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Green Schools as Learning Laboratories? Teachers' Perceptions of Their First Year in a New Green Middle School

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Abstract: Many K-12 school districts are embracing energy conservation efforts and constructing environmentally sustainable buildings with the purpose of lowering operating costs of their facilities. Investments in green infrastructure to improve operating efficiencies and occupant health are important but the impact of green buildings on instructional practice should also be considered. This study focused on teachers' perceptions of the many impacts of a new sustainably designed middle school on students and teachers and explores the use of the school as a learning laboratory. Grades 6-8 teachers participated in open-ended focus group discussions near the end of the first school year in their new green building. An emergent coding framework was created to characterize conversation topics. Analysis of the coding yielded insights into seven major categories of teachers' perceptions of the impact of the new green school on their work in the building and their students' attitudes and academic performance. The seven major coding categories of green infrastructure, student behavior, student awareness, teacher awareness, curriculum, health, and professional development were further analyzed to formulate considerations and recommendations for others to capitalize on the instructional potential of sustainably designed school facilities as learning laboratories.

Keywords: green schools, learning laboratory, sustainability education, teachers' attitudes, instructional practice

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A growing trend in the United States is for school systems to build green, high performing environmentally sustainable school buildings. These *green schools* are built to Leadership in Energy & Environmental Design (LEED) standards, which is the environmentally conscious criterion of the U.S. Green Building Council. Green schools accounted for over a third of new education construction in 2010 (McGraw-Hill Construction's Green Outlook Report in McGraw-Hill Research Foundation, 2010) and over 90% of K-12 schools reported that between 2009-2012 their new construction or renovations were green (McGraw-Hill Construction, 2012). The driving factor for the green building phenomenon has been economics due to the fact that the buildings save schools money throughout their lifetime. Many studies and market analyses such as McGraw-Hill Construction (2012) reported that reducing energy use, operational savings, and improving 10-year operating costs led school systems to build green. A 2006 national review of 30 green schools demonstrated that green schools have net cost to benefit savings of about $71 per square foot over traditionally constructed schools (Capital E, 2006). Although lowering operational costs are important considerations for school administrators we believe that research should also be expanded to consider the potentially positive influences of the new facilities on teachers, students and instructional practices.

The study that we present below adds to an emerging body of research in the sustainability education field that considers the effectiveness of schools in aspects of environmental and academic impact including the school culture, physical infrastructure and curricular applications. In the fall of 2013 the US Environmental Protection Agency, recognizing this need for more research, issued a solicitation for grant funding specifically to research environmental factors, children's health and performance, and sustainable building practices. We seek to address a void in the research of how teachers are directly impacted by green, high performance schools and specifically how their teaching is changed or enhanced by the green infrastructure at their local school sites. Along these lines, we consider the general research questions of if and how schools may capitalize on green schools as learning laboratories.

For the purposes of research in this area we characterize a green school as a learning laboratory if 1) the school building includes at least one, but preferably many, types of environmentally sustainable infrastructures and/or practices and 2) teachers are using the infrastructure and/or practices to enhance instruction. Some examples of environmentally sustainable infrastructure or practices include geothermal heating/cooling systems, solar energy capture or generation, rain water catchment, vegetative roofing, high performance architectural designs, and energy conservation practices. Some examples of the use of a green building to enhance instruction may include using the infrastructure as local examples of topics under study, collecting and analyzing data on the school site-based systems as project-based learning activities, manipulating or comparing systems or parts of the site as scientific experimentation, or service learning activities to improve environmental impact. We believe that the use of green schools as learning laboratories may produce positive impacts on student engagement and academic achievement as compared to instructional activities that are more abstract or textbook based. The use of green schools as learning laboratories opens many opportunities to build student pride and ownership of their schools, as well as student engagement in authentic inquiries as learning activities in many subjects.

The context of this study is a newly constructed green middle school in the central Ohio River Valley of the Midwest United States. The new school contains many green features such as: natural daylight harvesting, advanced geothermal HVAC, insulated concrete forms, solar light tubes, CO_2 monitoring systems, energy efficient kitchen design and appliances, LED

parking lot lights and task lamps, energy efficient hot water and security lighting, water bottle refill stations, electric meters for multiple zones, rainwater catchment system used for toilet flushing, a vegetative roof, rain barrels, rain garden, systems vital screen displays of data, low energy drinking fountains, and many reduced energy construction methods and materials. The new green school was built on the same property, directly across the parking lot from the old school building. Almost all of the teachers and staff transferred to the new green school, serving the same student population. The school and district serve suburban areas of a large mid-western metropolitan region. The district reports that student demographics are 94% Caucasian.

The research provided below is the first piece of a larger 6-year longitudinal study. The goal of the specific research presented in this paper is to illuminate the challenges and benefits throughout teachers' transitions into a new green middle school. This first piece of the 6-year study focuses on teachers' perceptions of their experiences and observations during the first year in the new green middle school (school year 2010-2011). Data for this research were collected from grade-level teacher focus group discussions near the end of the school year. The main research question guiding the study was: How do teachers perceive the impacts of the green technologies of the new school building on teacher instructional practices and student learning experiences?

Review of Literature

Contemplation of constructing a green school encompasses consideration of the planning, design, construction, and operation over the entire lifespan of the building, 50 to 60 years. The ultimate goal of the facility is to use the least amount of natural resources possible and minimize pollution and other negative environmental impacts. According to the U.S. Green Building Council, a green school is a healthy environment that saves money, energy and resources while facilitating learning (National Clearinghouse for Educational Facilities, 2010). The conceptual idea of a green school is a building that is sustainable, but primarily in regards to energy consumption. The difference between a green school and whole-school sustainability is a school practicing whole-school sustainability offers a "formal environmental education program" in addition to meeting LEED certification standards (Barr, 2011). In the case of the school under study, the facility is energy efficient, cost effective and has many possibilities for use as a learning laboratory but a formal plan for whole-school sustainability programming was not in place during the research data gathering period. The school under study does not have large-scale recycling/composting, gardening projects, does not serve local food in the cafeteria, or have a widespread formalized environmental education program.

According to the National Clearinghouse for Educational Facilities (2010), in "Green Schools as High Performance Learning Facilities," the physical condition of the classroom affects pedagogy. The physical environment can distract or contribute to the content and effectiveness of instructional activities (Earthman, 2009). For example, air quality affects both teacher and student health. Overall absenteeism can be decreased by improving air quality, which leads to more time to cover academic material. Chen, Jennison, Yang & Omaye (2000) in a study of 57 elementary schools found that for every 1.0 ppm and 50 ppb increase in CO and O_3, the absence rate would increase 3.79% and 13.01% respectively. Another study of school air quality found that exposure to increased NO_2 levels of the order of greater than or equal to 80 ppb was associated with significant increases in sore throat, colds, and absences from school (Pilotto, Douglas, Attewell & Wilson, 1997). Other studies have correlated indoor air quality

with asthma (Smedje, Norback & Edling, 1997), nasal issues (Norback et al., 2000) and health and productivity (Ajimotokan, Oloyede & Ismail, 2009).

Light levels also influence student and teacher performance. Prolonged exposure to bright light allows students' circadian rhythms to stabilize and improves students' sleep cycles. Schneider's (2002) report of schools in Washington, DC and Chicago and the McGraw-Hill Research Foundation report (2010) include findings from multiple prior studies that found that appropriate lighting improves test scores, reduces off-task behavior, and plays a significant role in achievement and that daylight fosters higher student achievement. Additionally, sound insulation is another important feature of infrastructure, allowing students to focus on classroom activities and not surrounding noises. Schneider (2002) also cited other sources that found that good acoustics are fundamental to good academic performance. The McGraw-Hill Research Foundation agreed in their report in 2010 that background noise and echoes in school classrooms can have a negative impact on teachers and students. Additionally, the temperature of the classroom affects the students' ability to concentrate along with teacher morale and effectiveness (National Clearinghouse for Educational Facilities, 2010; Schneider, 2002). All of the aforementioned effects of infrastructure are explored in this study of the teachers' perceptions of the functionality of their new green school and potential use of the school as a learning laboratory.

Many factors influence the functionality of a facility including season, cleanliness, occupant behavior, budget, operations and management (National Clearinghouse for Educational Facilities, 2010). One important variable we will analyze in the broader 6-year longitudinal study, not presented in this paper, is time. We will compare reports of the building's features during the first three years in operation. During periods of renovations, both students and teachers may experience difficulties. However, overall improvements and changes to school environments can enhance learning and teaching, which counteracts the inconvenience of construction (Earthman, 2009).

Earthman's (2009) research reveals the possible negative effects of poor physical conditions of the facility on the level of effort teachers exert, the effectiveness of instruction, low morale and job satisfaction. Measuring teachers' perceptions of their work environments is important because in order for the students to have successful learning outcomes teachers must feel empowered and supported, not distracted by the infrastructure. Teachers who are happy with their classroom reported looking forward to teaching and feeling optimistic about their schools compared to other schools (Earthman, 2009). Naturally, the level of teacher happiness manifests in the manner they approach teaching and interacting with their students.

Medrick (2013) defines sustainability education in two parts, consistent with Sterling (2001). Part 1 is education *for* sustainability as the means and process by which we educate citizens in how to achieve global and local sustainable communities. Part 2 is education *as* sustainability as the means to which we educate citizens in the values, opportunities, and choices to be responsible agents that contribute to future society and ecological systems. Sustainability education fosters personal development through formal and non-formal learning that is grounded in our experiences of the world. "Such learning, exemplified by much of alternative education, is more engaged, experiential, and addresses the physical, mental, and spiritual components of our roles in the world and human society" (Medrick, 2013, p. 2).

Green buildings afford a new generation of students the opportunity to learn about sustainability and engage in sustainable practices. Green buildings may help create a generation of *sustainability natives*, experienced in ecological sound lifestyles. A sustainable school is more

than a building's infrastructure; it includes curriculum, operations, maintenance, organizational behavior and community involvement (Barr, 2010). The idea of green buildings as learning laboratories is similar to ideas and research in the field of place-based education, which some researchers consider interchangeable with the term sustainability education. Becoming conscious of the school site by extending pedagogy toward the site, place-based education makes learning more relevant to the lived experiences of teachers and students (Gruenewald, 2003). Green schools include indoor and outdoor infrastructure and spaces that provide opportunities for sustainability education. As illustrated in the case of Flatlands Public School, teachers may deliberately make use of these opportunities and teach environmental issues or content or they may do so without overtly realizing it (Miles, 2013).

Empirical research results from the education research field regarding the benefits of environmentally conscious school buildings on teacher and student attitudes and student learning outcomes is limited. Studies from the building construction field such as a 2005 Turner Construction survey of executives in the building sector involved with green schools report that green schools reduced student absenteeism and improved student performance on standardized test scores (Capital E, 2006). The field is ripe for environmental educators to further explore. A significant difference between our research and others in the field, such as Barr's whole-school sustainability research, is that we focused on a case study of one newly constructed green school to characterize aspects of the professional lives and impressions of teachers as they and their students adjusted to a new green building. The Teachers were provided with open-ended questions to allow for free form dialogue between the teachers themselves as opposed to one-sided surveys, which prompt for specific themes. As a result, the research reveals in-depth, specific evidence about teachers' impressions of the new facility and the functionality of the school as a learning laboratory.

Methods & Analysis

This study was conducted using an ethnographic research approach. The lived experiences of middle school teachers were researched as a case study of the first year of a newly constructed school that incorporates over 20 green or sustainable infrastructure features. Data were collected during teacher focus groups near the end of the school year. Teachers attended the focus group discussions during their planning periods as part of job embedded training. All teachers that were present at work that day attended the focus group discussions as job embedded training with the goals of research data collection and learning from each other about their perceptions of their new green school. A limitation of this study is that most but not all of the teachers present voiced their perceptions in the group discussions. Following research with human subjects guidelines, teachers were aware that participation in the research (personally speaking during the voice recording of the focus group discussions) was voluntary according to research procedures outlined in the consent forms. A few teachers did mention to the researchers that they did not speak simply because they wanted to hear and learn from their colleagues and did not have new information to add, not because they did not want to contribute to the research. Teachers met with the researchers in focus groups within grade levels, with separate group discussions for grades 6, 7, and 8 teachers. Each of the grade level focus groups contained teachers of core subjects (math, science, social studies, language arts) and specials classes such as physical education, band, technology education, special education, etc… The average number of teachers in each focus group discussion was 13. All teacher focus groups were audio recorded and transcribed verbatim.

Each group discussion began with an introduction of the researchers and the research project. Time for this introduction was not included in the research data. Specific time of teacher talk that followed this introduction was 19:32 for the 6th grade group, 16:31 for the 7th grade group, and 17:42 for the 8th grade group. The focus group discussions ended when it was clear to researchers that the teachers did not have anything else to add to the conversation. This followed the use of prompts and extended wait time. The focus group discussions used simple discussion prompts to solicit open ended responses. The researchers prompted the group discussions by simply asking the teachers to comment on their experiences and their students' experiences in the first year in the new green middle school. Secondary prompts asked teachers to elaborate and to comment on topics such as knowledge of the green infrastructure, impacts on instruction, and impacts on students.

The main research question guiding the study was: How do teachers perceive the impacts of the green technologies of the new school building on teacher instructional practices and student learning experiences? Within this research context the authors sought to gather feedback about teacher knowledge of the green infrastructure, use of the infrastructure for learning opportunities, obstacles for using the building as a learning tool, and impact on student academic performance, engagement, behavior, and environmental awareness.

An emergent coding framework was developed and iteratively refined throughout an initial process of the three researchers working collaboratively. The developed emergent coding framework is organized into seven major categories of student awareness, student behavior, green infrastructure, curriculum, teacher and student health, professional development (PD), and teacher awareness (See Figure 1). The complete coding framework of all 25 subcategories is provided as Table 1. Codes were applied to the transcripts to each turn of talk. Each coded turn of talk also included an attitudinal measure. Turns of talk that represented a particular code with a positive attitude were identified with a rating of 1, negative attitude with a -1, or a 0 if not present. The categories of student behavior and teacher and student health could also be coded with an N for no change being mentioned by the teachers.

Figure 1. Seven Major Emergent Coding Categories

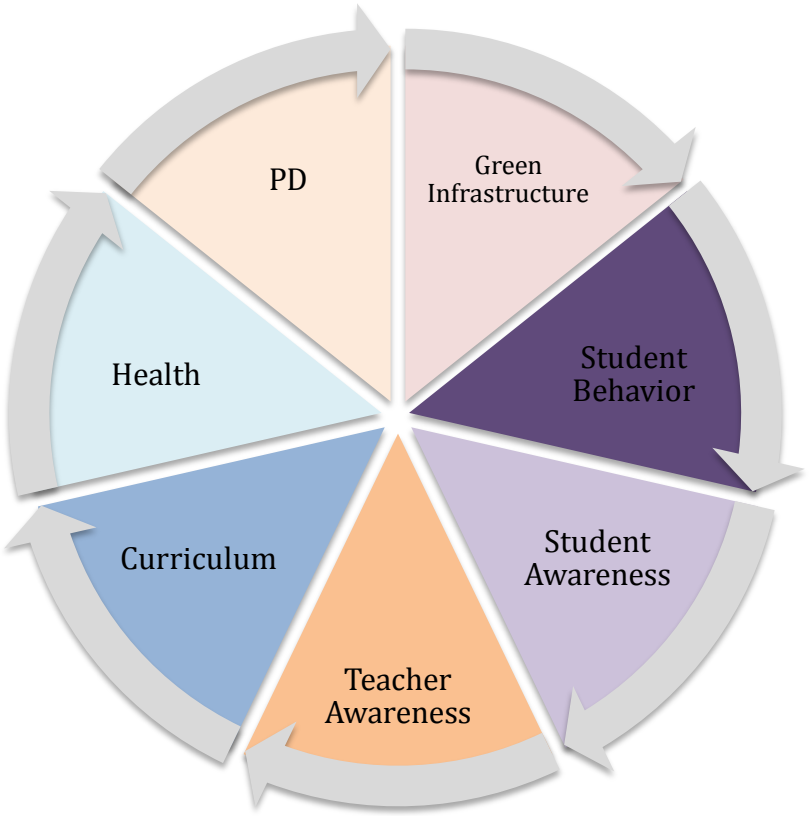

Table 1. Complete coding framework

Green Infrastructure	Student Behavior	Student Awareness	Teacher Awareness	Curriculum	Health	Professional Development
-Lighting -Bathrooms -Data Displays -Sound insulation -Outdoor classroom -HVAC / Geothermal -Vegetative roof -Solar -Layout	-Discipline -Engagement -Attendance	-Knowledge of infrastructure -Knowledge of environmental issues -Inquiry of green infrastructure	-Knowledge of infrastructure -Knowledge of environmental issues -Inquiry of green infrastructure	-Curriculum implemented as new or modified lessons or assessments -Curriculum ideas of new or modified lessons or assessments	-Physical health teachers or students -Mental, emotional health or impact on	-Feedback on professional development -Requests for additional professional development

					stress level of teachers or students	

Once the coding framework was finalized each of the three researchers independently applied codes to all teacher turns of talk in each of the three grade level transcripts. The researchers then met to discuss all 291 coded turns of teacher talk. The researchers particularly discussed instances of discrepancies in coding and argued these codes until coder consensus was reached. The final codes from this process of coder consensus were analyzed for findings.

Provided next are examples of coded turns of talk for each of the major coding categories of the emergent framework. The first example is one in which a seventh grade teacher talked about the use of electrical lights and daylight harvesting provided by specifically designed window bays and light tubes. This example was coded under the general category of *green infrastructure* and subcategory of lighting with a positive attitudinal measure.

Example 1: "Yeah, it's rare that I even need the lights on."

The second example is coded as the general category of *student behavior* and subcategory of attendance with a positive attitudinal measure. Attendance in this example is a reflection of enrollment in the school. The attendance subcategory was defined in the context of this study in two ways, effects on enrollment in the school and daily attendance records. This seventh grade teacher was commenting on the fact that some students have transferred to this new green school from other public and private schools in the area.

Example 2: "I would say there are more kids coming to this school though this year because of its [green features]. You know that come from other schools."

The third example is coded as *student awareness* in the subcategory of knowledge of infrastructure with a positive attitudinal measure. The fourth example is coded similarly but with a negative attitudinal measure. Sixth grade teachers in these examples described instances in which they were able to gauge how aware students were of the different green features of the building. Example 4 references the phenomena that the solar light tubes create rainbow colors from the diffraction of the light through tubes into the hallways.

Example 3: "They know more than we do."

Example 4: "So they're like fascinated with that but I don't think they have a clue how it is happening. It's just the fact that it is there."

The next example is a series of turns of talk that illustrates *teacher awareness*. The questions were coded as inquiry examples and the responses were coded as knowledge of infrastructure. All of these turns of talk were assigned a positive attitudinal measure. This exchange of eighth grade teachers highlights the inconsistency in that some teachers still had questions about green features of the building near the end of the school year while other teachers had acquired knowledge.

Example 5: "I do have a question about the roof, the uh what do you call it?"
"Vegetation roof." "The green roof." " Yeah, are teachers even allowed to use it and

what would they use it for?" "And what are they growing? I would love to grow some herbs out there." "They use it for filtrating the water, the run off. To clean the runoff. Am I right?"

The next example is one of how an eighth grade teacher implemented a change in the curriculum to focus an English class writing assignment on renewable energy sources knowing that their school included geothermal and solar energy technologies. This example was coded as a modification to a lesson in the *curriculum* implemented category with a positive attitudinal measure.

Example 6: "I gave them an opportunity to write a portfolio piece that was either informative or persuasive on renewable energy sources."

In a counter example another eighth grade teacher described how some teachers also felt restricted by a need to focus on core content standards. This example was coded as *curriculum* idea of modified or new lessons with a negative attitudinal measure.

Example 7: "If it doesn't directly relate to core content, we don't have time…"

The next example from a sixth grade teacher is a comment about positive effects of the new building on physical *health*.

Example 8: "I think there are less illnesses. You know allergies and things like that, where. I know teachers, as far as myself, there was so much mold and dust and everything in the old building so I noticed a difference, health-wise…"

The last examples are of *professional development* feedback and of more professional development requests that eighth grade teachers mentioned.

Example 9: "At the beginning of the year we walked the building and went through what was there, and I don't think it was just science teachers."

Example 10: "If there were some informational things that were great that they could give you, that could be good reading piece[s]."

Results

Codes from grades 6, 7, and 8 were combined to enhance validity and better capture themes across the entire middle school. Combining grade levels helped to minimize statistical influence of any one teacher or grade level of teachers on the findings. Combining grade level codes also added statistical power to the number and distribution of codes. The combined codes across all grade levels were summarized into total counts of positive, negative, no change, all codes (sum of positive, negative, and no change counts), and an attitudinal summary (positive minus negative counts) for each specific code. Each of these totals was then ranked by the frequency in which they appeared. Table 2 shows the distribution of the seven major coding categories (Figure 1) across all three grade levels.

Table 2. Coding distribution by major categories of codes.

Total of All Major Codes (+, -, N)	Sum of Attitudinal Measure (positive codes –	Positive Codes	Negative Codes

	negative codes)		
9 Health 23 Student Awareness 25 Professional Development 32 Student Behavior 57 Teacher Awareness 72 Curriculum 73 Green Infrastructure	-45 Green Infrastructure -2 Health 3 Student Awareness 8 Student Behavior 17 Professional Development 28 Curriculum 31 Teacher Awareness	3 Health 13 Student Awareness 14 Green Infrastructure 19 Student Behavior 21 Professional Development 44 Teacher Awareness 50 Curriculum	4 Professional Development 5 Health 10 Student Awareness 11 Student Behavior 13 Teacher Awareness 22 Curriculum 59 Green Infrastructure

Table 2 sheds light on the major topics that the teachers talked about in the focus group discussions. This table shows that teachers talked about teacher awareness, curriculum, and green infrastructure the most. When considering a positive or negative attitudinal measure, teachers talked about the green infrastructure in a negative way most frequently. They talked about curriculum and teacher awareness in positive ways most frequently. Professional development also emerged as frequently occurring in the conversations. While Table 2 shows what the major topics of conversation were based on counts of turns of talk and some insight into attitudes related to those major topics more in-depth analysis was needed to answer the research question.

Since the turns of talk were coded by subcategories of the coding framework, the researchers were able to analyze the results in more detail. The combined subcategory codes of grades 6, 7 & 8 were then analyzed for findings. After ranking the frequency of subcategory codes, researchers determined the location of natural breaks in the subcategory codes, at the same time also considering sets of major codes that appeared most frequently. Breaks in the frequency distribution revealed findings about the research question of how teachers perceive the green technologies of the new school building impacted teacher instructional practices and student learning experiences. Major items that were identified included general functionality issues of the *infrastructure*, *teacher awareness* combined with a need for *professional development* to learn more about the functions of the infrastructure, and conversations about the potential *curriculum* uses of the green features. Table 3 shows the specific codes that were identified as most frequently occurring along natural breaks in the distribution of final coding. The actual count of the coding along with the general coding categories and subcategories are listed in Table 3.

Table 3. Findings from coding distribution by subcategories of codes.

Total of All Codes (+, -, N)	Sum of Attitudinal Measure (positive codes – negative codes)	Positive Codes	Negative Codes
21 Curriculum: Modifications Implemented 22 Infrastructure: HVAC 36 Teacher Awareness: Knowledge of Infrastructure 48 Curriculum: Modification Ideas	-20 Infrastructure: HVAC -9 Infrastructure: Bathrooms -9 Infrastructure: Data Display -5 Infrastructure: Vegetative Roof 7 Teacher Awareness: Knowledge of Environmental Issues 10 Teacher Awareness: Knowledge of Infrastructure 12 Student Behavior: Attendance 12 Curriculum: Modification Ideas 13 Curriculum: Modifications Implemented 14 Teacher	17 Curriculum: Modifications Implemented 18 Professional Development: Requests 22 Teacher Awareness: Knowledge of Infrastructure 30 Curriculum: Modification Ideas	13 Teacher Awareness: Knowledge of Infrastructure 18 Curriculum: Modification Ideas 21 Infrastructure: HVAC

	Awareness: Inquiry 18 Professional Development: Requests		

Infrastructure

Comments about infrastructure features were particularly focused on comfort and impacts on instructional practices. There were complaints about the HVAC system, temperature of the water fountains, time required to bring systems online, lighting, and loud noise of high efficiency hand dryers. Some of these systems were not functioning properly at the time of the opening of the building or needed adjustments once the building was occupied. The 6th grade focus group accounted for the highest number of comments related to moisture. There may be a correlation between the location of the 6th grade classrooms and issues with the HVAC system's moisture regulation. However, negative comments persisted across all grade levels about various features of the infrastructure.

In general, the teachers had a negative response about the infrastructure operating in an efficient manner from the start of the school year to accommodate the instructional needs of the teachers and students. The HVAC system appeared to have some operational parameters that were difficult for teachers to adjust to. For example, teachers expressed that the temperature in the rooms varied from extreme cold to hot. Additionally, the data display of statistical information about the building's energy conservation was not functional for the teachers to access. Teachers expressed their frustration that they could not retrieve data about the building to incorporate into the curriculum.

Teacher Awareness and Professional Development

Teacher knowledge and awareness of the green features in the building was mixed. They collectively requested additional professional development to expand their awareness of the green features of the facility. Some teachers acknowledged a lack of complete understanding of green infrastructure and how to utilize it to enhance instruction. While knowledge of infrastructure is an issue for a large number of teachers, a handful of teachers conveyed extensive

knowledge of the features. From listening to the voices in the audio recording, researchers are able to determine that it was a small number of the same teachers that provided the majority of correct knowledge comments. Teachers that voiced correct conceptions were typically science teachers. Thus, teacher's knowledge of environmental features is not consistent. Some expressed familiarity while others were seeking more professional development (PD). The amount of PD requests demonstrates that teachers acknowledge that in general they are not yet confident or comfortable with their knowledge of features and how to incorporate the green features of the building into instructional practice.

Curriculum

In the first year of operation, some teachers had modified lessons to incorporate the green features of the school. Many more had ideas of how to potentially use the building as a teaching tool, particularly in the science department. A general consensus and belief among the teachers is that utilizing green infrastructure in instruction is primarily a job for science teachers or the STEM Encore elective classes. Overall, teachers reported a mixed interpretation of the students' knowledge and attitudes towards the green building. Some reported that students remain relatively unaware of the large-scale implications of the new building, but are primarily impressed by the newness of the school.

Teachers were able to identify ideas for modifications of curriculum to include green features of the building, however only a small number of teachers had implemented any of the curriculum ideas. Ideas for curriculum modifications rated both positively and negatively. Teachers expressed positive ideas more often, as negative ideas for curriculum related to utilizing green school features were noted as ones in which teachers felt restricted by the standards they were required to teach. When prompted, teachers were able to identify ideas and suggestions for methods of incorporating features in the instruction, but comparatively few had implemented lessons using the building's green infrastructure as an instructional tool. Some examples of the use of green features in instruction included the following topics and activities: light meter data collection and analysis, graphing, angle of the sun/seasons activity, natural winds, informational writing about facility and functions, geographical implications on green energy use, geothermal data analysis and layers of the Earth, primary and secondary energy resources, geography, writing contest on energy use, persuasive essays on renewable energy, vegetative roof research, monitoring and analysis of rain barrels, comparisons of energy use and infrastructure features, measurements of rainwater harvesting, energy transformations, economics of the school operations, green energy day, recycling, technology in the context of the building features, and architecture.

Discussion & Recommendations

Schools are choosing to invest in green technologies because of long-term financial savings, but we believe they should also consider educational benefits and attitudinal effects. Four major topics were identified from the teacher focus groups for consideration. The topics of functionality of green infrastructure, teacher awareness, professional development, and curriculum that utilizes the green school as a learning laboratory were important conversation pieces reflected upon by grade 6-8 teachers near the end of their first year in a new green middle school. These topics have implications to consider for this particular school as well as other school systems planning to build and move into new green school buildings.

A period of adjustment is necessary for teachers and students to acclimate to a building's new infrastructure and for the administration and operations personnel to adjust and refine functionality issues associated with opening a new building, especially one with many new green technological features. We believe that teachers' negative comments about any infrastructure issues will decrease with time as adjustments are made to the systems and all occupants of new green school buildings increase their understanding of the operational systems.

Teacher awareness and professional development are critically important to consider when going through the process of designing, building, and settling into a new green school. Teachers in this study acknowledged mixed understanding of the building systems, knowledge of environmental issues, and how to leverage the opportunities of place-based education within the restraints of academic standards. Teachers at new green schools will benefit greatly from professional development prior to moving into their building along with continued training throughout an initial adjustment period and beyond. Professional development should focus on conceptual understandings of green infrastructure and curriculum development that capitalizes on the unique opportunities such as real-life school-based examples, systems monitoring, analysis of data, and reading, writing, and artistic activities.

A successful green school that realizes and implements the benefits of sustainability education would require active, cross-curricular teaching to incorporate environmental themes into instruction. Instruction could start at the design stage with architecture, in which teachers can begin to plan to use specific green infrastructure features in their instruction. Similarly, teachers need successful tools and methods for gathering and sharing data about energy production and consumption and other building systems including metrics from features such as rainwater catchment systems and run-off into rain barrels from vegetative roofing compared to standard roofing. Perhaps some helpful tools would be online collaborative ones such as wikis, for sharing developed curriculum and access to data displays specific to green school buildings.

In order to utilize a green school as a learning laboratory at its fullest potential schools must shift their attention beyond only the economic returns and focus on the long-term benefits to student achievement and student and teacher personal and academic behavior. Recognition of both student and teacher attitudes towards the building are essential to ensure success. Teachers are a critical component of the operation of any school but consideration of the professional development of teachers in new green school facilities should receive heightened attention.

One recommendation is that knowledgeable and passionate teachers can be identified and utilized as professional development team leaders that can help raise awareness, knowledge levels, and collaboratively guide other teachers to explore the connections between academic standards and place-based sustainability education. These teachers could act as local leaders, curriculum developers, and facilitate professional development. Another step towards the model of whole-school sustainability education programs at green schools can be to create student clubs or teams such as Energy Wise, Green Construction, or Sustainability Student Teams that focus on a variety of environmental topics such as recycling and community gardening initiatives. The school in the study presented above has experienced some successes with an Energy Wise and Construction 101 clubs. Groups such as these may spur additional ideas to implement into the general curriculum.

Future Research

This study is part of a larger 6-year study which includes additional research foci and collection of other data. The larger study, currently in the analysis stage, seeks to ultimately

characterize how teachers use the sustainable features of the school in instruction, as well as impacts on students' attitudes and academic performance. Numerous data have been collected from the last three years of the old traditionally built middle school and the first three years of the new green school. Other data under analysis in this broader study include additional teacher focus group discussions during years 2 and 3 after moving into the new green school, attendance reports of teachers and students, standardized test scores, referrals to the nurse, and discipline referrals. The larger research study includes approximately 4,500 current and past middle school students and 60 teachers at the focus school site and a comparison school within the same school district. We expect to finish analysis of data in this larger study and disseminate findings about students' attitudes and academic performance in the near future.

Additional research in this emerging field of green schools as learning laboratories is needed to realize the potential benefits of using green schools and green infrastructure in the approach of place-based sustainability education. Studies on the health benefits and cost analyses should continue as green technologies are continually becoming more efficient and effective. Additional research is necessary in the focus area of educational benefits of green school buildings. Specific areas of potential further study include attendance (students and staff), behaviors and attitudes, standardized test scores, and everyday instruction. Researchers should remain aware that the newness and cleanliness of any school facility is a variable important to consider when analyzing the data. It is also important to consider that an adjustment period is to be expected when teachers and students are acclimating to any new school building, green or traditional. Analysis of teacher focus group discussions from years 2 and 3 in the school study presented above will help tease out effects of the newness of the school and the anticipated adjustment period for teachers to become comfortable in the school environment. It is anticipated that after the adjustment period teachers will report less distractions and be able to take more advantage of the school as a learning laboratory.

Lastly, professional development and curriculum are exciting potential areas for development and research in the field of green schools as learning laboratories. This study shows that for teachers to fully embrace and implement learning experiences utilizing green school facilities as learning laboratories new professional development opportunities should be designed and implemented. Sustainability education professional development has become increasingly important for in-service and pre-service teachers. Many schools across the country have been recognized or are aware of the process to become recognized as U.S. Department of Education Green Ribbon Schools. Pillars and elements of Green Ribbon Schools do not just include environmental impact and costs and improved health and wellness. Pillar 3 of this recognition program is Effective Environmental and Sustainability Education (U.S Department of Education, 2014). Designing and implementing sustainability curriculum that is interdisciplinary, develops STEM content knowledge and thinking skills along with civic engagement are requirements of this 3rd Pillar. Many opportunities exist for professional development and curriculum advances in this area.

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Icon Image for Article
Collage of Some of the Green Infrastructure at the Study School