Project Learning in Science: 6th Graders' Scientific Investigations

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This article presents rationale for an enhanced inquiry approach to science education that authentically integrates content knowledge and application skills in a middle school science curriculum. Such pedagogy ensures students' attainment of national and state standards for learning science and multiple literacies (e.g. language arts and technology) recognized as tools for science achievement; it also provides developmentally appropriate instruction aligned with characteristics of young adolescent learners. Two projects are described; in both, students research, experiment, construct, create, compose, and report, integrating multiple complex skills in ways that simulate real world science investigation. Results demonstrate that students recognize their work as relevant and take responsibility for quality and outcomes.

Introduction: Learning Science, Acting as Scientists

The process of testing current theories, constructing new knowledge, and posing more questions continues in science as in other domains, but occurs at warp speed now when compared to previous historical periods. We enter the 21st century with the beginning of a technology revolution that has changed our lives in the work place, in schools, and at home (McLaughlin, 2011). Tierney (2008) notes that, "the advent of digital spaces, especially the advent of hypertext, represents a revolution in communication of a magnitude exceeding the printing press" (262). Schools that prepare students for the future they will face embrace technology as an additional, integral tool for science instruction, supported inquiry, and students' examination of past, current, and personal research in pursuit of answers to questions they have posed. Students directly experience inquiry as a tool for learning; they don't just study the language of inquiry, memorizing definitions or reading about scientific hypotheses, inferences, or processes (Olson & Loucks-Horsley, 2000). In effective classrooms from kindergarten through grade 12, science activities (i.e. instruction and students' responses) "mirror the processes used by professional scientific researchers" (Hanauer, Jacobs-Sera, Pedulla, Cresawn, Hendrix, & Hatfull, 2008, 1880).

New Common Core State Standards (CCSS), the Framework for K-12 Science Education Standards (NRC, 2012), and the Next Generation Science Standards (NGSS) outline rigorous competencies (CCSSO & NGA, 2010; NGSS, 2012; http://www.nextgenscience.org/overview-0#Scientific%20Literacy). Specifically, the CCSS call for students to: 1.) compose clear, coherent, and organized writing, 2.) conduct projects that build knowledge through investigation, and 3.) draw evidence from texts and investigations to support responses (CCSSO & NGA, 2010, NGSS, 2012). In addition, the NGSS (2012) suggest practices that are language intensive. The new science standards note, "Communicating in written or spoken form is another fundamental practice of science" (NRC, 2012, p. 60) — that scientists use "specialized ways of talking and writing" (NRC, 2012, p. 43).

Integrated with principles outlined in the science framework are the five "Es" for learning science (Bybee, Taylor, Gardner, Van Scotter, Carlson, Westbrook, & Landes, 2006). The first two Es, engagement and exploration, center on learners' consistent participation, inquiry, and knowledge gathering from multiple sources. The third E involves learners' ability to express and use information acquired.

Similarly, the Framework for K-12 Science Education (NRC, 2012) describes "spheres of activity" (p. 44) for scientists. One sphere, like the first two Es, is centered on inquiry and investigation (NRC, 2012). But, what should teachers do to create and support such experiences for their students? Useful exemplars for transforming theories, principles, and standards to effective pedagogy guide teachers' decision-making and planning.

In their compilation of case studies on effective science classrooms, Michaels, Shouse, & Schweingruber (2008) describe educators at work, actively applying research, testing theories, and meeting standards for science instruction. The stories illustrate the complexities that teachers face in the process of orchestrating active student learning and application of that knowledge; details help readers envision and design rigorous, engaging scientific inquiry appropriate for their curricular objectives and students. Case studies allow teachers to analyze how research-tested, best practices have been successfully applied in specific contexts. Case study format includes detailed descriptions or scenario-type examples (Dunn & Brooks, 2004). There has been an increased acceptance of the case study design as "researchers realize that valuable information can be gained through rich anecdotal study--particularly when experimentation or other quantitative methods are not possible or desired" (Nath, 2005, p. 396). In a scenario style, this article introduces a science classroom working toward the same goals within school-specific structures. Students' work products, responses, and behaviors provide qualitative data; quantitative data include students' consistent success on district assessments and quarterly grades in science.

Performance tasks assigned — ones appropriately connected to science standards and curricular goals — allow students to make decisions, be responsible, and authentically demonstrate declarative (content) and procedural (application) knowledge they have acquired. Such behavior indicators verify that students are moving toward internalizing and applying scientific principles in ways observed in a community of scientists. "More and more jobs demand advanced skills, requiring people to be able to learn, reason, think creatively, make decisions, and solve problems. An understanding of science and the processes of science contributes in an essential way to these skills" (CSMEE, 1996, 1).

A meaningful infusion of technology and language arts skills into science instruction reaps multiple benefits along with an increase of socialization toward and motivation for learning and using science. These outcomes include connecting curricular science content to in-the-moment, real world phenomena, integrating knowledge domains, promoting collaborative learning and inclusion of Bloom's established higher order thinking skills and newest digital taxonomy (Anderson & Krathwohl, 2001; Church, 2007); they spark students' interest in science research, promoting inquiry and science discourse as well as ensuring opportunities for learning in a social context (McLaughlin, 2010). "With expert guidance by the program advisors and mentors, students learn to think like scientists" (Zaikowski & Lichtman, 2007, 29). Authentic, integrated learning experiences are more than simply effective pedagogical practice; they are what national and state teaching standards expect.

Connecting to Common Core Standards

According to the English Language Arts Standards for Science and Technical Subjects — Grades 6-8 in the area of *Key Ideas and Details*, students need to be able to cite specific textual evidence to support analysis in science and technical texts (RST.6-8.1), determine the central ideas or conclusions of a text and provide an accurate summary of it (RST.6-8.2), and precisely follow a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks (RST.6-8.3). In the area of *Integration of Knowledge and Ideas*, students need to be able to integrate quantitative and technical information expressed in words with information expressed visually (e.g. in a flowchart, diagram, model, graph or table) (RST.6-8.7), distinguish among facts, reasoned judgment from research, and speculation (RST.6-8.8), and compare information gathered from experiments, simulations, or multi-media sources with that from readings on the topic (RST.6-8.9) (Common Core State Standards Initiative, 2012, 1). In the NY list of standards for Mathematics, Science, and Technology, the fourth is directly related to science and the fifth is related to technology. Standard 4 states, "Students will understand and apply scientific concepts, principles, and theories pertaining to the physical setting and living environment and recognize the historical development of ideas in science." Standard 5 states, "Students will apply technological knowledge and skills to design, construct, use, and evaluate products and systems to satisfy human and environmental needs" (New York State Academy for Teaching and Learning, 2012, 1). These standards clearly reflect an integration of knowledge and skills across cognitive and affective domains.

As an educational exit outcome, students are expected to have acquired sufficient declarative and procedural scientific knowledge that allows them "to engage in public discussion on science-related issues, to be critical consumers of scientific information related to their everyday lives, and be able to continue to learn about science throughout their lives" (NRC, 2012, 1). The National Research Council (2012) has further outlined scientific practices as expected performance goals for students. These include: posing questions and defining problems, creating and using models, planning and conducting investigations, analyzing and interpreting data, employing mathematics and computational thinking, constructing explanations and solutions, participating in debate discourse based on evidence, and, finally, gathering, analyzing, evaluating, and communicating data.

Considering this daunting, but doable challenge, science teachers in a rural middle school with middle to low socio-economic status (SES) students have woven long-term projects into the tapestry of their science curriculum. These projects go a long way in providing an avenue for demonstrating the outcomes described through enhanced inquiry that integrates language arts, science, and technology learning as well as some mathematical concepts. They also align with what research has outlined as characteristics of adolescent learners and compatible pedagogical practices that enhance adolescents' social, emotional, and cognitive development.

Developmentally Appropriate Practice: Instruction Compatible with Characteristics of Adolescent Learners.

Developmentally responsive curriculum aligns content, materials, tasks, and expectations in ways that offer students acceptable challenges while being responsive to their interests and needs (Bredekamp & Copple,1997; Kellough & Kellough, 2008; Scales, 1991, 2003; Wiles, Bondi, & Wiles, 2006). *Developmentally appropriate practice* (DAP) involves instruction that is in "harmony with the natural growing process" (Shea, 2011, 8). Although typically associated with early childhood practice, DAP applies at all levels of learning and instruction. When teachers integrate DAP with developmentally responsive curriculum, they demonstrate skills in use, encourage learners to approximate the behaviors modeled, and initiate timely interventions based on identified needs; they gently shape and refine students' competence toward the expected outcome (Holdaway, 1979). DAP must recognize the diversities in any classroom while meeting content and performance standards. Learners also need to be inspired to engage — to invest time, attention, and interest.

Middle school curriculum that stresses inquiry is highly motivating for young adolescents; in such an environment, students are encouraged to ask content relevant questions, construct responses, examine their thinking against conflicting information, draw conclusions and communicate their understanding (Olson & Loucks-Horsley, 2000). Through this investigative protocol, learners begin to appreciate that, although an inquiry process is complex, the practice is essential for lifelong self-directed learning (Connors & Perkins, 2009). The activity also leads to critical reasoning and consideration of alternative explanations (CSMEE, 1996). It must be noted, however, that some research has cautioned the efficacy of such pedagogical practices (Mayer, 2004). More recently, however, other researchers analyzing the controversy, defined conditions necessary for effective inquiry pedagogy.

Alfieri, Brooks, Aldrich, and Tenenbaum (2011) reiterate the caveat associated with inquiry (discovery) learning. Their meta-analysis of *unassisted* inquiry learning (not guided by the teacher or mentor) versus direct instruction found the latter to be superior when measuring student learning. However, a second meta-analysis comparing *enhanced* inquiry learning (teacher assisted) with direct instruction (or other forms of instruction) found enhanced inquiry to be superior. In enhanced inquiry learning the teacher prepares students for the learning task and guides them along the way, making sure that learners have sufficient content and procedural knowledge to perform successfully. Some amount of direct instruction will always be necessary as well as ongoing assessment of students' understanding (Marzano, 2011). Effective teachers are always perfecting a balance of these instructional roles; they are *the sage on stage* and *the guide on the side* as appropriate, meeting students' needs for scaffolding. Knowing that "A good idea— poorly implemented — is a bad idea" (Ainsworth & Viegut, 2006, 109), teachers ensure that learners in these environments are motivated to fully participate by placing students' interests at the forefront.

Motivation and engagement are high throughout these activities because students experience choice, ownership, collaboration, and responsibility; they feel empowered and secure with taking risks in the supportive environment that is established. The success they realize propels them forward.

Setting the Stage for Junior Scientists

Effective science teachers understand that "learning science is something that students do, not something that is done to them" (CSMEE, 1996, 20). The National Science Education Standards, guided by the principles of quality science education for *all* children, science learning as an active process, practice of contemporary science, and continuous revision of science education to match respected research, require that students move beyond merely a body of knowledge and processes to develop inquiry skills as a habit of mind. Through inquiry, students learn to describe phenomena (i.e. objects and events), ask pertinent questions, construct plausible theories, test these theories against accepted knowledge, analyze the results, and communicate conclusions to others (CSMEE, 1996; Olson & Loucks-Horsley, 2000); they begin to appreciate that, although the scientific method is complex, following it is fundamental if real-world research projects are to be considered relevant to the life of the community and have any significant impact (Connors & Perkins, 2009). Students also learn how to effectively engage in critical reasoning and consideration of alternative explanations (CSMEE, 1996).

The scenario that follows describes middle school projects that meet these characteristics of effective science pedagogy. They were carefully planned for student ownership, enhanced inquiry, scaffolded instruction, differentiated teaching, and timely interventions throughout the process.

Organizing Work: Two Models for the Scientific Process

It's imperative for success that students have a curiosity about, enthusiasm for, and commitment to the topic and scientific process involved in completing the project they have selected to pursue (Zaikowski & Lichtman, 2007). Appreciating that "inquiry-oriented teaching engages students" …[and]…"inquiry-oriented programs at the middle school grades have been found to generally enhance student performance" (Haury, 1993, 2), effective teachers find ways to accommodate such pedagogy. It's important, however, to note that inquiry learning approaches do not exclude the use of textbooks and other instructional resources (Haury, 1993). With this pedagogy and classroom environment as a goal, Brian Shea (2nd author) and colleagues worked collaboratively on two projects described here to enhance student achievement, inspire genuine motivation for learning science, and integrate standards that students were expected to meet.

In lieu of a final exam in science, 6th grade students in Brian's school were given the option of completing a project. They had four choices: constructing a model, creating an invention, conducting an experiment, or writing a research report. This project, as an exam, made up 20% of students' final grade in science. Specific requirements for each project were outlined. All projects required an initial proposal, daily log, oral presentation, bibliography, and an exhibit. Those who constructed a model, created an invention, or conducted an experiment prepared a report on their work as well, using an outline of subheadings that were to be addressed. Students who conducted interviews with people associated with their topic received extra credit. Work began in March; project presentations were held in May. Connor's hypothesis for his solar powered car experiment stated that direct sunlight would make it go faster than artificial sources of light. His report included data from his experiments. See Figures1 and 2.

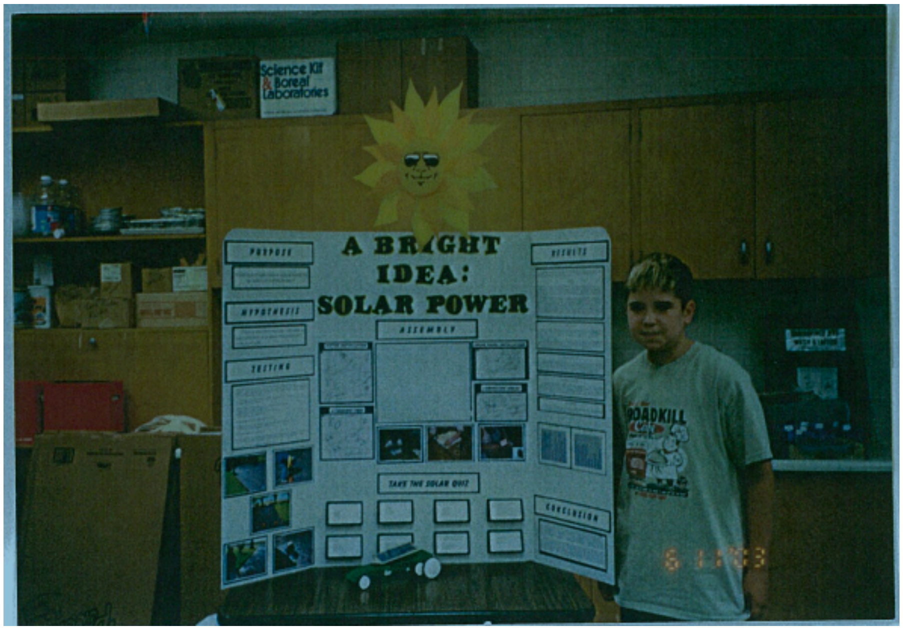
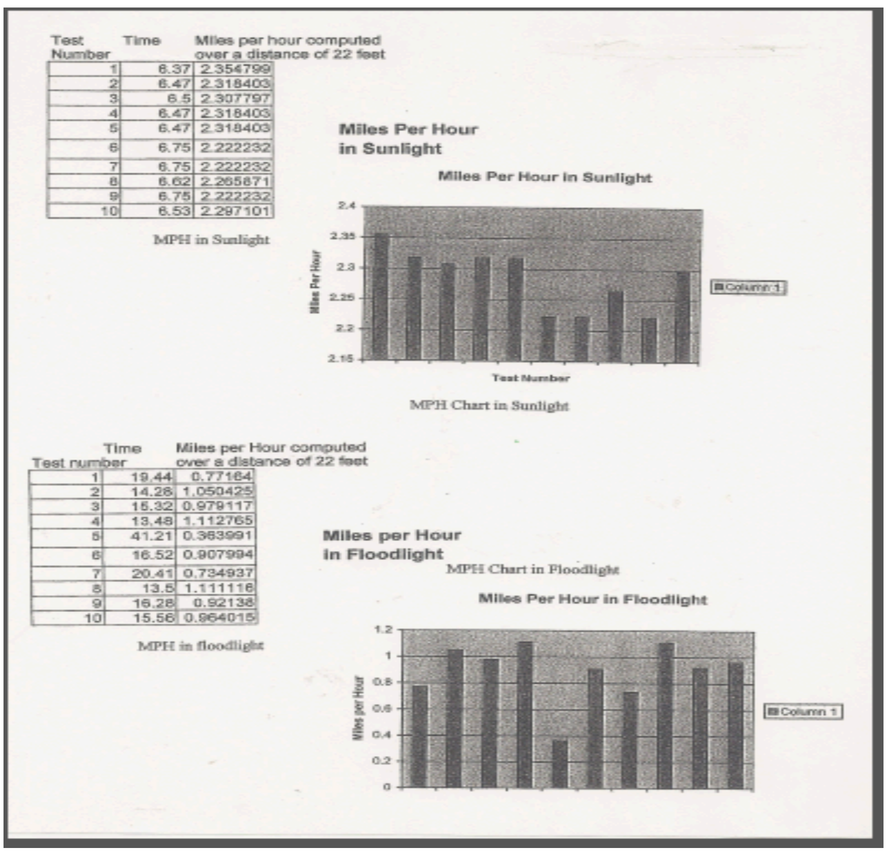


Figure 1: Connor's project



Test Number	Time	Miles per hour computed over a distance of 22 feet
1	6.37	2.354799
2	6.47	2.318403
3	6.5	2.307797
4	6.47	2.318403
5	6.47	2.318403
6	6.75	2.222232
7	6.75	2.222232
8	6.62	2.265871
9	6.75	2.222232
10	6.53	2.297101

MPH in Sunlight

Test number	Time	Miles per Hour computed over a distance of 22 feet
1	19.44	0.77164
2	14.28	1.050425
3	15.32	0.979117
4	13.48	1.112765
5	41.21	0.363991
6	16.52	0.907994
7	20.41	0.734937
8	13.5	1.111116
9	16.28	0.92138
10	15.56	0.964015

MPH in floodlight

Figure 2: Connor's data

Very recently, Brian introduced a different project to his 6th grade science students. It was coordinated with a study of earthquakes. Students worked with a partner to act as scientists and engineers. Initially, they learned about different types of earthquake waves and building designs (content knowledge) before putting that knowledge to use in designing a building that would withstand earthquake testing (procedural knowledge). They used multiple text, media, and technology resources for researching information. Their construction was limited to the following building materials: a) up to 200 craft sticks, b) up to 200 wood splints, c) up to 200 toothpicks, Titebond glue, and material for the base (e.g. Styrofoam, wood, linoleum). The building had to meet the following requirements: 1) It had to be 45 cm tall. 2) It had to have 3 stories. 3) Each story had to be 15 cm high. 4) Each story had to have a floor; however, the floor did not need to be solid. 5) It had to have a flat roof. 6) It could not have solid walls; it had to be more like scaffolding. 6) The building's base had to be 22.5 X 22.5 cm. See Figures 3 and 4.

Figure 3: Project 1

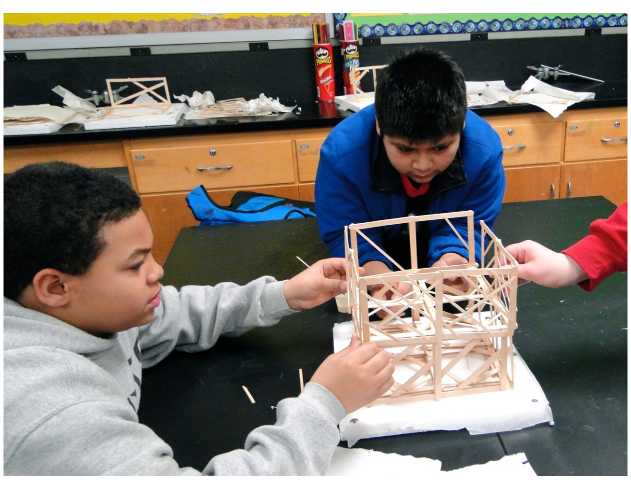


Figure 4: Project 2

Once the buildings were completed, they were tested on the "Shake Rattle and Roll Earthquake Board" to test whether the structure would actually withstand an earthquake. After testing their construction, building designers (student pairs) responded to a series of reflective questions through discussion and writing (TD/CT Kit, 2012). Examples of these included: What would you do differently next time? Explain why. What part of the building design was a success? Explain why.

After his building passed the shake test, one student, who had thoroughly embraced self-initiated scientific thinking, took his experiment to another level. He decided to evaluate how much weight the building could withstand on its roof. See Figure 5. This information would be important in locations where structures might be subject to large snowfall amounts, mudslides, or landslides; these structures would need to withstand a large amount of weight on their roof without collapsing. It could mean life or death for those inside. Jack began to pile textbooks on his building; soon other teams experimented in the same way.

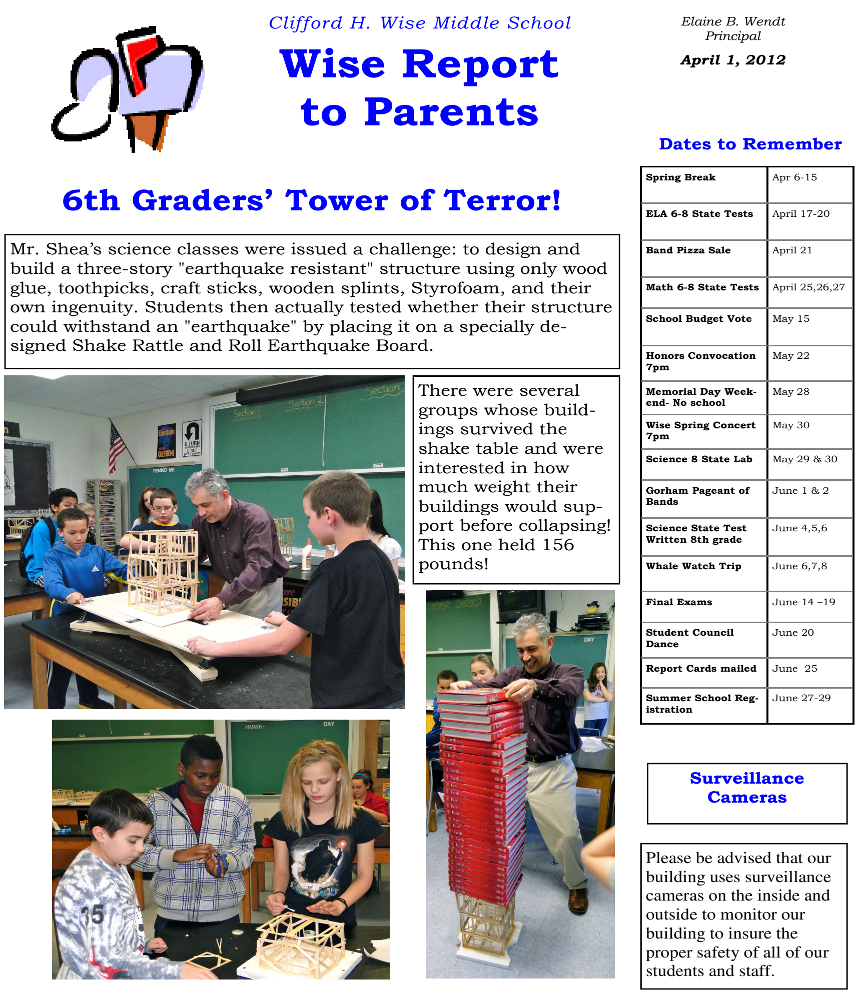
Figure 5: Jack's roof stress test

Sharing and Communicating Learning

Parents were informed of the project, requirements, and timelines. They were encouraged to support their child's efforts. Families and the community at large (e.g. administrators, other classes, School Board, community members, and reporters) were invited to the Presentation Fair.

Both the students and Brian felt that an audience added authenticity to students' scientific reporting. "Public relations is often overlooked, but very important in sustaining the program…this type of recognition fosters a spirit of community" (Zaikowski & Lichtman, 2007, 31).

The science fair was well attended by parents, other students, and community members. The local newspaper covered the event and included a lengthy article in the local paper. The earthquake project was reported in the district newsletter, informing community members of the results; many people in the school and community had personally contributed materials to the project. It would not have been possible to finance it in this small district in these economic times without that support. See Figure 6.



Clifford H. Wise Middle School

Wise Report to Parents

Elaine B. Wendt
Principal

April 1, 2012

6th Graders' Tower of Terror!

Mr. Shea's science classes were issued a challenge: to design and build a three-story "earthquake resistant" structure using only wood glue, toothpicks, craft sticks, wooden splints, Styrofoam, and their own ingenuity. Students then actually tested whether their structure could withstand an "earthquake" by placing it on a specially designed Shake Rattle and Roll Earthquake Board.

There were several groups whose buildings survived the shake table and were interested in how much weight their buildings would support before collapsing! This one held 156 pounds!

Dates to Remember

Spring Break	Apr 6-15
ELA 6-8 State Tests	April 17-20
Band Pizza Sale	April 21
Math 6-8 State Tests	April 25,26,27
School Budget Vote	May 15
Honors Convocation 7pm	May 22
Memorial Day Weekend- No school	May 28
Wise Spring Concert 7pm	May 30
Science 8 State Lab	May 29 & 30
Gorham Pageant of Bands	June 1 & 2
Science State Test Written 8th grade	June 4,5,6
Whale Watch Trip	June 6,7,8
Final Exams	June 14 –19
Student Council Dance	June 20
Report Cards mailed	June 25
Summer School Registration	June 27-29

Surveillance Cameras

Please be advised that our building uses surveillance cameras on the inside and outside to monitor our building to insure the proper safety of all of our students and staff.

Figure 6: Medina Central School District newsletter reporting the earthquake project

Achievement in Multiple Domains

Brian made criteria transparent to all stakeholders by using a clear and comprehensive grading rubric to assess each project; the rubric weighted both the exhibit and the presentation. Exemplars of previously completed projects were shared and analyzed for how each met criteria. Students were also provided detailed guidelines at the beginning of the project. Learning and performance indicators were continually monitored as students' completed the work. The teachers intervened to assist individuals or groups in ways that scaffolded learners through difficulties and propel them forward in their journey. Students were assessed for their acquisition of grade level expectations; teachers also evaluated students' dispositions toward science (i.e. scientific habits of mind and motivation for learning science).

Assessment data collected reflected both quantitative and qualitative measures; these included paper and pencil quizzes, performance testing, interviews, portfolios, student presentations, and teacher observations. Data revealed students' ability to transfer learning from one context to a new one — from knowledge acquisition to knowledge application. Results from these formative assessments guided the teacher's next instructional step (Keeley, 2011). Formative, in-the-moment assessment "fits well into inquiry-based instruction because it is easily embedded into activities and rich classroom discussions" (Keeley, 2011, 22). When learning is measured for depth of understanding and quality of application, the achievement reported is more stable.

Students demonstrated achievement across multiple domains. They gained knowledge that related directly to real world phenomena that has recently had worldwide attention due to disasters across the globe. They gained confidence as researchers and experimenters, taking full responsibility for acquiring essential facts when constructing an effective structure with a partner. Total immersion in the scientific protocol undergirded Jack's initiative to act on his immediate inquisitiveness — his new hypothesis about the building's ability to accommodate stress from weight on its roof.

As mentioned, the results of both projects were communicated to all stakeholders in ways that recognized students as self-directed learners who are capable of working collaboratively and following sophisticated investigative protocols. CSMEE (1996) suggests that stakeholders include the student, other teachers, administrators, parents, the community, policy makers, and appropriate government agencies (CSMEE, 1996). The reporting in these situations created an authentic audience for students' presentation of knowledge; it was also an opportunity to inform the community about the schools' curriculum, students' accomplishments, and teachers' effectiveness.

Conclusion

When we consider schools as environments for natural exploration, inquiry (discovery) learning emerges (Schrementi, 2011); "there is a shift from learning about the world to one that is being engaged with the world" (Zukowski, 2011, 83). Gardner (2007) notes a profound difference in students' ongoing motivation and depth of understanding when evaluating the pedagogy of learning about the world versus learning from it. Environments that foster enhanced inquiry, consider playfulness, curiosity, wonder and imagination to be essential components (Schrementi, 2011; Thomas & Brown, 2011).

Learning in school can and should prepare students for the lives they will live. It needs to stimulate an appreciation for learning and a disposition to continue doing so as a lifelong pursuit. Zaikowski & Lichtman (2007) found that a significant number of students who engaged in enhanced inquiry research in school went on to study science in college. Those students as well as others who did not go on to major in science were found to have "gained important life skills that serve them well in all walks of life" (32). As teachers, we plant the seed of knowledge and nurture growth as long as we can; when the process is marked with pedagogy that aligns with research-tested practice, students achieve and society is enriched.

References

Ainsworth, L. & Viegut, D. (2006). *Common formative assessments*. Thousand Oaks, CA: Corwin Press.

Alfieri, L., Brooks, P., Aldrich, N., and Tenenbaum, H. (2011). Does discovery-based instruction enhance learning? *Journal of Educational Psychology*, 103(1), 1-18.

Anderson, L. & Krathwohl, D. (Eds.) (2001). *A taxonomy for learning, teaching, and assessing: A revision of Bloom's Taxonomy of Educational Objectives*. New York, NY: Longman.

Bredekamp, S. & Copple, C. (1997). *Developmentally appropriate practice in early childhood programs*. Washington, DC: National Association for the Education of Young Children.

Bybee, R., Taylor, J. A., Gardner, A., Van Scotter, P., Carlson, J., Westbrook, A., & Landes, N. (2006). *The BSCS 5E Instructional Model: Origins and Effectiveness*. Colorado Springs, CO: BSCS.

Center for Science, Mathematics, and Engineering Education (CSMEE). (1996). *National science education standards*. Washington, D.C.: The National Academies Press.

Church, A. (2007). *Bloom's digital taxonomy*. Retrieved from http://www.techlearning.com/techlearning/archives/…/AndrewChurches.pdf. Accessed 1/29/12.

Common Core State Standards Initiative (2012). *English Language Arts standards: Science and technical subjects*. Retrieved from http://www.corestandards.org/the-standards/english-language-arts-standards/science-technical/grades-6-8/. Accessed 2/4/2012.

Connors, M. & Perkins, B. (2009). The nature of science education. *Democracy and Education*, 18(3), 56-60.

Council of Chief State School Officers (CCSSO) & National Governors Association (NGA). (2010). *Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science and Technical Subjects*. Washington, D.C.: Common Core State Standards Initiative.

Dunn, D. and Brooks, K. (2004) *Teaching with Cases*. Halifax, NS: Society for Teaching and Learning in Higher Education.

Gardner, H. (2007). *Five minds for the future*. Boston, MA: Harvard Business School Press.

Hanauer, D., Jacobs-Sera, D., Pedulla, M., Cresawn, S., Hendrix, R. & Hatfull, G. (2008). Teaching scientific inquiry. *Science*, 314, 1880-1881.

Haury, D. (1993). Science teaching through inquiry. *ERIC/CSMEE Digest*, ERIC Identifier: ED359048.

Holdaway, D. (1979) *The foundations of literacy*. New York, NY: Ashton Scholastic.

Keeley, P. (2011). With a purpose. *Science & Children*, 48(9), 22-25.

Kellough, R. & Kellough, N. (2008). *Teaching young adolescents: Methods and resources for middle grade teaching* (5th ed.). Upper Saddle River, NJ: Pearson Merrill Prentice Hall.

Marzano, R. (2011). Art & science of teaching. *Educational Leadership*, 69(1), 86-87.

Mayer, R. (2004). Should there be a three-strikes rule against pure discovery learning? The case for guided methods of instruction. *American Psychologist*, 59, 14-19.

McLaughlin, M. (2010). *Content area reading: Teaching and learning in an age of multiple literacies*. New York, NY: Pearson.

Michaels, S., Shouse, A.W., Schweingruber, H.A. (2007). *Ready, Set, SCIENCE!: Putting*

Research to Work in K-8 Science Classrooms. Washington, DC: The National Academies Press.
Nath, J. (2005). The role of case studies in the educational field. *International Journal of Case Method Research & Application*, 17(3), 396-400.
National Research Council Committee (NRC). (2012). *A framework for K-12 science education: Practices, crosscutting concepts, and core ideas*. Washington, D.C.: The National Academies Press.
New York State Academy for Teaching and Learning (2012). *Standards for mathematics, science, and technology*. Retrieved from http://www.p12.nysed.gov/nysatl/mathstand.html. Accessed 2/4/12.
Next Generation Science Standards (NGSS). (2012). *Next Generation Science Standards for Today's Students and Tomorrow's Workforce.* Washington, D.C. : Achieve, Inc. Report at http://www.nextgenscience.org/overview-0#Scientific%20Literacy. Accessed 9/1/12).
Olson, S. & Loucks-Horsley, S. (Eds.)(2000). *Inquiry and the National Science Education standards: A guide for teaching and learning*. Washington, D.C.: National Research Council.
Scales, P. (1991). *A portrait of young adolescents in the 1990s: Implications for promoting healthy growth and development*, Carrboro, NC: Center for Early Adolescence, School of Medicine, University of North Carolina at Chapel Hill.
Scales, P. (2003). Characteristics of young adolescents. In National Middle School Association, *This we believe: Successful schools for young adolescents* (43-51). Westerville, OH: National Middle School Association.
Schrementi, L. (2011). Assessing inquiry learning. *Science and Children*, 48(9), 38-43.
Shea, M. (2011). *Parallel learning of reading and writing in early childhood*. New York, NY: Routledge/Taylor and Francis.
Teacher-Developed/Classroom Tested (TD/CT) Kit (2012). Towering Toothpick Disaster: An Earthquake Kit. 46434. Retrieved 4/11/2012 from http://sciencekit.com/towering-toothpick-disaster-kit-teacher-developed-classroom-tested/p/IG0019935/.
Thomas, D. & Brown, J. (2011). *A new culture of learning: Cultivating the imagination for a world of constant change.* Charleston, SC: CreateSpace.
Tierney, R. (2008). The agency and artistry of meaning makers within and across digital spaces. In S.E. Israel & G. G. Duffy (Eds.). *Handbook of Research on Reading*, 261-288.
Wiles, J., Bondi, J., & Wiles, M (2006). *The new American middle school: Educating preadolescents in an era of change* (3rd ed.). Upper Saddle River, NJ: Pearson prentice Hall.
Zaikowski, L. & Lichtman, P. (2007). Scientific discovery for all. *The Science Teacher*, 74(3). 28-33.
Zukowski, A. (2011). Potter, Chesterton and imagination: Grounding for a new learning environment. *Momentum*, 42(3), 82-83.