Eastern Oregon STEM

Science & Engineering Practices in EO-STEM Lessons

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As part of the evaluation of the Eastern Oregon STEM (EO-STEM) Math Science Partnership grant, the external evaluator used the Science and Engineering Practices framework from the Next Generation Science Standards[i] to analyze STEM units produced by the project. The units are a major output of the grant, and the evaluator conducted the analysis to address two concerns:

1. Based on observations in many STEM classrooms, attributes of the Practices, such as students posing questions, collaborating on solutions, and thinking critically, can be more challenging to implement than are specific content standards. The modeling of Practices and the creation of classroom environments that elicit "scientist-like" behaviors are emerging aspects of teaching for many instructors. The content standards are specified in the units; the attributes of the Practices are not. Educators who want to adopt or adapt these units should have a way of identifying what the opportunities are at each stage of a unit for introducing Practices, and a way of estimating the relative levels of effort required at each lesson.
2. People charged with evaluating the units (whether in terms of value for adoption or fidelity of their implementation) should have a way of quantifying their judgements. The NGSS Practices provide a standards-based checklist that allows administrators, professional developers, evaluators, or researchers to describe and measure levels of implementation, growth over time, and areas for improvement. The Practices can be used on their own or as an alternative measure to validate other types of judgements or locally developed instruments.
3. A special problem for classroom observers is knowing when to observe. By identifying the relative "richness" of lessons in terms of Practices, observers can plan their visits to identify the most dynamic parts of a unit where an observation is most likely to capture the extent of lesson implementation, teacher professional development, and student learning.

Science & Engineering Practices

The framework used in the analysis was the evaluator's SEP Checklist, which takes the published NGSS Practices and parses compound / complex sentences into components, such that a rater can give partial credit for evidence of some but not all criteria for a Practice. The numbers of Practices described by NGSS at each grade level appear in Table 1:

Practice Area	PK-G2	G3-G5	G6-G8	G9-G12
Asking Questions & Defining Problems	3	5	5	5
Modeling	4	6	7	6
Planning and carrying out investigations	6	5	5	6
Analyzing data	5	5	8	6
Mathematical and computational thinking	4	4	5	5
Constructing explanations and designing solutions	3	5	8	5
Engaging in argument from evidence	7	6	5	6
Obtaining, evaluating, and communicating information	4	5	5	5
Grade-Level Total Number of Practices	36	41	48	44

The Checklist was originally developed as an observation tool, scripted with Microsoft Excel macros to allow rapid data recording on a tablet. In an observation context, the instrument includes –besides the Practices checklist—fields for recording and timing various teacher roles, student groupings, technology uses, student engagement. The instrument also includes fields for demographic data and narrative notes. Although some of these classroom attributes might be inferred from lesson plans, the analysis here concentrates only on the Practices. Subsequent observations in spring 2016 will assess to what extent experienced teachers can address the potential Practices in the unit plans, along with how different classroom practices correlate with the Practices.

The evaluator examined five multi-lesson units authored by project teachers and selected by the EO-STEM project for dissemination. Units were formatted in a standard template that included lesson-by-lesson descriptions with standards addressed, sequence of activities, and teacher guidelines and materials. The units included four at middle grades and one at the elementary level (Table 2).

Because the number of NGSS Practices varies across the eight areas and across grade level, raw tallies tend to weight areas with more Practices. To avoid this effect, the lesson analyses below converted the tallies of Practices identified in each practice lesson into percentages of the total numbers of practices possible for each of the eight NGSS areas of interest. The mean proportion of Practices recognized across all grade levels, units, and lessons was .28 of the number of Practices theoretically possible. NGSS expects Practices at each grade level to build on related Practices at earlier grades. Recognizing a Practice at one level implies that students are also learning or exhibiting attributes of the practice appropriate for a lower level. This is not always the case, but the correlation between total percentage of practices implied across grades and those for the intended grade of a lesson is .97. The mean percentage across grades was .35 of potential practices at the observed grade level and all lower levels.

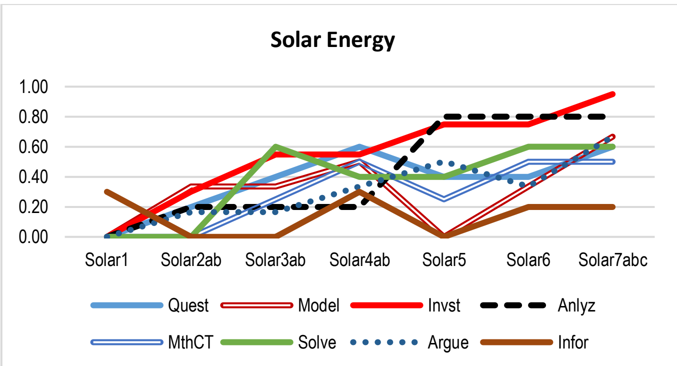
The line charts in the following section show the estimated percentage of possible practices of each type that could be displayed in each lesson or lesson group over the course of each unit. The bar charts show the percentage of total possible practices (all types) for each lesson or lesson group.

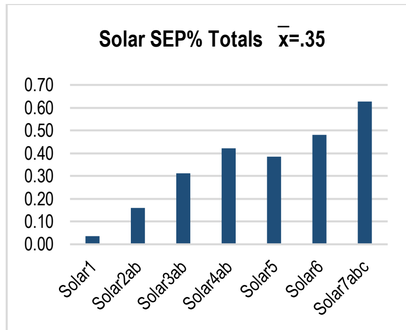
The tallies of Science & Engineering Practices used to construct the charts are those of the EO-STEM evaluator. If the Practices are used in a published lesson description, the tallies should be repeated, ideally by the lesson authors and at least one other grade-level teacher. NGSS, while very detailed, leaves room for interpreting what is a concrete example of a Practice. Raters should come to consensus about the definitions of the Practices within their application to a particular project or set of materials.

EO-STEM Units

Solar Energy

Level	# Lessons	Content Summary.
Grade 4	7 over 12 periods	Discussion of thermal energy (lessons 1); construction of a thermometer (2-3); exploration of the effects of color (4-5), angle (6-7), location (8), and insulation (9) on thermal energy; and creation of a solar oven as an engineering work sample (10-12). One lesson is devoted to protractor use, and Vernier probes are used if available for taking measurements.

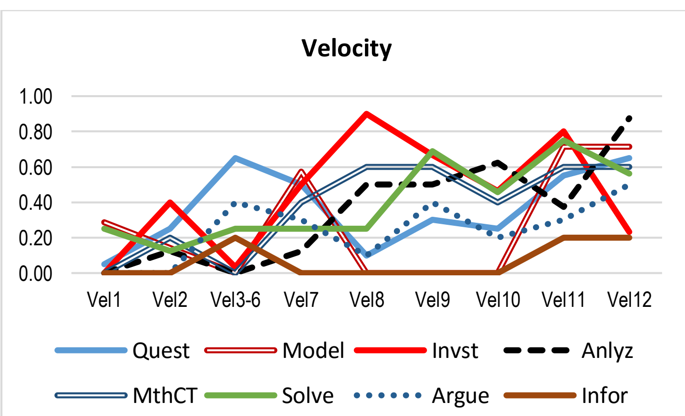


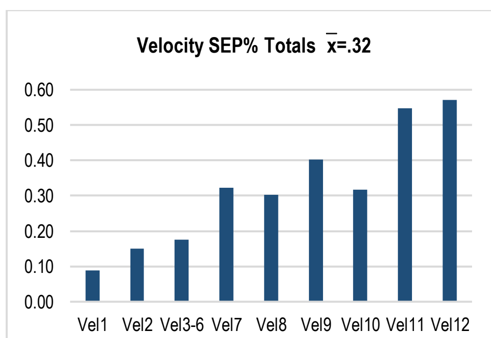


- The percentage of Practices addressed per lesson increases over the unit. Seven of eight practices increase, with the engineering work sample being particularly rich.
- The unit plan incorporates construction time as part of multi-session lessons. Classroom visitors should note that periods devoted solely to handling materials may not display as many Practices as periods involving planning, questioning, modeling, and data analysis.
- Information Practices (area #8) as defined by NGSS are addressed sporadically in this unit through initial readings and then through reporting on intermediate and final projects.

Velocity and Variable Relationships

Level	# Lessons	Content Summary.
Grade 8	6 over 13 periods	Introduction to motion (lessons 1-2), devoted to constructing mousetrap cars (3-6), data collection (7-8), redesign and retesting (9-10), data analysis (11), and creating an Engineering Work Sample (12-13). Mathematics lessons are paired with each science lesson to provide appropriate computation and analysis tools.

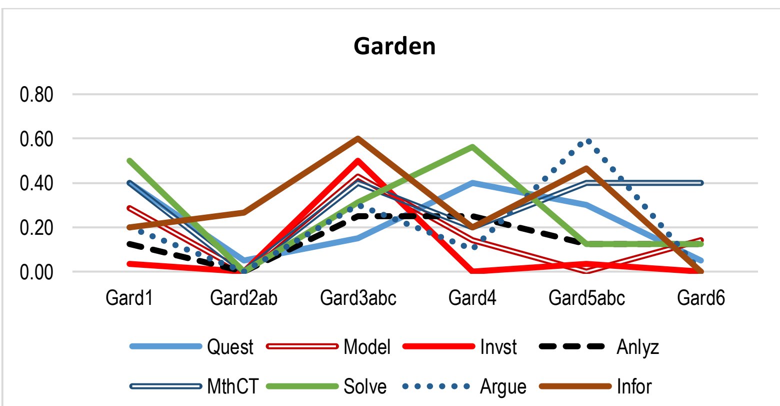


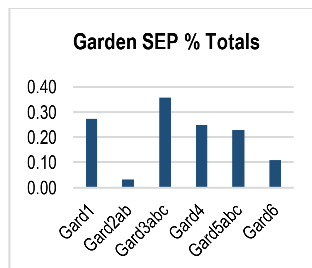


- The percentage of Practices addressed per lesson increases over the course of the unit.
- Project construction classes take a large proportion of time, but may address a relatively low number of Practices.
- Redesign and data analysis classes tend to exhibit relatively high numbers of Practices.
- The specific Practices addressed vary widely with classes. For instance, student planning (Practice area #3) is elicited after initial development when the students have data and analysis tools to work with, not (as might be expected) at the beginning of the unit, when the students are mostly following instructions.
- Information Practices (area #8)—at least as defined by NGSS—are not addressed by most lessons in the unit. NGSS places emphasis on understanding and integration of text and other sources, whereas this unit relies largely on hands-on activities supported by lecture.

Garden Proposal

Level	# Lessons	Content Summary.
Grade 6-8	6 over about 11 days, plus related math lessons	Introduction to soil issues (lesson 1), soil conservationist guest speaker on soil conservation (2-3), soil quality testing (4-6), master gardener consult on soil quality (7), budget and brochure development (8-10), oral presentations (11). Within the 2 ½ weeks allotted for the Garden Proposal, related math units address ratios and proportion, budgeting, and a formal assessment of math concepts at the end of the project.



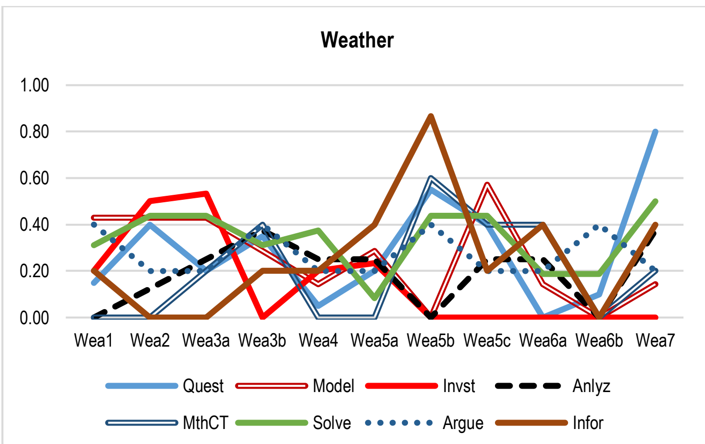


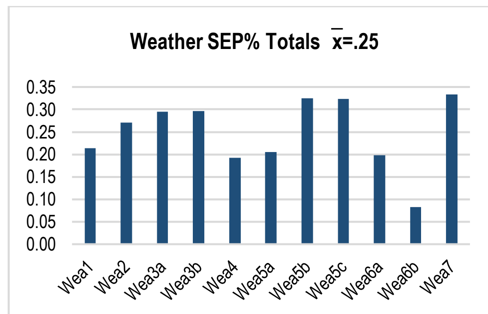
- The Garden Proposal, like the Solar Energy unit, was designed to be taught by several instructors in multiple simultaneous courses in Math and Science/Engineering.
- The NGSS chart tracks the Practices implied by the Science and Engineering lessons. However, the unit also specifies explicit math instruction in skills necessary to complete the activities. A formal assessment of the math content takes place after the project activities.
- The lesson plans may not convey the potential for some activities. For instance, the second and third periods involve a guest speaker and student account of what they learned. Teachers are encouraged to prompt appropriate questions, and depending on the nature of those prompts, the learning could be either passive or engaged.
- This lesson might benefit from additional editing. For instance, the online unit archive is divided into six lessons, while the unit overview describes eight lessons.

- Math lessons may not appear with the engineering units to which they relate and which they often precede. This is temporally accurate-- math skills need to be practiced before they are used in the project. However, it would aid those interested in adopting the unit to have the scope and sequence across content areas aligned throughout the materials, perhaps with a more detailed table in the Unit Overview.

Weather

Level	# Lessons	Content Summary.
Grade 6-8	7 lessons over 11 periods	Basic causes of weather (lesson 1), air pressure (2), light angles and temperature (3-4), weather maps (5), storm tracking (6-8), lightening (9-10), and weather graphing (11).

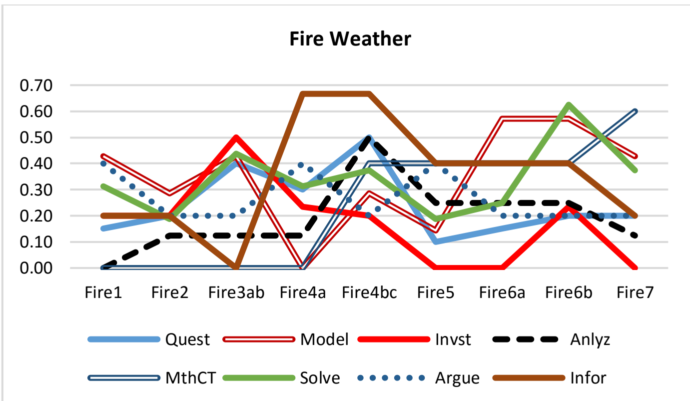


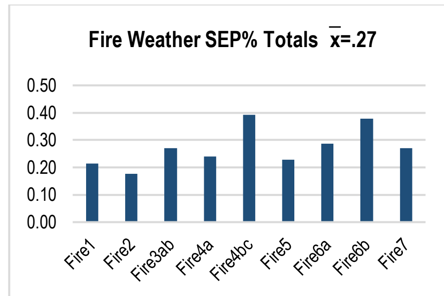


- The Practices addressed per lesson peak at intervals rather than increasing over the unit.
- Information Practices are strongly represented in the middle of the unit at the beginning of the lesson sequence where students are learning about weather maps.
- A large proportion of Math Practices are invoked toward the end of the same lesson series.
- The final weather graphing exercise involves a large number of Practices around Asking Questions. Although question-posing is often introduced at the beginning of units as part of the motivation or anticipatory set, this unit treats questioning as a higher-order skill that draws on prior knowledge.

Fire Weather

Level	# Lessons	Content Summary.
Grade 6-8	8 lessons over 14-17 periods	Related to the general weather unit, but with the special context of wildfire forecasting. Lesson 1 is the same as in the Weather unit. Other lessons include the fire triangle (2), relative humidity, air pressure, and wind (4-5), air quality (6 to 7-9), lightening (10), graphing factors in fire spread (11-13), fire danger rating indices (14-15), weather forecasting (16-17).





- The overall percentages of Practices addressed per lesson and the points where they are addressed are similar to the patterns observed in the related Weather unit.
- The culminating activity (providing a weather forecast for fire commanders), elicits a large number of practices in the areas of Math, Problem Solving, and Modeling.
- The Fire unit addresses aspects of weather and related math skills that the Weather unit does not. An instructor might want to pool the units and select the most appropriate lessons for the students' abilities and place in the curriculum.

Summary

Two general patterns are evident in the opportunities to address Practices. The Velocity and Solar Energy units have trajectories that demand increasing demonstration of Practices over time. There are larger or smaller numbers of Practices addressed within this trajectory, but the overall trend increases. From the standpoint of an administrator or researcher who wants to see students attempting the maximum number of Practices, later lessons are usually richer. The Garden Proposal and the two weather-related projects have more of a "wavelet" pattern. The numbers of Practices addressed in the unit plans are more constant across the lessons, rising and falling as the lessons take up different aspects of content.

According to one of the authors of the Garden and Weather units, the three sets of lesson are driven by the underlying math content, taking advantage of practical applications to introduce and practice several middle-grade math standards. This may be a fundamental difference in types of NGSS-based STEM projects, one that should be considered by program developers in planning and evaluating future initiatives. A project that is primarily focused on the engineering design process might be expected to require and display increased numbers of Practices over time, and progress or success would be evaluated by the overall observed growth. In contrast, a skill-focused project needs to be evaluated in terms of its several stages. Progress in terms of NGSS Practices would depend on efficiently introducing each topic and invoking the related practices within a two or three-lesson cycle. A later topic would not necessarily involve any more opportunities for learning or exhibiting Practices, unless topics are explicitly designed to build on earlier lessons.

For this particular set of units, the optimal times for observers to see students learning or demonstrating Science & Engineering Practices would be during the last third of Solar Energy and Velocity; either of the student projects (soil testing or budget/brochure development) in the Garden Proposal; and either of the last two student projects within the Weather and Fire Weather units.

In terms of disseminating the work of EO-STEM, a major concern is time. On the one hand, each of these units takes a large commitment of time within a school year. On the other hand, if project-based learning is intended to emulate the world of work and advanced study, even a three-week unit is too short to represent the continuous growth of knowledge in a professional setting. To incorporate this kind of learning experience on a regular basis, teachers would have to be able to draw on a wide variety of units adapted or adaptable to their standards and student abilities. The kind of analysis presented here would help educators select units, but the exercise is only meaningful if there is a large archive of units in a common format to start with.

One suggestion to leverage the legacy of the many Oregon Math Science Partnerships would be for the state, possibly working through its STEM Hubs, to coordinate the products of the various past and current grants so that Oregon educators can rapidly connect to units and resources that meet the needs of Oregon STEM education.

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[i] *The Next Generation Science Standards is a registered trademark of Achieve. Neither Achieve nor the lead states and partners that developed the Next Generation Science Standards was involved in the production of, and does not endorse, this product. **Reference:** NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Appendix F: Science and Engineering Practices. Washington, DC: The National Academies Press. (www.nextgenscience.org)