Redesigned High Schools for Transformed STEM Learning: Performance Assessment Pilot Outcome

Jeremy V. Ernst
Virginia Tech

Elizabeth Glennie
RTI International

Need for STEM Knowledge

Science, Technology, Engineering, and Mathematics (STEM) education content and conceptual learner proficiencies are at the forefront of a national conversation on educational reform (Kuenzi, 2008; Kuenzi, Matthews, & Mangan, 2006). With broad implications such as readiness skills for the future STEM workforce, global competitiveness, economic vitality of a nation, (Langdon et.al, 2012) it is of focal importance to provide active, experiential, and meaningful experiences to learners (Stage & Kinzie, 2009). A solid grounding in STEM education can bolster the U.S. economy. The U.S. Labor Department projects that 26 of the 30 fastest-growing occupations for 2018 will require preparation in the STEM fields, and 14 of them will require a bachelor's degree or higher (Lacey & Wright, 2010). States have been successful in encouraging students to take more courses in science and math before graduation (Shettle, et al., 2007). High school graduates' course taking in mathematics and science has increased from 1982 to 2007, and more recent graduates have taken more advanced mathematics and science courses as well (Dalton, et al., 2007). However, among U.S. students, degree completion in the STEM fields has declined by 50 percent since 1960 (U.S. Government Accountability Office, 2006). Currently, only 16 percent of undergraduate degrees in the United States are in STEM-related fields, placing the U.S. far behind the international community (i.e., 64 percent of undergraduates degrees in Japan are in STEM fields) (U.S. Department of Education, 2010).

Some students graduate from high school unprepared for the rigors of postsecondary coursework in the STEM disciplines, which makes it more difficult to complete a post-secondary degree in a STEM field. According to national data from ACT, of the high school graduating class of 2008, only 43 percent of ACT-tested students were ready for college-level math, and only 29 percent of ACT-tested students were ready for college-level science (ACT, 2010). In 2007-08, of first year undergraduates in life and physical sciences fields of study, 22 percent reported taking a remedial course (Sparks & Malkus, 2013).

Assessment

Foundational student-centered educational experiences at the secondary level promoting active learning involvement, not only effectively builds science competency when compared to other means, but also enhances self-direction, motivation, and interest in learning (Samsonov, Pedersen, & Hill, 2006). However, characteristic gauges of secondary learner preparedness are not necessarily consistent with actual practice in promoting the application of knowledge (Ostler, 2012). Post-secondary students exhibiting indicators of academic non-continuation, such as low grade point average or matriculation status, are typically underprepared based on lived and formative educational experiences (Ernst & Clark, 2012; Clark & Ernst, 2013; Ernst & Moye, 2013). Sparkman, Maulding and Roberts (2012) report identifiable indicators among postsecondary student successes and paired high school performance abilities and intellectual skill. Secondary academic assessment has typically concentrated on problems with a single answer predetermined to be correct. This was a reasonable practice when the STEM workforce sought individuals who could simply exhibit knowledge rather than a fuller extent of higher-order cognitive abilities such as creativity, the ability to analyze and apply information, and evaluative thinking (Neal 2009). Assessment in STEM-based educational environments has traditionally been based on exploring the cognitive dimensions of remembering and understanding with little carryover into application, analysis, evaluation, and creation. Oberg, (2009) states the principal intent and rationale for inclusion of standards-based classroom assessment is to inform instruction and expand higher-order learning.

Neal (2009) describes an alternative academic assessment process that accounts for the performance basis related to content, thinking processes, and skills. Performance-based practice includes a task and an accompanying assessment piece that describes the qualities of performance that are identified in course objectives. These assessment practices challenge students to utilize the higher-order cognitive abilities of creation, analysis, and application in relation to course objective criteria categorized and scored through assessment rubrics.

Carr and Harris (2001) distinguish that effective assessment is a fundamental component of instruction and is pertinent to proximate knowledge (as cited by Oberg, 2009). Further, Oberg characterizes in his 2009 findings that students, in particular, students at-risk and students from culturally and linguistically dissimilar environments, benefit from assessment practices linked to instruction through promotion of competency-based learning connections in not only recalling but also demonstrating their learning. These performance-based learning experiences require students to synthesize concepts and theories from formal education and employ them in practice (Freda & Koplin, 2011).

According to Borthwick et al. (2007), there are three types of performance-based learning which share a mutual basis in the notion of situated learning: 1) the apprenticeship model, 2) the simulated reality model, and 3) the "enminding" model (as cited by Freda & Koplin, 2011). The apprenticeship model features professionals guiding students through actual work experience; the simulated reality model features learning tasks that emulate practice; the "enminding" model connects students' learning experiences and disciplinary education through authentic activities. The alignment of assessment strategy to promote STEM competency application and learner outcome in traditional environments typically falls within the "enminding" model whereby student engagement in STEM disciplines is furthered through performance-based extension activity.

Even through deployment of the enminding model, accountability initiatives and requirements that typically rely upon traditional cognitive assessment means are considerations within performance-based learning. This results in cognitive competency evaluation being a constant even with full-scale integration of performance-based learning approaches. Ernst (2008) highlighted evidence suggesting that cognitive assessments could be used in conjunction with performance assessments to further provide evaluation of educational and professional competencies. Considering this identified relationship, to what extent are students prepared to proficiently apply cognitive knowledge?

Educational Approach and Framework

Students learn more when instruction is presented in an appealing manner and is designed with students' learning styles in mind (Hein & Budny, 1999). Engaging students' interests increases their motivation to learn and promotes deeper understandings of content (McIntosh, Berman & Youniss, 2007). Educators strive not only to increase student knowledge but also to motivate students to gain an appreciation for what they are learning. If instruction motivates students, then students are likely to value their educational endeavors and perhaps even seek similar educational experiences in the future (Durik & Harackiewciz, 2007).

"Developing meaningful experiences while maintaining distinguishable curricular alignment requires significant deliberation provided that the intent is to convey authentically reflective and contemporary processes and approaches" (Ernst, 2013, p.31). Piaget and other constructivists believe that students create knowledge from observations and experiences (Piaget, 1954; Piaget 1974). Educational applications promoting effective development of associated skill and ability are traditionally situated within purposeful, relevant, and impactful contexts in support of extensions of knowledge (Knowles, 1980). The educational models of Kolb (1984) and Dewey (1964) advocate for and support reflective and experiential learning practices to promote intellectual process development. "Since conscious learning emerges from activity (performance)" it provides a plausible and logical framework for designing constructivist learning environments (Jonassen & Rohrer-Murphy, 1999, p.61).

Gülbahar and Tinmaz (2006) identify that school-based constructivist approach implementation not only extends students application opportunities, but also can enhance critical skills while forming learning practices through active participation. Dopplet (2003) highlights that "project-based learning is one of the methods grounded in constructivism by supporting student engagement in problem-solving situations" (as cited by Gulbahar & Tinmaz, 2006, p.309).

School wide project-based educational models and learning approaches are becoming more prevalent, specifically within STEM academy, magnet, and strand school formats. STEM schools may focus on more intense STEM coursetaking, these schools may also focus on an integrated project based learning method of instruction.

Re-Designed STEM Schools

With support from the Bill and Melinda Gates Foundation and the North Carolina General Assembly, the Department of Public Instruction, higher education partners, and local educators have created innovative STEM high schools across the state. Since 2007, North Carolina New Schools (NCNS) has worked to established STEM schools, which are designed to function as laboratories for students to solve real-world problems, understand relevance of mathematics and science, use technology, and experience out-of-school learning in co-curricular activities (NCNS, 2013). These schools are designed to be small, with about 100 students in each freshman class. They use a common instructional framework that emphasizes collaborative group work, writing to learn, questioning, scaffolding, classroom talk, and literacy groups in all classes. This instructional framework is designed to enhance student exploration and invention and to foster a culture of collaborative inquiry (NCNS, 2014). Some of these schools were schools that were redesigned as STEM schools, while others are early college high schools, which are located on college campuses, where students can take college classes and graduate in 4 or 5 years with an associate's degree or 2 years transferable credit to the University of North Carolina system. In this evaluation, 4 STEM schools were recruited for the performance assessments. Table 1 shows characteristics of these schools. Schools with a range of ethnic and poverty compositions in varied locales were recruited.

Site	Urbanicity	Total Students	Percent Under-Represented Minority	Percent Free or Reduced-Price Lunch
1	City	199	71.4	48.2
2	City	237	46.0	29.1
3	Rural	160	56.9	59.4
4	Rural	219	73.5	62.1

Source: National Center for Education Statistics Common Core of Data Public School Universe, 2012

Table 1. School characteristics

Table 2 presents the student performance on spring 2012 End of Course exams in Algebra 1 and Biology and the qualifications of teachers. In 2011-12, Algebra I and Biology were the only mathematics and science classes with End of Course exams. In three of these schools more than 95 percent of the students passed Algebra 1 and Biology. However, in one of these schools, only 70 percent of the students passed these exams. This is also the school with the lowest percentage of teachers who are fully licensed.

Site	Percent passing Algebra 1 End of Course exam	Percent passing Biology End of Course exam	Percent fully-licensed teachers	Percent novice teachers
1	>95%	86%	88.2	23.5
2	>95%	>95%	100.0	14.3
3	>95%	> 95%	100.0	71.4
4	70%	70%	63.2	26.3

Source: North Carolina School Report Card, 2012

Table 2: Teacher qualifications and student performance in STEM schools

Research Question

The following research question guided the initial pilot study of the student performance investigation: Do students in re-designed STEM high schools demonstrate identifiable proficiency in performance-based earth/environmental science assessments? This question was examined though isolating identified stage-based performance proficiencies. These proficiencies included evaluation, prediction, analysis, synthesis, and reasoning in the contexts of soil and water, clouds and weather, acid rain, and astronomy-based performance tasks.

Methodology

At the time of these assessments, North Carolina high school students were required to take 3 science courses including Earth/Environmental Science (North Carolina Department of Public Instruction, 2012). Performance assessments were conducted in four Earth/Environmental Science classes in four high schools. Teachers were provided with four semi-structured performance tasks to implement over a single Earth/Environmental Science course. Students (9th and 10th grade level) participated in regularly scheduled instruction and activities but engaged in these supplemental extension activities that required specified application of course content and exploration. The performance tasks were directly aligned with competencies and objectives found in the North Carolina Standard Course of Study Blueprint and each called for students to document their processes and findings in the form of a science notebook. The research team, using a performance-based assessment rubric, then assessed each performance task through science notebook documentation.

In preparation for the initial pilot implementation, a member of the research team scheduled a meeting with each Earth/Environmental Science teacher to discuss process and sequencing associated with the performance tasks. A project parental consent and student assent form was provided to distribute to the Earth/Environmental students and parents. One hundred and forty two consent/assent forms were distributed and 103 signed forms were collected. Following consent/assent planned competencies were addressed during regularly scheduled course instruction, where outside of class performance tasks were then implemented. Four performance tasks were implemented into the Earth/Environmental Science class:

1) Astronomy - Explain how the Earth's rotation and revolution about the Sun affect its shape and is related to seasons and tides.
2) Soil and Water Connections (Erosion) - Evaluate human influences on water quality in North Carolina's river basins, wetlands, and tidal environments,
3) Clouds and Weather - Predict the weather using available weather maps and data (including surface, upper atmospheric winds, and satellite imagery);
4) Acid Rain - Analyze the impacts that human activities have on global climate change (such as burning hydrocarbons, greenhouse effect, and deforestation).

Each competency-centered task consisted of a stated challenge requiring four student application activity phases involving research and investigation, brainstorming, exploration, and reflection. Each was incorporated where the Earth/Environmental Science teacher planned to address corresponding objectives. After the implementation of each performance task, science notebook artifacts were collected from participating students. Twenty seven consenting participants did not submit the performance tasks for assessment, therefore, the initial pilot performance assessment outcome analysis consisted of 76 student performance task participants totaling 1,672 scoring instances. The research team then assessed the collected performance tasks using the established performance metrics.

Initially, thirty cases from two different groups were selected by proportional stratified sampling for examining the interrater reliability of the rubric instrument. The rubric instrument used categorical scores 1-4 to represent the students' performance from low to high. Therefore the kappa test, developed by Cohen (1960), was employed to examine the degree of agreement on the categorical grading data of selected activities and each item between two judges. Cohen's kappa is a chance-corrected measure of association based on certain contingency table (Sheskin, 2007, p. 669). The kappa value, ranging from 0 to 1, indicates the agreement rate between two judges. The higher the kappa value is, the higher interrater reliability the instrument has. The collective Cohen's kappa could be considered as fair to good (Strenier & Norman, 2008; Fleiss, 1981; Gwet, 2010), suggesting an acceptable interrater reliability of the instrument examined (see Table 3).

Topic	Number of Measures	Collective Kappa
Earth's rotation	41	0.67
Earth shape	38	0.54
Earth revolution	49	0.70
Cloud & weather	62	0.64

Table 3. Cohen's kappa

Instrumentation

Freda and Koplin (2011) identify that performance-based assessment requires two essential features: 1) a structured or open-ended performance task, and 2) an accompanying assessment piece (describes the components of performance that are identified in course objectives). Performance-based assessment practices challenge students to use higher order cognitive abilities of application, analysis, evaluation, and creation in relation to course objective criteria categorized and scored through assessment rubric. Following the established stages and assessment protocols set by student performance metrics of the National Science Foundation funded Visualization in Technology Education Project, the Redesigned High Schools for Transformed STEM Learning Project constructed task metrics that isolate categorical indicators (see Figure 1 for a sample of the procedural performance assessment process). Categorical indicators were built upon high-order processes designated within existing state standard course of study blueprints.

Findings

Student's performance on each item was assessed based on established project rubrics. The score of each item ranked from 1 (the lowest) to 4 (the highest). The score of 3 meant that the performance achieved standards. To determine whether the students had achieved the requirements of standards on each assessed item in these performance-based activities, the current study compared the sample median of each item to the cut score 3. Students achieving 3 or higher were identified as proficient while students achieving below 3 were identified as not proficient. Summary statistics for the four performance measures separated by categorical indicators designated within existing state standard course of study blueprints can be found in Tables 4-7. Table 4 represents performance activities and sub-activities for astronomy in the row entitled "Item."

As previously noted, all performance tasks follow the application activity phases of research, brainstorming, exploration, and reflection. The first performance task

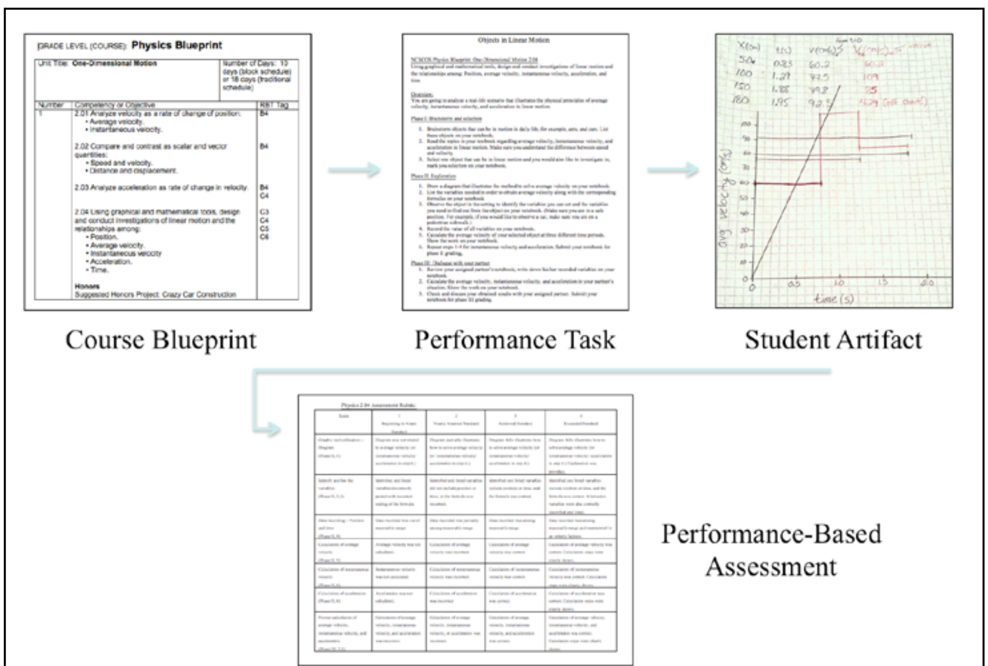

Figure 1. Performance assessment process

Item	1.1	1.2	1.3	1.4	2.1	2.2	2.3	3.1	3.2
Proficiency Rate	0.34	0.29	0.39	0.34	0.90	0.34	0.50	0.51	0.53
Median	2	1	2	1	3	2	2.5	3	3
Mode	2	1	1	1	3	1	3	3	3

Table 4. Astronomy task

Item	4.1	4.2	4.3	4.4	4.5	4.6
Proficiency Rate	0.63	0.50	0.13	0.88	0.88	0.50
Median	3.5	2.5	1	3	2.5	3
Mode	4	3	1	3	3	3

Table 5. Erosion task

Item	5.1	5.2	5.3	5.4	5.5	5.6	5.7
Proficiency Rate	0.51	0.66	0.40	0.45	0.46	0.24	0.36
Median	3	3	2	2	2	2	2
Mode	2	3	1	3	3	2	1

Table 6. Cloud and weather task

Item	6.1	6.2	6.3	6.4
Proficiency Rate	0.39	0.62	0.64	0.02
Median	2	3	3	1
Mode	1	3	3	1

Table 7. Acid rain task

Item	Indicator	P-value
Astronomy 2.1	Research and Investigation	<0.001
Erosion 4.4	Brainstorming	0.02
Erosion 4.5	Exploration	0.05

Table 8. Identified performance proficiency

focused on astronomy concentrating on the Earth's rotation. In the first activity, measuring research and investigation 1.1 specifically required depiction, 1.2 required documentation, 1.3 required observation, and 1.4 required explanation (see Appendix A for sample task and accompanying metric with corresponding sub-activities). Activity 2 focused on the shape of the Earth and 2.1 was an application sub-activity, 2.2 was an observation task, and 2.3 was a second application sub-activity. Activity 3 concentrated on the rotation of the Earth, specifically, 3.1 was a diagramming task and 3.2 was a simulation and explanatory task.

Based on measurement of student performance outcome in the first performance assessment, a 46 percent proficiency rate was identified among participants (see Table 4). In other words 46 percent of the student-artifacts had scores of at least 3 or "proficient." Fewer than half of the students were proficient in sub-activity 1.1, 1.2, 1.3, 1.4, and 2.2. It is noted that as this performance task progressed and elevated in complexity, the proficiency rate increased (i.e. sub-activity 1.2 is the lowest collective proficiency rate and sub-activity 3.2 is the highest collective proficiency rate).

Within the erosion performance task, the 4.1 activity included mapping and depiction, 4.2 consisted of analysis of consequences and formulation of relationships, 4.3 involved analysis of prospective impacts, 4.4 was comprised of observation and an application sub-activity, 4.5 encompassed observation and synthesis, 4.6 required problem identification and the proposal of a solution. The soil and water connections (erosion) activity performance-based outcomes identified a 59 percent proficiency rate (see Table 5).

Performance task 3 was built around cloud patterns and weather trends. Sub-activity 5.1 required observation and documentation, 5.2 was a diagramming task, 5.3 required explanations of observable indicators, 5.4 was a recording and analysis task, 5.5 was an observation and prediction task, 5.6 was a contrast and comparison task, and 5.7 was an explanatory and reasoning task. The cloud and weather performance scores featured a 44 percent proficiency rate among student participants (see Table 6). More than half of the students had proficient scores in 5.1 and 5.2 which indicates adequate levels of observation, documentation, and representation but only a quarter were proficient in 5.6, which requires comparative thinking.

Within the acid rain performance task, the 6.1 task activity included research question formulation, 6.2 consisted of observation and an application sub-activity, 6.3 involved analysis of trial and comparison samples, and 6.4 required problem identification and the proposal of a solution. The acid rain activity scores identified a 42 percent proficiency rate for student participants (see Table 7).

Activity outcome analyses of performance tasks were conducted using the nonparametric Wilcoxon Signed

Site	1	2	3	4
Proficiency Rate	0.30	0.67	0.60	0.60
Median	2	3	3	3
Mode	1	3	3	3
Range	3	3	3	3

Table 9. Performance proficiency by site

Ranks Test. The Wilcoxon signed-ranks test was employed since the original scores of student performance obtained for each of the assessed item were in the format of interval data (Sheskin, 2007, p.225). The test statistic for the test was compared to the designated critical value table based on the sample size of the participants. The critical alpha value was set at 0.05 for this investigation. The calculated p-values for the tests were determined to be larger than 0.05 except for metrics associated with performance criteria 1.1(Phase I: Brainstorm and Research - Evaluate human influences on water quality in North Carolina's river basins, wetlands and tidal environments) and 2.2 (Phase II: Exploration - Predict the weather using available weather maps and data including surface, upper atmospheric winds, and satellite imagery). The number of instances vary dependent on the number of constructs within each outcome variable. Statistically significant results are displayed in Table 8.

The analysis of data suggests that students demonstrate collective proficiency in performance-based assessment tasks specific to research and investigation through depiction/representation, brainstorming through observation and diagramming, and exploration through examination of difference (specified parameter ≤ 3).

Performance proficiency was also tabulated by implementation site (see Table 9). Of the 76 student participants, Site 1 consisted of 44 students (approximately 58 percent of the sample) where Site 2 had 20 participants, Site 3 had 8 participants, and Site 4 had 4 participants. It is of note that Site 2 had the highest performance-based proficiency rate, closely followed by Site 3 and Site 4. However, at Site 1, fewer than one-third of the students were rated as proficient.

Conclusions and Implications

Building application-based proficiencies through strategic educational approaches continues to be explored in regards to how it is positioned within formal educational settings. NCNS STEM schools are designed to function as problem solving laboratories for students to build STEM conceptual understandings through learning experiences. In these study sites, a majority of the students scored proficient in mathematics and science End of Course exams. However, even enhanced environments prove not to be fully conducive to performance-based proficiency although partial progressions are noted to be supported within this study.

Based on collective standard rates, approximately 48 percent of student participants demonstrated performance-based proficiency of knowledge. Human activities and water connections was the highest performing task and included mapping and depiction, analysis of consequences and formulation of relationships, analysis of prospective impacts, observation and application, observation and synthesis, analysis, and problem identification and the proposal of a solution. Three of the highest four achieving sub-activities (4.4, 4.5, and 4.7) were in the human activities and water connections. The single highest achieving sub-activity was 2.1 in the astronomy performance task and involved documentation of results from an application-based sub-activity.

Provided the assessment protocol employed utilizing study metrics, collective performance-based proficiency is isolated within three sub-tasks. One identifiable area of proficiency was found in research application and investigation within Astronomy and the other two areas of proficiency were identified within Erosion task indicators of brainstorming and exploration. Collective performance-based proficiency was not found in most sub-activities. This is inclusive of the other eight performed Astronomy tasks, the other four Erosion tasks, or any of the Cloud and Weather or Acid Rain tasks.

A variety of factors enter into degrees of performance-based proficiency as measured within the sample study. Among the sites, different assignment strategies were employed for the implementation of the performance tasks. For example, one instructor disclosed that the performance tasks were optional for students where another instructor identified that the performance task was a required and graded assignment. The implementation structures may have leveraged task performance with a higher expectation level than other formats. Also, student backgrounds, learner levels, and expectations of academic assembly may factor into demonstrated performance proficiencies. Much of each school's population is composed of students who were categorized as underrepresented minorities where many students also receive free or reduced price lunch based on familial economic status. The design of this study does not permit reporting on specific student participant demographics, as they are reported by project school site. This prohibits investigation of students classified as at-risk based on indicators, although, it should be qualified that the findings of the study be considered noting that the sample largely possessed at-risk indicators. The sample is composed of 9^{th} and 10^{th} students attending schools that by design largely employ project-based and application oriented learning exercises. However, students in earlier levels of secondary education (i.e. 9^{th} and 10^{th} grade) within these schools may not have had the extended exposure to school-based methods and approaches of learning and assessment as student in latter secondary grades within the same school.

Outside of acknowledgement of project site and student variations and differences, the overall lack of identified performance proficiencies within task categorical indicators cannot be altogether explained. There is an identifiable progression of post-secondary STEM education and STEM workforce knowledge and applied skillsets. Each project site supports elevated development of knowledge as indicated by accountability measures of end of course examinations. Based on the End of Course exam scores, teachers and administrators would conclude that the students were proficient in these subjects. The performance assessments conducted here show a gap between the state mandated assessments and the kinds of thinking assessed with this alternate method. NC has just adopted the Common Core standards and future research should examine how Common Core results align with this type of performance assessment.

This study shows developing levels of performance-based application abilities within the student sample, but uniform proficiency as demonstrated through academic indicators has yet to be attained. Cognitive conceptual knowledge and performance-based application ability within STEM education both maintain high degrees of importance, but holistic learner preparedness is only achieved when both reach demonstrable levels of proficiency. Both continue to be held in equal regard within the NCNS as evidenced by instructional frameworks and observable culture of collaborative inquiry within their classes. Evaluations identifying current successes. and areas for improvement, guide and expedite educational advancement. Evidence-based iterations of models and practices can help service providers refine educational offerings and approaches, thus maintaining a firm connection between research and the STEM classroom.

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Appendix A. Sample Activity – Astronomy Performance Task

Earth/ Environmental Science Blueprint 1.1.2: Explain how the Earth's rotation and revolution about the Sun affect its shape and is related to seasons and tides.

Activity 1: Earth's Rotation (approximately 60 minutes)

1. Research how and why the earth rotates. Draw a diagram of the earth with equator, cardinal directions, rotation direction, tropic of Cancer, tropic of Capricorn, rotation axis and its current angle in your notebook.
2. Research how to determine cardinal direction based on shadows of objects cast by the sun. Record in your notebook the time of day and cardinal direction indicated by shadows.
3. On a sunny day, go outside and observe the shadow of your home. Draw your home, its shadow along with nearby streets, and record the date and time in your notebook.
4. Given the indicators provided by cast shadows of objects, identify and explain the cardinal direction of your home's front door in your notebook.
5. Research Newton's law of universal gravitation and pay attention to the distance factor. Explain how tides are affected by earth rotation in your notebook.

Activity 2: Earth's Shape (approximately 60 minutes)

1. Obtain a rubber balloon (not water balloon). Fill the balloon with water until it reaches the size of an orange and tie its end. Stick two pieces of duct tape on opposite sides of balloon respectively. Run a kabob stick through the two pieces of duct tape and the center of the balloon.
2. Put the kabob stick in an upright position. Observe the shape of the balloon and draw it in your notebook.
3. Spin the balloon and observe how it changes its shape. Observe the shape of the balloon and draw it in your notebook.
4. Compare the drawings in step 1 and 2. Research and think what causes the change. Record your finding in your notebook.
5. Is earth in perfect spherical shape? Explain your answer in your notebook.

Activity 3: Earth's Revolution (approximately 45 minutes)

1. Research how and why the earth revolves around the sun. Draw a diagram of the sun and the earth in its current position as well as its projected positions at winter solstice, summer solstice, spring equinox, and fall equinox in your notebook.
2. Make an orange-size paper ball around a pencil. Draw the equator, rotation axis, tropic of Cancer, and tropic of Capricorn on the paper ball.
3. Simulate the earth revolution around the sun by revolving and rotating the paper ball around a light source in a dark room. Observe how the light distributes at different longitudes.
4. Considering earth's seasons, what will happen if the earth does not tilt on its rotational axis? Simulate the situation using your paper ball. Record and explain your findings in your notebook.

Earth Science 1.1.2 Assessment Rubrics:
Activity 1:

Scale	1 Beginning to Attain Standard	2 Nearly Attained Standard	3 Achieved Standard	4 Exceeded Standard
Diagram for the earth's rotation (step 1)	Diagram was not drawn or not related to the earth's rotation.	The earth was drawn with an identifiable but incorrectly placed equator, cardinal direction, rotation direction, tropic of Cancer, tropic of Capricorn, rotational axis or angle features.	The earth was drawn with the equator, cardinal directions, rotation direction, tropic of Cancer, tropic of Capricorn, rotation axis and its angle.	The earth was drawn with the equator, cardinal directions, rotation direction, tropic of Cancer, tropic of Capricorn, rotation axis and its angle. Additional features of earth rotation were drawn with explanation.
Cardinal directions indicated by shadows (step 2, 4)	Answer was not recorded or not related to the cardinal directions.	The midday observation indicated that shadows were due north in the U.S. However, it did not indicate time of observation.	The midday observation indicated that shadows were due north in the U.S.	The answer indicated that shadows at midday were due north in the U.S. An explanation was provided based on the earth's rotation diagram.
Picture of shadow (step 3)	Picture was not drawn or not related to student's home.	Student's home, its shadow and nearby streets were drawn. However, time and date were not recorded.	Student's home, its shadow and nearby streets were drawn. Time and date were recorded.	Student's home, its shadow and nearby streets were drawn. Additional objects and shadows were also drawn. Time and date were recorded.
Tide and earth rotation (step 5)	Explanation was not provided.	How tides are affected by earth rotation was implausibly explained.	Explanation was plausible and included correct interpretation of Newton's law of universal gravitation.	How tides are affected by earth rotation was explicitly explained by applying Newton's law of universal gravitation.

Activity 2:

Scale	1 Beginning to Attain Standard	2 Nearly Attained Standard	3 Achieved Standard	4 Exceeded Standard
Drawings of balloon (step 1, 2)	Balloon was not drawn for both step 1 and step 2.	Balloon was implausibly drawn for step 1 or step 2.	Balloon was plausibly drawn for both step 1 and step 2.	Balloon was plausibly drawn for both step 1 and step 2 with useful descriptions to aid understanding this experiment.
Shape change (step 2)	Answer was not recorded or not related to the change in balloon shape.	The change in balloon shape was implausibly explained.	The change in balloon shape was plausibly explained.	The change in balloon shape was plausibly explained with clear understanding of centripetal/centrifugal force.
Earth shape (step 3)	Either answer was not recorded, or answer indicated that earth is in perfect spherical shape without explanation.	Answer indicated that earth is or is not in perfect spherical shape with implausible explanation.	Answer indicated that earth is not in perfect spherical shape with plausible explanation.	Answer indicated that earth is not in perfect spherical shape with plausible explanation and clear understanding of centripetal/centrifugal force.

Activity 3:

Scale	1 Beginning to Attain Standard	2 Nearly Attained Standard	3 Achieved Standard	4 Exceeded Standard
Diagram for the earth revolution (step 1)	Diagram was not drawn or not related to earth's revolution.	The earth at some but not all of the following positions were correctly drawn with regards to the sun: winter solstice, summer solstice, spring equinox, and fall equinox.	The earth at positions of winter solstice, summer solstice, spring equinox, and fall equinox were correctly drawn with regards to the sun.	The earth at positions of winter solstice, summer solstice, spring equinox, and fall equinox were correctly drawn with regards to the sun. Additional features of earth's revolution were drawn with explanations.
Effects of the tilt of the earth's axis (step 4)	Answer was not recorded or not related to the tilt of the earth's axis.	The answer did not indicate that seasons would not change without the tilt of the earth's axis.	The answer indicated that seasons would not change without the tilt of the earth's axis.	The answer indicated that seasons would not change without the tilt of the earth's axis. Explanation was provided regarding how four seasons were created by the tilt of the earth's axis.

Jeremy V. Ernst is Director of the Office of Educational Research and Outreach and Associate Professor of Integrative STEM Education at Virginia Tech. He also serves as a Faculty Fellow at the Virginia Tech Institute for Creativity Arts and Technology. Dr. Ernst specializes in research focused on dynamic intervention means for STEM education students categorized as at-risk of dropping out of school.

Elizabeth Glennie is a Senior Research Analyst at RTI International. Her work focuses on the implementation and impact of educational policies on students, particularly the factors influencing success in secondary school and access to postsecondary education. She received her Ph.D. in Sociology from Duke University.