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Curriculum and Community Enterprise for New York Harbor Restoration in New York City Public Schools[1]

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Abstract

Active investigation of students engaging in problem solving in natural settings has consistently been shown to greatly benefit their learning process. They gain skills and knowledge, while increasing their interest, aspirations, and motivation to learn more. But how can we provide these rich opportunities in densely populated urban areas where resources and access to natural environments are limited? The Curriculum + Community Enterprise for Restoration Science (CCERS) project has developed and begun testing an educational model of curriculum and community enterprise to address that issue within the nation's largest urban school system. Middle school students study the New York Harbor estuary and the extensive watershed that empties into it, while conducting field research in support of restoring native oyster habitats. This project builds on the

existing Billion Oyster Project, and is being implemented across different settings by a broad partnership of institutions and community stakeholders, including Pace University, the New York City Department of Education, the Columbia University Lamont-Doherty Earth Observatory, the New York Academy of Sciences, the New York Harbor Foundation, the New York Aquarium, the River Project, the University of Maryland's Center for Environmental Science, and Good Shepherd Services.

Keywords: community, curriculum, New York Harbor, restoration science, middle school, STEM-C

The Curriculum and Community Enterprise for Restoration Science (CCERS) project focuses on important concepts in the geological, environmental, and biological sciences that typically receive inadequate attention in schools: watersheds and keystone species. This project builds on and extends the New York Harbor School's Billion Oyster Project. The educational model includes five interrelated components envisioned as pillars: A teacher education curriculum, a student learning curriculum, a digital platform for lesson plans and other project resources, field trips and aquarium exhibits, and an afterschool STEM mentoring program. The project is designed specifically to interest and benefit middle-school students in low-income neighborhoods with high populations of English language learners and students from groups currently underrepresented in STEM fields and education pathways.

Review of Literature

CCERS leaders initially identified project-based learning as a central component of their implementation. "Grounded in constructivist theory, project-based instruction affords many possibilities for transforming classrooms into active learning environments" (Krajcki, Blumenfield, Marx, & Soloway, 1994, p. 483). Implementing, evaluating, and researching the CCERS project requires in-depth understanding of the theoretical and conceptual bases of constructivism. Thus, curriculum development, as well as evaluation instruments and research design, are organized with the major tenets of constructivism in mind. According to Jones & Brader-Araje (2002, p. 2) "constructivism has been welcomed as a theory of knowing that more fully explains the complexity of the teaching-learning process." Constructivism plays an important role in science teacher education, as Naylor & Keogh (1999, p. 93) state it is "accepted that any current science teacher education course would be incomplete without reference to the extensive research in this area." Constructivist perspectives on teaching and learning are based on the theoretical contributions of scholars and educators like Montessori, Dewey, von Glaserfeld, Piaget, and Vygtosky. The following theorems describe key elements of constructivism: (a) knowledge is a consensual domain; (b) the learner is not a passive recipient of knowledge but that knowledge is constructed by the learner in some way. Ultimately, constructivism shifts the focus from the importance of the products of knowledge to the processes by which knowing occurs (Jones & Brader-Araje, 2002). This process can occur through problem-solving, which is an inherent element of a project-based learning design. More specifically, scholars argue "knowledge is contextualized and that learners solve real (complex and ambiguous) problems in situations where they use cognitive strategies, tools, and other individuals as resources" (Krajcki, Blumenfield, Marx, & Soloway, 1994, p. 485). Despite the long history of constructivism in learning theory and project-based learning in pedagogy, scholars are continuing to identify precisely how constructivism and project-based learning should be implemented in the classroom. Carlson & Wiedl (2013) described five general principles that should be followed in implementing an education project based constructivist notions of cognition. These include utilizing interactive teaching strategies, emphasizing reciprocal and metacognitive instructional approaches, and using assessments to emphasize mastery over performance goal learning.

Bachtold's (2013) recommendations for enhancing science learning expanded on Carlson & Wiedl's (2013) principles by describing the importance of teaching operative functions of a model or theory, carrying out scientific activities in the classroom, and studying real problems scientists have faced in order to elicit students' genuine exploration of a problem in a guided manner.

Ultimately, employing constructivism in the classroom allows educators to employ techniques long considered critical components of National Education in the Next Generation Science Standards (NGSS) which emphasize the importance of both oral and written inquiry to help students connect what they learn to real world observations and experiences (National Research Council, 1996, p. 36). Furthermore, the curriculum offers myriad opportunities for students to collaborate in groups, discuss and analyze data, and create reports to share what they have learned.

The National Research Council's recommendations are the building blocks on which NGSS were founded. Their research reports consistently emphasize the effectiveness of providing opportunities for students from diverse backgrounds to engage in scientific activities and develop their own explanations for results in both informal and classroom settings. (NGSS Lead States, 2013). Therefore, constructivism's theoretical links to project-based learning form the basis of the CCERS project's plans to improve STEM education for underserved students from disadvantaged communities.

Pedagogical Models

The following contains brief descriptions of the three learning models essential to development of the CCERS curriculum and Teacher Fellowship program: Bybee's 5E, Project Based Science Instruction, and Problem Based Learning.

Bybee's 5E Instructional Model. The 5E Model is a learning cycle emphasizing five different phases: engagement, exploration, explanation, elaboration, and evaluation. In the engagement phase, teachers foster student curiosity by asking them to complete a short activity that connects their existing knowledge to the new concept. During the exploration phase, students are asked to complete a task illustrating the new concept using their current knowledge. Then in the explanation phase, teachers provide new vocabulary terms and explain the new concept in detail for the first time. Next elaboration expands student understanding by providing additional activities for them to practice skills and deepen understanding of major concepts. In the evaluation phase, teachers and students assess students' learning and understanding. This model expands on previous models (Bybee, et al., 2006) developed from various prior studies that show learning cycle models (i.e. those where students explore a concept before it is explained to them) outdo traditional models (i.e. models where students are first taught a concept and then told to apply it). This model differs from others by including an engagement component in which students are instructed to make connections between new and old concepts to enhance their learning (see Figure 1).

Project Based Science Instruction (PBSI). According to Colley (2005)**,** in PBSI students work on a well-defined research question and teachers act as guides during the project. These projects can be conducted over the course of a unit, curriculum, or program. The responsibility of learning is placed on the students who decide what to learn, how to learn it, and for how long. This differs from the more general inquiry-based instruction, in which teachers dictate the question and procedures. This also differs from problem-based instruction where students are given an ill-defined problem, a goal, and steps to solve that problem. Teachers may struggle to use PBSI because they need to structure their lessons around specific standards (see Figure 2).

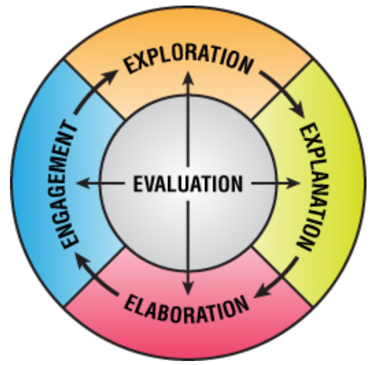

Figure 1: The 5E Instructional Model. This figure illustrates the model's five interrelated components (Akron Global Polymer Academy, 2016).

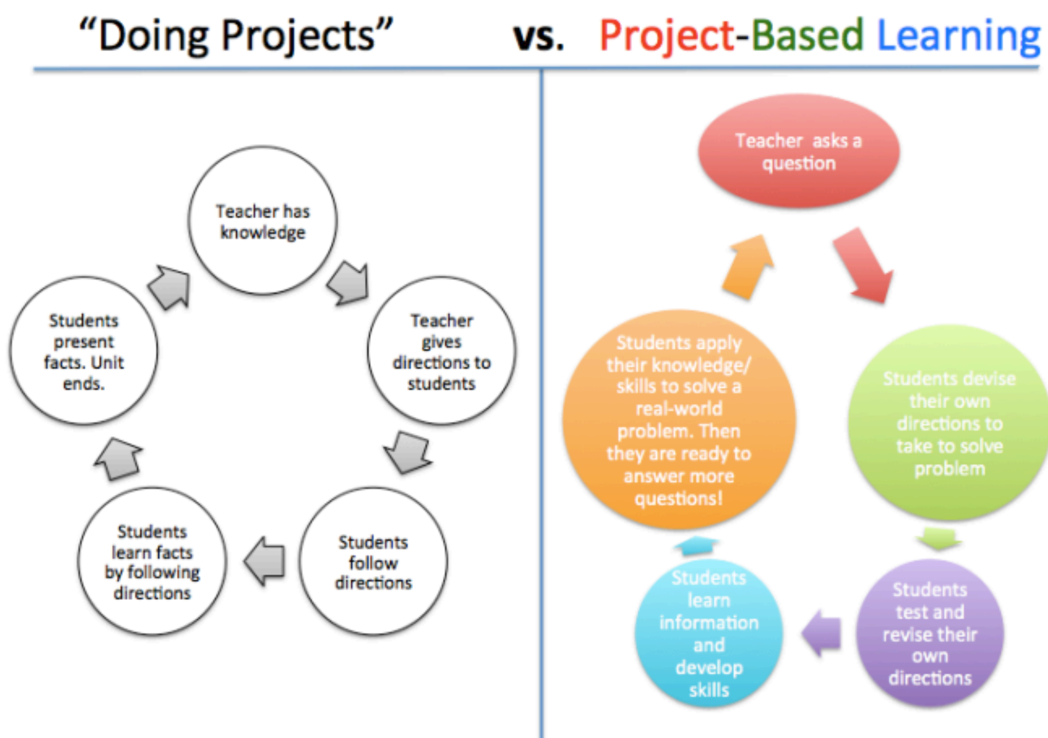

Figure 2: Project-based science instruction. This figure illustrates how project-based science instruction differs from traditional project implementation (Ellie, 2013).

Problem-based learning (PBL). Weisman et al. (2008) explained in this framework teachers present students with an "ill-structured" problem (or a problem that does not contain enough information to be solved on its own) with many possible solutions. Through guidance, students reflect on what they already know, identify learning challenges, brainstorm possible solutions, work on the problem, and then review their ideas. After this, students can come to a decision about the problem or continue to review possible solutions (see Figure 3).

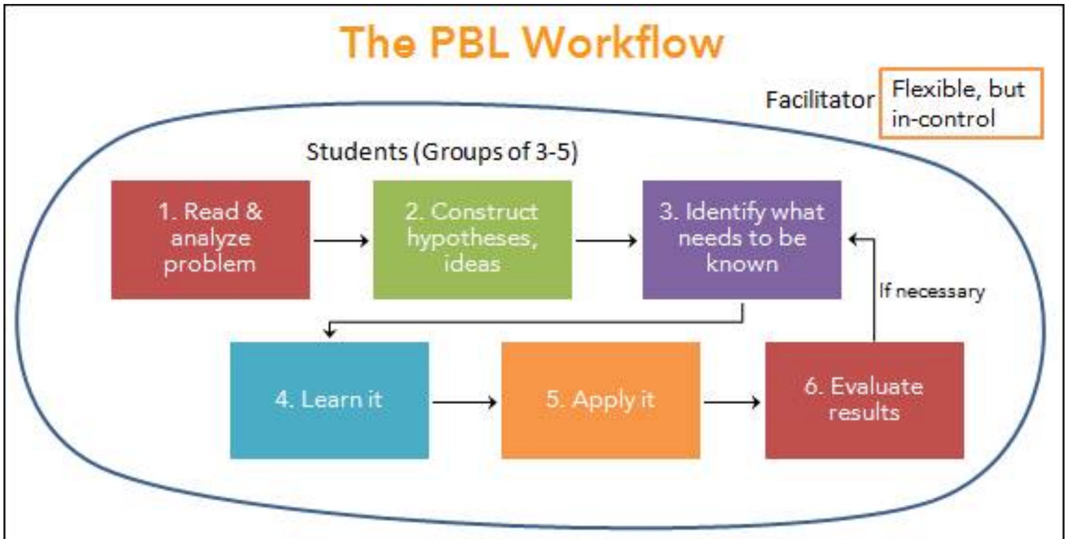

Figure 3: This figure illustrates the workflow for implementing problem-based learning (STREAM@sspp, 2015).

Weisman et al. (2008) used their research to develop and test a model of professional development in PBL for teachers. They used an iterative design-based research approach where the design and research informed each other and therefore evolved throughout the project. Teachers participated in summer workshops and meetings throughout the school year, and shared results at the end of the year. The goal of the intervention was to further develop teachers' ability to apply Pedagogical Content Knowledge (PCK) in the classroom. They found that teachers' PCK and clinical reasoning improved, but not their conceptual understanding of science.

There are many similarities or overlapping and complementary components among the models presented above. Many of the 5E Model components are analogous to components of PBSI and PBL. For example, the exploration phase in the 5E contains elements advocated in the PBL model in that students are not given all the information they need to solve the problem on their own. However, PBSI differs from the other models in that learning is student driven rather than teacher driven. Other models are more flexible because they allow teachers to not only control the classroom, but also directly explain possible solutions to students to the extent to they feel it is appropriate. To achieve the benefits associated with these three models, the CCERS recruited curriculum specialists and scientists to work with middle school teachers recruited from local public schools to collaborate on lesson plans, sharing their respective expertise and resources.

Methods

Teacher Training Fellowship

The objectives of the Teacher Training Fellowship are for teachers to 1) learn new instructional methods for project-based lesson planning; 2) increase their content knowledge through interactions with experts; 3) increase their skills through hands-on activities; 4) develop new lessons collaboratively; 5) receive expert direction and assistance implementing the new curriculum in their classrooms. To achieve those five objectives, partners developed a two-year Teacher Fellowship Program. Teachers received a stipend and course credit to attend monthly classes at Pace University and multiple Saturday field days. Participants were provided with all required equipment and supplies needed to complete activities. This professional develop program helps teachers develop pedagogical skills and incorporate new methods into their instructional toolbox. Teachers are recruited annually, thus, in their second year, Cohort 1 teachers build additional skills and confidence by mentoring Cohort 2 teachers.

Current Implementation. Within the CCERS educational model, the teacher training fellowship program at Pace University is Pillar One. The Billion Oyster Project's (BOP) existing curriculum for place based learning through ecosystem restoration activities has been used as the basis for developing new lesson plans and activities to teach Science, Technology, Engineering, Mathematical, and Computer Science (STEM-C) concepts and skills. BOP is a long-term initiative to restore the ecology of New York Harbor by engaging New York City students in hands-on marine science and stewardship. Founded by the New York Harbor School and New York Harbor Foundation in 2013, BOP aims to restore one billion live oysters to New York Harbor over the next 20 years, and in the process, educate thousands of New York City middle school students about the ecology of their local marine environment.

The teacher training fellowship program, named the "BOP Collaboratory," brings middle school teachers and scientists together at Pace University each month during the school year. Throughout the course of the two-year fellowship, teachers learn directly from guest experts, scientists, and STEM professionals through lectures, colloquium style classes, and hands-on workshops. During their first year fellows participate in monthly Saturday sessions conducted at locations throughout New York Harbor: Scientists and guest experts train teachers the skills needed to actively conduct field experiments and monitoring activities. During their second year, fellows train their students to continue these experiments and monitoring activities. Funding from the National Science Foundation (NSF) supports engaging three overlapping fellowship cohorts of 20 teachers to collaboratively develop and refine student lesson plans and field day methodologies; supplies needed for their students to engage in environmental monitoring and restoration activities; a digital platform to host lesson plans for download and development; and annual symposia for presentation of student research and program results.

The best practices for creating a similar program are presented in the following section: 1) teacher training as professional development; 2) teacher/scientist connection; 3) guest lectures; and 4) teacher buy-in. All of which have been incorporated into the Teacher Training Fellowship Pillar.

Teacher Training as Professional Development. One of the major components of the CCERS is an accredited teaching training and curriculum development program hosted by Pace University's School of Education and Seidenberg School of Computer Science. The New York Department of Education (NYDOE) requires teachers to complete 175 hours of professional development every five years in order to maintain their professional certification.

The purpose of this pillar is to improve teachers' understanding of restoration science concepts and practices; increase their efficacy at creating activities and implementing PBL; as well as enhancing teachers' ability to facilitate scientific inquiry among their students. Professional development is key to enhancing education effectiveness. Introducing new methods and improving teachers' skills yields positive student outcomes. At the middle school level gains are seen relatively quickly (Balfanz & Mc Iver, 2000). Thus, results are mutually reinforcing, motivating teachers to continuously strive to develop their skills; thereby, leading to ongoing improvements in teacher practices (Krajcki, Blumenfield, Marx, & Soloway, 1994). As research shows, teachers are more likely to change their practices when they focus their efforts on developing professionally (Guskey, 1985). When teachers feel comfortable with the scientific process, they can also better facilitate students' scientific investigation and scientific thinking skills (Baumgartner & Zabin, 2008).

Teacher/Scientist Connection. The university partners on this project have developed and implemented a training program and activities in which teachers collaborate with scientists to exchange knowledge and co-develop lesson plans for middle school students. This will improve teachers' environmental literacy and ability to explain scientific concepts with greater accuracy; thereby reinforcing teachers' decision to implement the restoration science based curriculum (Ernst, 2007). Inquiry based pedagogical practices demand teachers have deep knowledge and understanding of the subject matter in order to answer a wider variety of student questions and support their investigations (Fishman, Marx, Best, & Tal, 2003). Professional development courses that incorporate scientist-teacher partnerships have been especially effective at increasing teacher knowledge, self-efficacy, and application of inquiry based teaching (Powell-Moman & Brown-Schild, 2011; Caton, Brewer, & Brown, 2000), raising focus on content rather than coverage of course objectives (Powell-Moman & Brown-Schild, 2011), improving understanding of research-based teaching practices (McDonnough & Matkins, 2010), and increasing use of inquiry in the classroom (Caton, Brewer, & Brown, 2000). These partnerships are not only beneficial to teachers, they are also helpful to scientists as they increase understanding of science education and teaching practices, further enabling them to communicate and connect with lay audiences and communities (Caton, Brewer, & Brown, 2000; Siegel, Mlynarczyk-Evans, Brenner, & Nielsen, 2005).

The CCERS fellowship is especially important because actively exploring curriculum materials with others is a hallmark of successful scientist-teacher partnerships (Caton, Brewer, & Brown, 2000). Teachers attendance at field science days enables hands-on learning of environmental field techniques; thereby developing their skills to lead students through field science activities. All the hands-on activities coupled with the expertise of scientists increases teachers' scientific knowledge and skill in teaching inquiry-based restoration-oriented lessons, thereby improving their ability to teach students core STEM-C concepts in an engaging manner (McDonnough & Matkins, 2010).

Guest Lectures. The teacher training fellowship pillar further assists teachers by having Scientists-in-Residence (SiR) visit their classrooms and co-teach lessons. The SiR program is an alliance between a pillar 4 partner, the New York Academy of Sciences (NYAS), and the New York City Department of Education (NYCDOE). Graduate students and postdocs from STEM disciplines conduct authentic science projects, supervise experiments, and assist students in analyzing data and writing reports. This helps teachers overcome challenges they may experience when they begin implementing aspects of planning, management, and assessment of the project-based learning lesson plans (Thomas, 2000) in their second year of fellowship. Supporting teachers is crucial to the success of an innovation or program (Krajcki, Blumenfield, Marx, & Soloway, 1994), and provides the opportunity for teachers to continue developing and improving their teaching practices (Dresner & Worley, 2006). PBL has been underutilized in public schools, with low-performing students, and in high-poverty schools which lack resources (David, 2008). Therefore, this alliance was created to help fine-tune and strengthen the curriculum in anticipation of any adversities that might otherwise hinder implementation of new methods.

Teacher Buy-in. Teachers' beliefs affect their likelihood of adopting a new curriculum (Roehrig & Kruse, 2005). Teacher buy-in is crucial, as teachers must be willing to participate, take collective responsibility, and commit to changing their instructional practices (Lambert, 2003). CCERS partners developed the fellowship training with teacher buy-in in mind. By understanding that teachers are learners themselves, who also need the opportunity to collaborate, experiment, reflect, and modify their practices (Marx, Blumenfeld, Krajcik, & Soloway, 1997), partners ensured teachers' sustained motivation to participate in the fellowship. In the first year, Cohort 1 teachers contributed to writing and developing the initial STEM-C lesson plans, thereby enhancing their feelings of ownership over the process and results. Teacher buy-in and ownership of the new curriculum are essential to successful and ongoing implementation (Balfanz & Mac Iver, 2011).

The fellowship presents information about restoration science and ecology through a variety of instructional methods and activities. The collaboration with scientists is vital to teachers learning new practices, developing familiarity with the terminology, and building proficiency in demonstrating proper use of scientific equipment (Marx, Blumenfeld, Krajcik, & Soloway, 1998). This ensures teachers are engaged and receptive, as well as modeling how teachers can effectively convey new information to their students. Reciprocally, it is important teachers are recognized for their expertise regarding what practices are appropriate for their students and classrooms (Seethaler, Czworkowski, Remmel, Sawrey, & Souviney, 2013).

CCERS project leaders further promoted teacher buy-in by providing teachers with equipment for activities and ongoing access to other resources. As a condition of participation, school administrators were required to commit to fully supporting teachers' participation, allowing them full control over implementation of the curriculum and activities within their classes. All of these factors have been found to be especially important during the first year of implementation (Turnbull, 2002).

Project leaders' expectations were confirmed by an overwhelming increase in applications in the second year, for Cohort 2 of the fellowship. Cohort 1 teachers recommend the model and program to their colleagues, and continued to participate by leading microteaching lessons in the second year of monthly fellowship meetings. Project leaders anticipate that their efforts to continue expanding awareness and participation in restoration-based education will increase the number of urban middle school students receiving high quality, engaging STEM-C instruction, while also improving their local ecosystems (McCann, 2011).

Conclusion

In summary, the CCERS Teacher Training Fellowship provides teachers with the resources and skills necessary to teach core STEM-C concepts to their students through restoration science. The Teacher Training Fellowship will continue to provide engaging workshops for teachers while fostering ownership by allowing them to develop their own lessons, thus bolstering their buy-in. By using scientist-teacher partnerships, the CCERS program not only gives teachers the opportunity to gain skills and knowledge, but also provides them the support they need to continue improving. This training will ultimately improve the quality of STEM-C education these teachers provide to their students. In turn, the increased success of the CCERS model will enable it to provide resources to an ever-increasing number of teachers. As described above, prior research has highlighted how effective teacher training using teacher-scientist partnerships can be. However, this project also connects that teacher training with student curriculum, a digital platform, science exhibits and after-school programs to create a well-rounded experience for students by impacting STEM-C education within the local community. This project adds to the academic literature by describing how these partnerships form and flourish, thereby facilitating future replications in other locations with different partners for a variety of restoration science efforts.

The current project will directly involve over forty schools over the grant-funded period. At least sixty teachers will be recruited to participate in the fellowship and or other professional development workshops. Project leaders estimate the curriculum will benefit over 8,000 students in the initially funded three-year period. A quasi-experimental, mixed-methods research plan will assess the individual and collective effectiveness of the five project components. Regression analyses will be used to identify effective program aspects and assess the respective effectiveness of participation in various combinations of the five program components. Social network mapping will enable researchers to further assess and describe the overall "curriculum plus community" model.

References

Akron Global Polymer Academy. (2016). nsf.cyclepic.jpg. Retrieved from http://uakron.edu/cpspe/agpa-k12outreach/professional-development-modules/learning-cycle

Bachtold, M. (2013). What do students "construct" according to constructivism in science education? *Research in Science Education*, *43*(6)*,* 2477-2496. doi:10.1007/s11165-013-9369-7

Balfanz, R., & Mac Iver, D. (2011). Transforming high-poverty urban middle schools into strong learning institutions: Lessons from the first five years of the talent development middle school. *Journal of Education Student Placed at Risk*, *5*(1-2), 137-158.

Balfanz, R., & Mc Iver, D. (2000). Transforming high-poverty urban middle schools into strong learning institutions: Lessons from the first five years of the talent development middle school. *Journal of Education for Students Placed at Risk, 51*(1-2), 137-158. doi:10.1080/10824669.2000.9671384

Baumgartner, E., & Zabin, C. J. (2008). A case study of project-based instruction in the ninth grade: A semester-long study of intertidal biodiversity. *Environmental Educational Research, 97*(2), 97-114.

Bybee, R., Taylor, J., Gardner, A., Van Scotter, P., Carlson-Powell, J., Westbrook, A., & Landes, N. (2006, June). The 5E Instructional Model: Origins, effectiveness, and applications. Retrieved from http://bscs.org/sites/default/files/_legacy/_5E_Instructional_Model-Full_Report.pdf

Carlson, J. S., & Wiedl, K. H. (2013). Cognitive education: Constructivist perspectives on schooling, assessment, and clinical applications. *Journal of Cognitive Education and Psychology, 12*(1), 6-25.

Caton, E., Brewer, C., & Brown, F. (2000). Building teacher-scientist partnerships: Teaching about energy through inquiry. *School Science and Mathematics*, 100(1), 7-15.

Colley, K. E. (2005). Project-based science instruction: Teaching science for understanding. *Radical Pedagogy*. Retrieved from http://www.radicalpedagogy.org/radicalpedagogy/Project-Based_Science_Instruction__Teaching_Science_for_Understanding.html

David, J. (2008). What research says about: Project-based learning. *Educational Leadership, 65*(5), 80-82.

Dresner, M., & Worley, E. (2006). Teacher research experiences, partnerships with scientists and teacher networks sustaining factors from professional development. *Journal of Science Teacher Education, 17*(1), 1-14.

Ellie, B. (2013, May 4). Doing projects vs. project-based learning. *Creative Commons License.* Retrieved from http://msellieb.wordpress.com/2013/05/04/doing-projects-vs-project-based-learning/

Ernst, J. (2007). Factors associated with k-12 teachers' use of environment-based education. *The Journal of Environmental Education, 38*(3), 15-31.

Fishman, B. J., Marx, R. W., Best, S., & Tal, R. T. (2003). Linking teacher and student learning to improve professional development in systemic reform. *Teaching and Teacher Education, 19*(6), 643-658. doi:10.1016/S0742-051X(03)00059-3

Guskey, T. R. (1985). Staff development and teacher change. *Educational Leadership*, *42*(7), 57-60.

Jones, M. G., & Brader-Araje, L. (2002). The impact of constructivism on education: Language, discourse, and meaning. *American Communication Journal*, *5*(3), 1-10.

Krajcki, J., Blumenfield, P. C., Marx, R. W., & Soloway, E. (1994). A collaborative model for helping middle grade science teachers learn project-based instruction. *The Elementary School Journal, 94*(5), 483-497.

Lambert, L. (2003). *Leadership capacity for lasting school improvement*. Alexandria, VA: Association for Supervision and Curriculum Development.

Marx, R. W., Blumenfeld, P. C., Krajcik, J. S., & Soloway, E. (1997). Enacting project-based science. *The Elementary School Journal, 97*(4), 341-358.

Marx, R. W., Blumenfeld, P. C., Krajcik, J. S., & Soloway, E. (1998). New technologies for teacher professional development. *Teaching and Teacher Education, 14*(1), 33-52.

McCann, E. (2011). Restoration-based education: Teach the children well. In D. Egan, E. E. Hjerpe, & J. Abrams (Eds.), *Human dimensions of ecological restoration: Integrating science, nature, and culture* (pp. 315-334). Washington, DC: Island Press.

McDonnough, J. T., & Matkins, J. J. (2010). The role of field experience in elementary preservice teachers' self-efficacy and ability to connect research to practice. *School Science and Mathematics, 110*(1), 13-23.

National Research Council. (1996). National Science Education Standards. 36-176. Retrieved from www.nextgenscience.org

Naylor, S., & Keogh, B. (1999). Constructivism in classrooms: Theory into practice. *Journal of Science Teacher Education, 10*(2*)*, 93-106.

NGSS Lead States. (2013). *Next generation science standards: For States, by States.* Washington, DC: The National Academies Press.

Powell-Moman, A. D., & Brown-Schild, V. B. (2011). The influence of a two-year professional development institute on teacher self-efficacy and use of inquiry-based instruction. *Science Educator, 20*(2), 47-53.

Roehrig, G. H., & Kruse, R. A. (2005). The role of teachers' beliefs and knowledge in the adoption of a reform-based curriculum. *School Science and Mathematics, 105*(8), 412-423.

Seethaler, S., Czworkowski, J., Remmel, J., Sawrey, B. A., & Souviney, R. (2013). Bridging the divide between science and education: Lessons from a fruitful collaboration. *Journal of College Science Teaching, 43*(1), 54-59.

Siegel, M. A., Mlynarczyk-Evans, S., Brenner, T. J., & Nielsen, K. M. (2005). A natural selection: Partnering teachers and scientists in the classroom laboratory creates a dynamic learning community. *The Science Teacher, 72*(7), 42-45.

STREAM@sspp. (2015). The PBL Workflow. Retrieved from http://www.streamatsspp.com/pbl.html

Thomas, J. (2000). A review of research on project-based learning. San Rafael, CA: Autodesk Foundation.

Turnbull, B. (2002). Teacher participation and buy-in: Implications for school reform initiatives. *Learning Environments Research, 5*(3), 235.

Weizman, A., Covitt, B., Koehler, M., Lundeberg, M., Oslund, J. A., Low, M. R., Eberhardt, J., Urban-Lurain, M. (2008). Measuring teachers' learning from a problem-based learning approach to professional development in science education. *Interdisciplinary Journal of Problem-Based Learning, 2*(2), 29-60. Retrieved from http://docs.lib.purdue.edu/ijpbl/vol2/iss2/5

Endnotes

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