinking and problem solving, do as well as or better than students who learn through basic-skills instruction. According to Newmann, Bryk, and Nagaoka (2001):

> One limitation is that research relevant to [complex intellectual work] has tended to focus more on specific teaching practices and techniques such as class discussion versus teacher lecture, or cooperative learning activities versus individual seatwork, than on the intellectual demands embedded in classroom assignments (p. 11).

Newmann's research on authentic intellectual work is valuable to investigate teaching and learning in environments where higher-order thinking skills such as problem solving and inquiry are emphasized, and where technology is used to amplify these processes and motivate students to learn. One such environment is the middle school science classroom highlighted here. The reason for the focus on technology in science education is that technology tends to motivate students, and increased motivation leads to increases in learning and achievement (e.g., Becker, 2000; Bialo & Sivin-Kachala, 1996). Therefore, the purpose of this research project is to study the effect of the Ohio Schools Going Solar project on student perceptions toward learning in middle school science classrooms, using Newmann's concept of authentic intellectual work as the framework. It has the potential to inform educators, legislators, and funders regarding the conditions necessary to help teachers learn to design technology-supported work that will lead to higher student motivation to learn and achievement in science in general.

Research Question

Based on existing research and the Newmann framework, the following research question was developed: What is the effect of participation in technology-infused projects such as the Ohio Schools Going Solar (OSGS) project on student perceptions of learning science, specifically focusing on perceptions related to disciplined inquiry, construction of meaning, and application beyond the classroom?

METHODOLOGY

Sample

Subjects included seventh grade science students (*N* = 99 out of a total of 132) in one middle school in Northeast Ohio during the 2001–2002 school year. There were 56 (56.6%) males and 43 (43.4%) females, primarily Caucasian, spread across five class periods. Approximately 20% of students qualify for free and reduced lunch. Class sizes ranged from 27 to 30 students, and the average response rate per class was 71.4% (*SD* = 9.4%). The reason for this seemingly low level of response is twofold. For one, not all students completed all four surveys due to absence from school and students moving in and out of the school during the year. Second, special education students were excluded from the sample because researchers did not get permission to use their responses. However, based on analysis of demographic data, the sample is representative of students in the building, if special-needs students are not considered. In addition, the seventh-grade science teacher—the only one in her building—was interviewed informally throughout and following the research project about half a dozen times, and e-mail correspondence between the researcher and teacher was also analyzed as a data source.

Procedures

In 2000, the middle school under study became the third school in Ohio to install a solar panel system to collect, analyze, and share scientific data about the sun as part of a project developed by the Foundation for Environmental Education and the U.S. Department of Energy to promote federal initiatives such as the Million Solar Roofs and Energy Smart Schools, coordinated in Ohio by the Ohio Energy Project (OEP). The main goal of these programs is to become involved in schools, educate future energy customers about the wise use of natural resources, and provide tools for future scientists and engineers. Collaboration between the school, city, and local businesses covered the expenses for the installation of the solar panels. So far, the solar panel equipment has been used to collect data that is used by the seventh grade science teacher as a component in her alternative energy sources curriculum. The curriculum addresses various learning objectives in the Ohio Standards. (See Appendix A, page 238.)

During the 2001–2002 school year, students in seventh grade science investigated alternative energy at two different times. During the fall semester, students spent about three weeks learning about solar energy and other alternative energy sources through fairly traditional whole group instruction and individual research. The whole group instruction consisted of lecture and discussion, using a variety of sources that were displayed by way of the presentation system, including notes, charts and diagrams, data from the solar arrays, images, and video. The lecture was used to transfer basic knowledge about alternative energy sources, the discussion to address issues related to the different energy sources including cost, negative effects, and feasibility of large scale implementation (Newmann component: disciplined inquiry). Students also wrote individual research papers on a particular source and used their textbooks, other print resources, the Internet, and experts as resources, and composed their writing using a word processor (disciplined inquiry). This research was later used by student teams to build a device powered by an alternative energy source (construction of knowledge), using the Inventive Curriculum Project as a resource (U.S. Patent and Trademark Office, 1997). Student products ranged from solar cars and ovens to a solar bubble gum machine and windmills. Students demonstrated these creations to their peers, explaining what they had created and how it worked. They also documented the process of creating their devices in the research paper (disciplined inquiry; creation of knowledge).

During the spring semester, students used a WebQuest to investigate a variety of alternative forms of energy, including solar, wind, geothermal, and biomass energy (Fyfe, Birch, Mair, & Ostridge, 1998). In small groups, they studied one of the forms of energy in depth (disciplined inquiry). Each student took on the role of scientist, environmentalist, economist, or consumer within his or her group. Groups constructed arguments to convince a group of visiting fifth graders that their form of alternative energy was the best one (construction of knowledge, application beyond the classroom). They also taught the same fifth graders how to create an electrical circuit powered by a solar panel (construction of knowledge). The total length of the spring unit was about two weeks.

Data were collected throughout the academic year in the form of student surveys and teacher assignments. The surveys were administered immediately preceding and following both solar energy units, for a total of four rounds of surveys. To gather student data, a survey titled "Solar Panel Technology and Student Learning" was developed (see Appendix B, page 239). Although some of the questions are based on the enGauge student survey developed by the North Central Regional Educational Laboratory (NCREL, 2001), most questions were written to specifically address the research question for this project, using the three main constructs of the Newmann framework. Expert colleagues of the researcher as well as two seventh-grade teachers from the middle school under study checked the survey for content validity and appropriateness of use with seventh graders. After discussing their suggestions, the questions were revised where necessary and appropriate.

Each survey administration followed the same procedure. At the beginning of the class period, students were instructed to read each question carefully and answer it to the best of their abilities. Surveys were collected as students finished them; there was no time limit. The researcher visited the classroom on several other occasions as an observer, including the final project presentations during the fall semester and the presentations to the fifth graders during the spring semester. This gave the researcher an opportunity to look at student projects and presentations. Additional data were collected for data triangulation, including teacher-made assignments and materials related to both units, informal interviews with the teacher, and e-mail correspondence. The teacher assignments were analyzed using the Newmann framework (see below for a detailed description), while the other data sources were examined for patterns within and across sources to investigate what the teacher thought about the impact of student exploration of various solar technologies on their learning.

Data Analysis

Student survey data were entered into SPSS 11.0 (2002). Ninety-nine students completed a survey for each of the four rounds. Reliability coefficients were calculated separately for student responses on the questions related to solar energy (α = .7436) and life science (α = .6330) across the second, third, and fourth administrations. Because results are reported in aggregate fashion, these coefficients can be considered sufficient. According to Wolf (1997),

> One can use measures with somewhat lower reliability to describe the performance of groups than one would be able to use to describe the performance of individuals. In practical terms, measures with reliabilities as low as 0.5 can be used to describe the performance of class groups. (see also Allen & Yen, 1979)

The survey data were then broken down into sections to analyze them specifically for each of the three constructs in the research question. Questions 9–12 were used to investigate the effect on perceptions of disciplined inquiry, questions 8 and 13–15 for construction of knowledge, and questions 16–19 for application beyond the classroom. Due to the ordinal nature of the data collected, frequencies and chi-square analysis were used to look for statistically significant differences between life science and science involving solar technology, both after the first and second units. Moreover, the third and fourth rounds of surveys were used to detect possible differences in student learning before and after the second solar unit was taught. The latter was not possible for the first solar unit because of the large amount of missing data on the first survey.

In addition to the survey responses, analysis of teacher assignments was conducted using rubrics based on the work of Fred Newmann (Newmann & Associates, 1996; see Appendix C, page 242). Each document was scored by two researchers (with a 95% inter-rater reliability) against seven standards including organization of information, consideration of alternatives, disciplinary content, disciplinary process, elaborated written communication, problem connected to world beyond the classroom, and audience beyond the classroom. Five of the categories were scored on a 3-point Likert-type scale, and the remaining two on a 4-point Likert-type scale. The scores were combined to yield an overall score on a 0–23 scale. Scale scores were then divided into categories that represent four levels of intellectual achievement: no challenge (0–6), minimal challenge (7–13), moderate challenge (14–19), and extensive challenge (20–23). Finally, a content analysis of teacher interviews and e-mail correspondence was performed using a constant-comparative method (Glaser, 1978) to detect potential patterns in teacher thoughts related to the effect of student exploration of various solar and other alternative energy technologies on their learning.

Results

With regards to the elements that make up disciplined inquiry, regular life science and science including solar energy were compared using survey questions 9 through 12 (Table 1).

Table 1. Comparing Life Science and Solar Science on Disciplined Inquiry

Survey question	χ^2 difference after first unit	χ^2 difference after second unit
9. Depth of understanding life science problem / 10. Depth of understanding solar science problem	21.32*	4.28
11. Amount of communication in life science / 12. Amount of communication in solar science	9.97*	.18

*$p < .05$

Questions 9 and 10 asked about the level of understanding a student tries to attain when solving a problem related to life science and solar energy respectively, a component of Newmann's concept of disciplined inquiry. After the first solar unit, students indicated they were more likely to study a problem in depth to find the best possible solution (χ^2 (2, N = 98) = 21.32, $p < .05$) when studying solar energy. After the second solar unit, students indicated no difference between the depth of understanding they tried to achieve when working on a life science problem as compared to a solar energy problem (χ^2 (2, N = 98) = 4.28, $p = .05$).

This difference in outcome may have been caused by the difference in projects for the units, even though they did not differ much when it comes to authentic and intellectual complexity, getting scores of 20 and 21 (on a scale of 23) respectively. This indicates that both assignments can be characterized as "extensively challenging." Students enjoyed the hands-on projects in the fall because of the amount of experimenting and problem solving. They mentioned this in open-ended survey responses through statements such as, "It's tons more fun than taking notes because we are inventing," and "I like how we have to think a lot more to get things working." In contrast, during the second unit, students worked in cooperative groups to learn about one of four alternative forms of energy, researching it from the perspectives of an environmentalist, economist, scientist, and consumer. Following this unit, students indicated that they had a better understanding of the alternative forms of energy, including how they work, what they cost, and how they affect the environment. However, open-ended responses did not indicate that students went as far or did as much to get a deeper understanding as they did during the first unit.

In addition, students were asked about communicating with others when working on life science problems as opposed to solar energy problems (survey questions 11 and 12; see Table 1); these items can be categorized under Newmann's idea of elaborate communication, which is part of disciplined inquiry. Following the first solar energy unit, students indicated that they tend to work more with others to find a solution when working on solar energy problems (χ^2 (2, N = 98) = 9.97, p < .05). After the second unit, there was no difference (χ^2 (2, N = 98) = .18, p = .05). Students worked in groups during both units and had the opportunity to talk to experts. In addition, students wrote research papers to go along with their solar powered devices, including a description of how they built their devices and the process they went through to get them to work.

With regards to the second element of Newmann's concept of authentic intellectual work, construction of knowledge, about 50% of students indicated they learn best in science class when they study class notes, concept maps, and weekly calendars to answer questions in class or for homework (survey question 13). Although this is consistent with the relatively low ranking of "use what I have learned in school in my life outside of school" (survey question 8; see Table 4) and seems to indicate a more traditional way of learning facts and procedures, the sequence of survey administrations did show a statistically significant upward trend in the percentage of students who said they used "new and creative ways to apply what I know and can do to a science problem" (survey question 13), from 13.8% in the first administration to 21.1% in the fourth administration (χ^2 (1, N = 95) = 5.33, p < .05). It is unclear whether this increase can be attributed to students having more experience in learning related to alternative forms of energy or life science in general (potential maturation effect).

When comparing life science to solar science regarding the nature of student knowledge construction (survey questions 14 and 15), there were statistically significant differences both after the first and second units, χ^2 (3, N = 97) = 22.99, p < .05, and χ^2 (3, N = 95) = 65.91, p < .05, respectively. After the first solar unit, students indicated that they were more likely to "do research to find the answer to a science question," and to "use new and creative ways to apply what I know and can do to a science question." After the second solar unit, students said they were more likely to "do research to find the answer to a science question."

The third and final element of authentic intellectual work is the application of learning beyond the classroom, resulting in an authentic product or presentation with meaning or value beyond success in school. The final product of the first solar unit was a solar-powered device, including a paper and a presentation. The second solar energy unit ended with student presentations to fifth graders, as well as seventh graders teaching fifth graders how to create an electrical circuit using a solar panel. Were these final products meaningful beyond the classroom? The surveys indicate that students were more interested in learning about alternative energy sources such as solar power as compared to both science and other schoolwork (Table 2).

Table 2. Student Interest in Solar Work as Compared to Other Work

Survey question	Solar more interesting (after first unit)	Solar more interesting (after second unit)
16. Compared to other school work	89.8%	75.3%
17. Compared to other science work	81.4%	63.3%

Compared to other science work, students found the first unit more interesting than the second one, χ^2 (3, N = 97) = 42.48, p < .05. Compared to other schoolwork, the first unit was more interesting to students than the second unit, χ^2 (3, N = 97) = 30.90, p < .05. Again, the difference could possibly be attributed to the different nature of each unit.

Even though interest was high, when asked about application of learning beyond the classroom, students were divided on the issue. (See Table 3.) The results in Table 3 seem to correlate with the frequency of open-ended answers (question 20), in which 29 of 98 students (29.6%) mentioned the importance of alternative resources for the environment, and 22 of 98 (22.4%) mentioned energy costs. This finding also seems to coincide with student responses related to communication with experts (survey question 18). Students indicated they communicated with experts, community leaders, or other people at most a few times in a grading period when studying alternative forms of energy (χ^2 (2, N = 98) = 43.25, p < .05. after the first unit; χ^2 (2, N = 97) = 50.61, p < .05 after the second unit).

Table 3. Application of Student Learning Beyond the Classroom

Survey question	A lot	A little
19. Learning relates to things outside of school (after first unit)	44.4%	55.6%
19. Learning relates to things outside of school (after second unit)	38.1%	61.9%

Overall, the data tend to indicate that disciplined inquiry and knowledge construction were more important to students than value beyond the classroom. When asked what they do while studying solar panel technology, students indicated that they were most likely to communicate with classmates about what they were learning (disciplined inquiry), which was also reflected in statements provided in an open-ended question at the end of the survey: "It is fun to see what my classmates and I have come up with," "I like teaching other people about solar energy," "I can give info to others," and "I like getting others' opinions." This was followed by the application of prior knowledge (disciplined inquiry) to learn new things as indicated by statements such as "I enjoy the hands-on experience and *using what I know* to solve problems." The ranking for the other three responses (related to knowledge construction and application beyond the classroom) to this question differed between the first and second solar unit (Table 4).

Table 4: Rank of Student Use of Knowledge in Solar Energy Units

	Unit	
Rank Order	1	2
1	"communicate with people outside of school about what I'm learning"	"communicate with classmates about what I'm learning"
2	"use things that I know to learn new things"	"use things that I know to learn new things"
3	"create my own questions"	"create my own questions"
4	"use what I have learned in school in my life outside of school"	"use what I have learned in school in my life outside of school"
5	"communicate with classmates about what I'm learning"	"communicate with people outside of school about what I'm learning"

Informal teacher interviews and e-mail correspondence seem to confirm the findings from the survey. Content analysis of the raw data yielded the following themes: First, students used more technology, allowing for more creative and inventive processes. For example, one group of students used a small solar panel to run "a flicker checker that was used in the classrooms to check for the efficiency of the fluorescent lighting in the school" (Teacher e-mail, 1/28/02). Second, students were more focused and motivated, working more and better in class as well as at home. One student created a variety of electrical circuits powered by solar panels, learning from his father, who is an electrician (Teacher interview, 5/10/02). Third, students became knowledgeable about alternative forms of energy that relatively few people know about, took ownership in this knowledge and presented it in a convincing way. The teacher even mentioned that some of them "knew more than I did!" (Teacher e-mail, 1/28/02).

DISCUSSION

The results from this study indicate that the curriculum and technology associated with the OSGS project are having a positive effect on student perceptions related to science learning. This is especially the case when students are given the opportunity to utilize higher-level skills that are commonly associated with Newmann's notion of complex intellectual tasks and the learner-centered approaches to learning science as described earlier. According to the survey data, the first unit seemed to have had a larger effect on student perceptions than the second one, which could possibly be explained by the fact that the first unit required more disciplined inquiry, hands-on work, construction and application of knowledge, use of different types of technology tools, and problem solving, a finding that may confirm that learner-centered and hands-on knowledge-building processes are the most effective ways of learning science (e.g. Krajcik, Czerniak, & Berger, 1999). With regards to disciplined inquiry, depth of understanding and elaborated communication were seen as more important after the first unit only. Application of prior knowledge ranked second.

Under Newmann's category "construction of knowledge," original application of knowledge and skills to new problems showed an upward trend in student use of new and creative ways to solve a science problem. At this point, it is unclear whether this increase can be attributed to students having more experience in learning related to alternative forms of energy or life science in general. However, about 50% still adhere to learning best when using weekly calendars, class notes, and concept maps, which seems to indicate a fairly traditional way of learning. Further study is needed to investigate whether this is caused by students having been programmed to learn in traditional ways since they entered school, or if a 50/50 split is actually an improvement when compared to regular science or other subjects.

When it comes to application beyond the classroom, students were almost equally divided as well. Even though each unit included a culminating activity in the form of a presentation to classmates or other students, about half of the students did not see the value of studying alternative forms of energy as it applies to their own lives. The other half discussed the importance as having to do with the importance of solar energy as an alternative resource, environmental impacts of various energy sources, and the fact that alternative energy sources are renewable. Possible explanations for this split could include the lack of student reflection on their learning, or the fact that new knowledge learned and communication related to this new knowledge mostly stayed inside the classroom during and following each unit, without having clear opportunities to apply it to real-life situations outside of school. One notable exception to this phenomenon is one pair of students who constructed a flicker-checker, a simple device that uses a small solar panel to check indoor lighting efficiency. The students began by measuring this efficiency throughout the entire middle school, and making suggestions for improvement, and then expanded on this by visiting local businesses and performing the exact same tasks there.

How does technology play a role in this context? Existing research has indicated that technology can be used to enhance complex intellectual tasks by providing support and tools (Jonassen, 2000b; Kozma, 2000), and can be as simple as the flicker-checker tool. Even though there was a relatively high rate of technology use in the OSGS project, areas where technology was used the least—e.g. in direct instruction at the beginning of the first unit—showed little or no positive changes. This can be explained by the fact that when compared to more learner-centered approaches, this type of instruction is relatively ineffective. Technology has the potential to change this, because it forces students and teachers into a more hands-on learning experience. An example would be the use of various technology tools in the building project phase, and other active approaches such as Learning-for-Use and the project-based science model (Edelson, 2001; Krajcik, Czerniak, & Berger, 1999).

CONCLUSION

Results of the study indicate that the OSGS project has a positive effect on students with regards to their perceptions of learning science, especially when it comes to disciplined inquiry and construction of meaning. The different nature of the units also seems to indicate that the more concrete and hands-on science learning is, the more effective it is perceived to be by students. In addition, this study shows that technology can play an important role. However, there is definitely room for improvement. Some of these improvements could come from changes in the curriculum, such as added student reflection activities throughout the unit, more varied uses of technology, and more focused opportunities for students to make connections between classroom learning and application to their lives. The latter may be increased once students get access to an interactive Web site maintained by the Ohio Energy Project that will allow them to share their solar data with schools in other parts of the world, and once additional technology tools, such as mobile computing devices and digital cameras, are added to the classroom.

In addition, some of the limitations of this study need to be addressed in future investigations. For one, the majority of data collected came from student surveys, which may raise some reliability issues due to the fact that the data is self-reported. Second, even though students were told that the instrument administered was a survey, a "testing" perception may still have existed. Third, it should be mentioned that the same survey instrument was used at four different times, potentially causing a testing effect—i.e., students answering questions in a certain way because they remember them from previous administrations. A follow-up study will include a wider variety of data sources, including student-created concept maps and test scores, which may alleviate some of the limitations associated with the present study.

Therefore, future study will focus on how curriculum development such as adding reflective components and increased sharing of learning as advocated by Newmann's framework affects higher-order thinking, problem solving, and depth of understanding for students involved in the OSGS project. Moreover, the effect of students having a wider audience for their learning will be investigated. As more technology becomes available for teacher and student use, additional research will be conducted on how students are using these additional tools as intellectual partners for knowledge construction, representation, and reflection as described by Jonassen (2000a, 2000b), Novak and Gowin (1984), and Salomon, Perkins, and Globerson (1991); and whether this technology does indeed increase student learning, to add to the limited evidence that is available in this area (Waxman, Lin, & Michko, 2003). Also, Newmann, Bryck, and Nagaoka's (2001) contention that learning that requires intellectually complex work will lead to higher scores on standardized tests will be tested by correlating survey results to student scores on the Ohio proficiency test for science.

Contributor

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APPENDIX A: OHIO STANDARDS ADDRESSED BY THE OSGS PROJECT[1]

Earth Science:

S34: Investigate the impact of overpopulation and increased use of resources.

S35: Identify ways that human activities can induce hazards and accelerate many natural changes (ex. Urban growth and waste disposal).

S37: Identify and research science concepts involved in real-world problems, establish important connections among the disciplines of biology, earth science, and physics.

Technology:

S19: Effectively use available science equipment such as thermometers, microscopes, and computers (including the Internet) to gather and show data about natural objects, organisms, and events.

S21: Evaluate and communicate risks and benefits of technological developments.

Math:

M20: Describe and represent relationships (patterns/functions/sequences) with tables, graphs, rules, and words.

Social Studies:

SS30: Acquire interpretations and analyze information on civic issues; draw conclusions from graphs and charts; weigh alternative viewpoints.

Language Arts:

LA15: (reading): Gather, evaluate, and integrate information from multiple sources, such as firsthand experiences and technology/library resources, to prepare reports and presentations.

LA18: (speaking and listening): Listen actively and critically and respond to various comments to determine meaning.

LA19 (speaking and listening): Demonstrate oral language skills such as tone of voice, articulation, eye contact, and appropriate gestures to communicate effectively to an audience.

[1] Ohio Department of Education, 1999a, 1999b, 2001a, 2001b

APPENDIX B: SOLAR PANEL TECHNOLOGY AND STUDENT LEARNING

Student Survey

Instructions:
Thank you for helping us out by participating in this survey. Please read all instructions and questions carefully, and mark your responses clearly. You may use pen or pencil.

<u>Part I: Learning Environment</u>.
For each of the questions below, mark the box that states the best answer for you.

I decide what to study and learn <u>in my science class</u>.

1❐ Rarely 2❐ Sometimes 3❐ Often

I decide what to study and learn <u>when doing a solar energy project</u> for my science class.

1❐ Rarely 2❐ Sometimes 3❐ Often

3. I work in a team with other students <u>in my science class</u>.

1❐ Rarely 2❐ Sometimes 3❐ Often

4. I work in a team with others <u>when doing a solar energy project</u> for my science class.

1❐ Rarely 2❐ Sometimes 3❐ Often

5. Have you used solar panel technology …

in the last week? 1❐ Yes 0❐ No
in the last month? ❐ Yes 0❐ No

6. What <u>technology</u> do you use when studying solar energy?
(check all that apply)

1❐ solar panels 4❐ computers 2❐ batteries
5❐ tools (e.g. hammer, screwdriver, pliers)
3❐ measuring tools 6❐ Other, describe ________________________________

7. What <u>other resources</u> do you use when studying solar energy? (check all that apply)

1❐ Information sources such as books or the Internet
2❐ Building materials such as wood, nails, screws, cardboard
3❐ Other people such as your teacher, your parents, or other adults
4❐ Other, describe ________________________________

8. Which of the following do you do when using solar panel technology? (check all that apply)

- $_1$❒ create my own questions
- $_2$❒ use things that I know to learn new things
- $_3$❒ communicate with classmates about what I am learning
- $_4$❒ communicate with people outside of school about what I am learning
- $_5$❒ use what I have learned in school in my life outside of school

Part II: Disciplined Inquiry

9. When I am working on a science problem like I do in life science

- $_1$❒ I want to find a quick and easy solution without having to do a lot of work.
- $_2$❒ I study the problem to find a good solution.
- $_3$❒ I carefully study all the details of the problem so I can find the best possible solution.

10. When I am working on a science problem involving solar energy…

- $_1$❒ I want to find a quick and easy solution without having to do a lot of work.
- $_2$❒ I study the problem to find a good solution.
- $_3$❒ I carefully study all the details of the problem so I can find the best possible solution.

11. To solve a science problem like I do in life science…

- $_1$❒ I work best by myself.
- $_2$❒ I ask for help only when I need it.
- $_3$❒ I often work with others to find a solution.

12. To solve a science problem involving solar energy…

- $_1$❒ I work best by myself.
- $_2$❒ I ask for help only when I need it.
- $_3$❒ I often work with others to find a solution.

Part III: Construction of Knowledge

13. I learn best in science class when

- $_1$❒ I study class notes, concept maps, and weekly calendars.
- $_2$❒ I use the class notes, concept maps, and weekly calendars to answer questions in class or for homework.
- $_3$❒ I use books or the Internet to find the answer to a science question.
- $_4$❒ I can use new and creative ways to apply what I know and can do to a science problem.

14. Which of the following do you do most when working on a science problem for class?

- $_1$❒ I study class notes, concept maps, and weekly calendars.
- $_2$❒ I use the class notes, concept maps, and weekly calendars to answer

questions in class or for homework.

3❐ I do research to find the answer to a science question.

4❐ I use new and creative ways to apply what I know and can do to a science problem.

15. Which of the following do you do most when working on a solar energy problem for class?

1❐ I study class notes, concept maps, and weekly calendars.

2❐ I use the class notes, concept maps, and weekly calendars to answer questions in class or for homework.

3❐ I do research to find the answer to a science question.

4❐ I can use new and creative ways to apply what I know and can do to a science problem.

Part IV: Application Beyond the Classroom.

16. Compared to other school work, using solar panel technology in school is:

1❐ not as interesting.

2❐ about the same.

3❐ a little bit more interesting.

4❐ a lot more interesting.

17. Compared to other assignments in science, using solar panel technology in school is:

1❐ not as interesting.

2❐ about the same.

3❐ a little bit more interesting.

4❐ a lot more interesting.

18. How often do you communicate with experts, community leaders, or other people about solar panel technology?

1❐ never

2❐ a few times in a grading period

3❐ once a week or more often

19. How does learning with solar panel technology in school relate to things you do/will do outside of school?

1❐ very little

2❐ a lot

20. What are the most important things you learned about solar energy and other forms of alternative energy this school year? Why do you think these things are so important?

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APPENDIX C: RUBRIC FOR ASSESSMENT OF AUTHENTIC & INTELLECTUAL COMPLEXITY

Based upon the research of Newmann (1995), this rubric is designed to examine the extent to which specific technologies helped students meet high standards of achievement by assessing the authentic and intellectual quality of assignments given to students.

Assignment reviewer ____________________________
Date rubric completed ___________
General description of the assignment:
Total Score for Assignment (sum of ratings) ____________________

Standard 1: Organization of Information

3 = High: The task calls for interpretation of nuances of a topic that go deeper than surface exposure.

2 = Moderate: Students are asked to gather information that indicates some selectivity and organizing beyond mechanical copying but are not asked for interpretation, evaluation, or synthesis.

1 = Low: The task requires little beyond mechanical copying or surface exposure.

Standard 2: Consideration of Alternatives

3 = High: The task involves the identification and weighing of alternatives, perspectives, or points of view.

2 = Moderate: The task involves students in considering alternatives although the weighing of alternatives may not be an expectation.

1 = Low: The task does not ask students to consider alternative, perspectives, or points of view.

Standard 3: Disciplinary Content

3 = Success in the task clearly requires understanding of concepts, ideas, or theories central in a discipline.

2 = Success in the task seems to require understanding of concepts, ideas, or theories central in a discipline, but the task does not make these very explicit.

1 = Success in the task can be achieved with a very superficial (or even without any) understanding of concepts, ideas, or theories central to any specific discipline.

Standard 4: Disciplinary Process

3= Success in the task requires the use of methods of inquiry or discourse important to the conduct of a discipline. Examples of methods of disciplinary inquiry would include looking for mathematical patterns or interpreting primary sources.

2 = Success in the task requires use of methods of inquiry or discourse not central to the conduct of a discipline.

1 = Success in the task can be achieved without use of any specific methods of inquiry or discourse.

Standard 5: Elaborated Written Communication

4 = Analysis/Persuasion/Theory—The task requires the student to show his/her solution path and to justify that solution path, i.e. to give a logical argument, explain his/her thinking, or to justify results, or the task requires explanations of generalizations, classifications and relationships relevant to a situation, problem, or theme. Examples include attempts to argue, convince, persuade and to develop or test hypotheses.

3 = Report/Summary—The task requires some organization of material. The student is asked to give clear evidence of his/her solution path but is not required to give any mathematical or logical argument to justify his/her solution path, or to explain his/her thinking, or the task calls for an account of particular events or series of events ("This is what happened."), a generalized narrative, or a description of a recurrent pattern of events or steps in a procedure ("This is what happens." "This is the way it is done").

2 = Short Answer Exercises—The task requires little more than giving a result. Students may be asked to show some work, but this is not emphasized and does not require much detail, or only two or three brief sentences per question are expected.

1 = Multiple choice exercises—fill in the blank exercises answered with less than a sentence

Standard 6: Problem Connected to the World Beyond the Classroom

3 = The question, issue, or problem clearly resembles one that students have encountered, or are likely to encounter, in life beyond the classroom. The resemblance is so clear that teacher explanation is not necessary for most students to grasp it.

2 = The question, issue, or problem bears some resemblance to real world experiences of the students, but the connections are not immediately apparent. The connections would be reasonably clear if explained by the teacher, but the task need not include such explanations to be rated 2.

1 = The problem has virtually no resemblance to questions, issues, or problems that students have encountered, or are likely to encounter, beyond the classroom. Even if the teacher tried to show the connections, it would be difficult to make a persuasive argument.

Standard 7: Audience Beyond the Classroom

4 = Final product is presented to an audience beyond the school

3 = Final product is presented to an audience beyond the classroom, but within the school.

2 = Final product is presented to peers within the classroom.

1 = Final product is presented only to the teacher.