Partnership for Effective Science Teaching and Learning

Literacy Connections – Gathering, Reasoning, and Communicating with Evidence

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Overview

The Partnership for Effective Science Teaching and Learning (PESTL) brings together five school districts and two universities to provide sustained and comprehensive science professional development with the goal of improving student learning, interest, and achievement in science. The partnership's leadership committee includes teachers, administrators, curriculum specialists, and university science educators and scientists. PESTL focuses on teachers development of the knowledge, skills, and dispositions to effectively engage students in gathering science information, reasoning to develop explanations supported by evidence, and communicating science explanations using models and arguments supported by evidence.

The PESTL program is a three-year professional development program for teachers in grades 3-6. The program is currently in year three with the second cohort of 120 teachers. Teachers annually participate in over 100 hours of science professional development with the following objectives:

1) Increase teacher pedagogical content knowledge for science specific to disciplinary core ideas, crosscutting concepts, and science and engineering practices,
2) Develop teachers' use of effective instructional strategies in science,
3) Develop deep understanding of science standards,
4) Refine alignment of instructional resources and formative assessment tasks to the science and engineering practices, crosscutting concepts, and disciplinary core ideas,
5) Develop meaningful and useful understanding of the nature of science,
6) Increase teachers' interest in and enjoyment of science learning.

The PESTL program includes a five-day summer seminar, two after school instructional alignment sessions and an annual content course specific to each teacher's grade-level (two Saturday sessions and online modules). These components of the professional development are linked through structured science professional learning communities (PLCs) facilitated at each school by a teacher facilitator who has received additional preparation in conducting the PLCs. The approaches to instruction presented in the PESTL professional development program are strongly influenced by the research presented in the National Academies of Sciences, *Taking Science to School* (National Research Council (NAS), 2007).

Science and Engineering Practices

The literacy connections in the PESTL program provide teachers with structures to engage students in a progression of learning across the science and engineering practices organized by: 1) Gathering, 2) Reasoning, and 3) Communicating science information, concepts, and ideas. Instructional strategies are modeled as teachers use the practices to engage in science performances and prepare to engage their students in a similar manner. Evidence is central throughout the practices and significant time is devoted to reflecting on the role of evidence in instruction and student performances. Teachers develop ways to distinguish between gathering practices (e.g., investigations, observations, obtaining information) and reasoning practices (e.g., constructing explanations, designing solutions, analyzing data, developing arguments). Additionally, the use of models across gathering, reasoning, and communicating receives specific attention. Teachers gain utility with the core ideas and crosscutting concepts and the role of these two dimensions in developing evidence. Significant time is devoted to instructional strategies that engage students in gathering information through investigations, models, and reliable sources and ways of developing information as evidence for constructing explanations of phenomenon. Modeling instructional strategies, engaging teachers in science performances, and reflecting on the nature of science instruction develops deeper understanding of the instruction leading to meaningful student science performances.

Connecting Literacy Principles from CCSS ELA and A Framework for K-12 Science Education

Science writing and classroom discourse does not start with a question, but rather from wondering about phenomena and gathering information through reading, listening, and/or investigating. Just as gathering information to write about how a frog jumps is more engaging when sitting on the bank of a warm pond, with feet in mud and frog in hand, so too is gathering information when the student is engaged with the phenomena. Gathering information is an essential component of science; however, it must be contextualized within students' current and/or past experiences to make sense (Driver, Asoko, Leach, Mortimer, & Scott, 1994). Constructing understanding requires context connected to existing knowledge. Building that context requires engaging students in wondering about phenomena and developing strategies to investigate, in multiple ways, the evidence that can be used to support explanations of the phenomena. Classroom discourse only begins with gathering; however, students must engage in reasoning practices with the information to makes sense of the phenomenon and develop meaningful arguments supported by evidence.

Gathering information through purposeful reading is best done when coupled with reasoning that connects evidence to explanations leading to productive student dialogue and meaningful writing (Beauchamp, Kusnick, & McCallum, 2011). Student science performances are not complete until the student engages in communicating explanations supported by evidence and reflecting on connections from core ideas, crosscutting concepts, and observations/measurements from investigations. The PESTL program uses models purposely in all three phases of the practices (i.e., gathering, reasoning, communicating) to extend and make student thinking visible. Reflecting on the relationship of evidence to explanation is essential for meaningful written and oral communication. Written and oral reflection on learning contributes to students' ability to more fully engage in the science and engineering performances within new contexts.

Practices Phases	Science and Engineering Practices	Literacy Expectations
Gathering	• *Obtain Information* • *Ask Questions/Define Problems* • *Plan and Carry Out Investigations* • *Use Models to Gather Data* • *Use Mathematics & Computational Thinking*	*Ask questions to gain understanding.* *Obtain information* through careful reading of relevant and reliable text and listening to reliable sources. • Develop and organize ideas, concepts, and observations (data and measurements from investigations).
Reasoning	• *Evaluate Information* • *Analyze Data* • *Use Mathematics and Computational Thinking* • *Construct Explanations/Solve Problems* • *Develop Arguments from Evidence* • *Use Models to Predict & Develop Evidence*	Evaluate information for evidence and relate *explanations and arguments to appropriate evidence.* • "Explain how an author uses reasons and evidence to support particular points in a text, identifying which reasons and evidence support which point[s]" (p.14)
Communicating	• *Communicate Information* • *Use Argument from Evidence (written/oral)* • *Use Models to Communicate*	*Communicate* in meaningful ways through speaking and writing *that use evidence to support arguments.* • Write informative/explanatory texts to examine a topic and convey ideas and information clearly. • Present information, findings, and supporting evidence such that listeners can follow the line of reasoning and the organization, development, and style are appropriate to task, purpose, and audience.

Table I: Organization of instruction across gathering, reasoning, and communicating with connections to science/engineering practices (National Research Council (NRC), 2012) and CCSS ELS (National Governors Association Center for Best Practices & Council of Chief State School Officers, 2010).

Developing Meaningful Classroom Discourse

Effective classroom discourse does not just happen; it is carefully planned and executed. Development of a clear vision for the use of core ideas and crosscutting concepts, central to student arguments, must be considered during instructional planning and lesson development. The hierarchies of questions teachers pose must be carefully crafted to provoke students to ask relevant questions, gather additional information, elicit explanations, or relate relevant evidence to arguments. Instructional planning has manifold purposes; not the least of which is keeping the focus on core ideas and crosscutting concepts central to the phenomenon under investigation. Equally important are the questions that will help the teacher avoid telling the "punch line" of the student performance. Presenting phenomena and questions in ways that give students room to use core ideas such as, matter is made of particles, forces are transferred in collisions, or for every action there is an equal and opposite reaction (e.g., the paper floats more slowly to the floor when it is flat because air is made of particles and the paper must move the air particles and this take force), requires posing questions that engage students in connecting the cause and effect of phenomena to core ideas. Science education should engage students in applying science concepts, ideas, and practices to make sense of novel phenomena with underlying principles related to other phenomenon they have engaged in previously. Identifying phenomena and topics for discussion that help students make progress with respect to making sense of new phenomena requires careful planning to develop a deeper understanding of fewer science concepts (NAS, 2007).

Instructional Alignment to Student Performances

Engaging teachers in instructional alignment of lesson ideas to the three dimensions described in the *Framework* (NRC, 2012) is another component of the PESTL program. Instructional alignment sessions are conducted by the leads of the PESTL program and typically have 4-10 teachers from a single grade-level meet for 2-3 hours. Teachers engage in planning student performances at the intersection of the three dimensions. The lesson ideas create scaffolding for making student thinking visible and opportunities for students to communicate reasoning (See Appendix A). Engaging teachers in the alignment process and thinking deeply about the nature of quality science instruction is the central purpose of the alignment sessions.

PESTL Classroom Observations

The PESTL program measures instructional changes using the PESTL Observation Protocol. The protocol provides insights into the degree to which teachers engage students in science and engineering across four scales: 1) "Talk and Argument" as described in *Ready, Set, Science!* (Michaels, Shouse, & Schweingruber, 2007); 2) Using Models; 3) Core Ideas; and, 4) Investigations. The changes in instruction related to Talk and Argument and Models reveals insights into the engagement of students in developing knowledge and skills related to literacy and science. The Talk and Argument section of the protocol has four sub-scales: a) ratio of student/teacher interaction; b) number of times the teacher extends student thinking during classroom discourse; c) the extent of inter-student discussion; and d) students' use of evidence to support explanations. The "Using Models" section of the protocol has four sub-scales: a) Uses models/representations to connect to crosscutting concepts and core ideas; b) Uses examples and analogies effectively; c) Uses models to assess student understanding; and, d) Science writing or representations are used by students.

Students and teachers in the experimental and control groups are observed annually in a 45-minute episode of science instruction. The sub-scales are rated on a five-point rubric. The performance of teachers in the experimental group was found to be significantly higher during years two and three (See Appendix B).

Conclusions from PESTL

Sustained professional development changes classroom instruction. Instructional strategies to engage students in using evidence to support explanations resulted in significant differences from observed classrooms of teachers not receiving professional development. The changes were significant after two years of professional development and continued to increase after three years. Structuring the science practices in ways that lead to communicating science reasoning provides a useful platform for teachers to engage students in developing skills across many of the expectations of the Common Core State Standards for English Language Arts and Literacy in Science. Engaging students in meaningful science performances requires instructional strategies and structures to examine phenomena, classroom expectations for student engagement in reasoning, and norms for communicating through writing and oral discourse.

References

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Appendix A

Performance – 2013 Nebo School District	
4th Grade	**Title**
Topic – Weathering of rock and the water cycle	***"When Cycles Collide"***

Performance Expectation: NGSS – Make observations and/or measurements to provide evidence of the effects of weathering or the rate of erosion by water, ice, wind, or vegetation.
[Clarification Statement: Examples of variables to test could include angle of slope in the downhill movement of water, amount of vegetation, speed of wind, relative rate of deposition, cycles of freezing and thawing of water, cycles of heating and cooling, and volume of water flow.]
[Assessment Boundary: Assessment is limited to a single form of weathering or erosion.]

Performance Expectations: Lesson – Construct explanations for the role of the water cycle in the weathering of rock on Earth.

Student Science Performance

Gather Information

Carry Out an Investigation

Students in groups of three investigate the weathering of rocks and the role of the water cycle in the process. Each group places three rocks on the side of the school building in a location where water from a downspout or drip edge may fall on the rocks. Students record observations (e.g., pictures, diagrams) in a notebook once per week for a couple of months.

(Hints: Use sandstone, granite, and shale or similar rocks. Place rocks on the west or south side of the building in the winter for best results. Groups may select different locations, some on west, some south, some under waterspout, some away from spout, some in a dry place near building. Some groups could keep their rocks in the school.)
(Hint: In locations without freeze thaw cycles the rocks can be soaked in water and place in a freezer through five or six cycles over a period of a week.)
(Hint: You may want to keep a calendar on the wall for students to check off the observations each week on the same day (every Monday or Friday).

Reasoning

Construct an Explanation from Evidence

Students construct an explanation for how the rocks changed over time and why there were differences in the three rocks and across the various groups. They support the explanation with evidence they collected from the investigation. Students individually write in their notebooks the explanation and the evidence to support their argument for the mechanism that changed the rocks.

Develop an Argument from Evidence

Class Discussion - Sample Questions to Initiate Discussion
Conduct a class discussion and engage students in argument from evidence *(Hint: See chapter five of RSS)*
Q: Why did some rocks change more than others?
Q: What caused the rocks to change?
Q: How did water and/or temperature cause the change (mechanism)?
Q: What evidence do you have that water expands when it freezes?
Q: Where in nature does this process occur?
Q: How could you slow down the process of weathering? Where would you want to slow the process?
Q: Where did the rock material go when it weathered?
Q: Where did the water come from?
Q: Where does the energy come from that moves the water to the roof of the school?

Extend thinking through the questions about where they see this process in the natural world.
Students relate the water cycle to the weathering of rock in nature. They write an explanation and include examples from natural systems.

Communicating
Developing models and communicating information
Students individually develop in their notebook a series of models to communicate their explanation for how rocks weather and the role of the water cycle in the process of weathering of rocks. Students individually write an explanation for the weathering observed in the investigation and the role of water in the weathering of rock. They connect evidence for how the rock weathers to their explanation.
(Hint: Expect models that show the relationship between the expansion of water when it freezes and the weathering of rock connected to the ways water gets to the exposed rock via the water cycle.)

Science Essentials	
Science Practices Carry Out an Investigation Construct an Explanation Develop and Use Models	Make careful observations that generate evidence. Discuss and compare observations with others observing the same events. Explain science observations using evidence. Share explanations with others. Use representations to explain phenomena. Use representations to reflect on mechanisms of how things work. Share science concepts and understandings with others using representations. Share science findings in writing and graphic presentations to others.
Crosscutting Concepts Cause and Effect Stability and Change	Identify and describe the causes of phenomena. Describe the conditions necessary for phenomena to occur. Use evidence to support explanations for the causes of phenomena. Identify the components contributing to the cause of an effect. Identify things that trigger changes to a system that was previously stable. Explain patterns of change over time. Analyze patterns of change and stability.
Disciplinary Core Ideas Earth and Universe Matter Energy	Matter cycles. Energy is involved when matter changes. Energy from the sun powers the cycling of matter on Earth. Matter is made of particles. Matter is conserved.

Appendix B

Mean Difference in Ratings by Experimental Condition for all Three Years Combined

	Treatment Group (*n* = 117)		Control Group (*n* = 39)			Levine's Test of Homo-geneous Variances			
Dependent Variable	Mean	Standard Deviation	Mean	Standard Deviation	Mean Diff.		**t*	Diff.	Sig.
Composite Scales									
Talk & Argument	3.64	1.12	2.17	1.08	1.47	Yes	7.15	154	< .0001
Investigation	3.09	1.22	1.75	1.00	1.34	Yes	6.22	154	< .0001
Modeling	2.67	1.25	1.48	1.10	1.19	Yes	5.31	154	< .0001
Summary Judgment	3.34	1.13	1.90	0.85	1.44		8.40	86	< .0001

*Note: Since Levine's test indicated that the variances were significantly heterogeneous for the Summary Judgment variable; the *t*-test formula with adjusted degrees of freedom was used to test whether the mean difference between the two groups for this variable was statistically significant. Consequently, the degrees of freedom reported for the Summary Judgment variable is a smaller number than for the other variables.