the quest for quality in afterschool science

The Development and Application of a New Tool

by Anahit Evoyan Papazian, Gil Gabriel Noam, Ashima Mathur Shah, and Caitlin Rufo-McCormick

Studies have found that, though many students have generally positive attitudes toward science, technology, engineering, and math (STEM), their attitudes toward school science are "mixed" (Sjøberg & Schreiner, 2006). Students' initial interest in science often dwindles because of the way science is taught in school (Krajcik, Czerniak, & Berger, 2003).

By contrast, out-of-school time (OST) programs are intermediary spaces that connect opportunities across a range of contexts (Noam, Biancarosa, & Dechausay, 2003). STEM experiences in OST can cultivate and multiply students' initial interest in science, helping students to stay motivated and engaged to learn STEM in school. Afterschool and summer settings are being identified as environments for engaging youth in STEM and building their interest in pursuing future STEM careers (Coalition for Science After School, 2004).

Growing evidence shows that participation in OST activities positively supports youth development in general (Hall, Yohalem, Tolman, & Wilson, 2003; Vandel,

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Reisner, & Pierce, 2007) and STEM learning in particular (Tamir, 1991). However, simply participating in a self-identified STEM program is not sufficient. Youth will benefit more if they participate in *quality* afterschool programs (Mahoney, Levine, & Hinga, 2010). In fact, participation in a low-quality program can negatively affect youth development (National Institute on Out-of-School Time, 2009). Therefore, a common understanding of quality indicators in STEM OST is vital not only for researchers and evaluators but also for afterschool program leaders and staff.

An important way of knowing whether programs are of high or low quality is to observe them systematically and reliably. Such observation is practically impossible without good definitions of what constitutes quality. Observation tools employing such definitions and related indicators are being developed and applied both in schools (Bill and Melinda Gates Foundation, 2012) and in OST programs (Gitomer, 2012). Reputable observation tools for assessing STEM instruction in school settings include the Reformed Teaching Observation Protocol (Piburn et al., 2000) and the Classroom Observation Protocol (Weiss, Pasley, Smith, Banilower, & Heck, 2003). The OST field has several observation tools, as described by Yohalem and Wilson-Ahlstrom (2009), for assessing program quality generally. However, "instruments designed specifically for observing informal settings in science are only now being designed and researched" (Gitomer, 2012, p. 2).

In order to address this gap, researchers at the Program in Education, Afterschool, and Resiliency (PEAR) created the Dimensions of Success (DoS) assessment tool to help OST programs and researchers monitor and measure quality. The DoS tool allows observers to collect systematic data along 12 quality indicators to pinpoint the strengths and weaknesses of afterschool science learning experiences. These data can then be used to guide technical assistance and professional development and to help programs choose and modify curricula to meet students' needs (Noam & Shah, in press). The previous work on afterschool quality assessment, especially the research done by Yohalem and colleagues (2009), along with the existing national frameworks of STEM assessment, guided the development of the DoS tool.

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DoS is taking the lead in establishing definitions of and indicators for STEM program quality. This paper describes the development of the DoS tool, outlines its structure and the professional development that enables its use, and presents a case study of its application in an urban OST program offering STEM activities. Use of DoS is facilitating program improvement in OST programs and networks across the country.

Development of the DoS Observation Tool

In 2006, the research team at PEAR was invited to evaluate the effectiveness of the Summer METS (math, engineering, technology, and science) Initiative, which was established by the Kauffman Foundation to expand opportunities for student participation in science and technology-related summer activities and to better assist underserved youth in metropolitan Kansas City. In 2007, in addition to surveying 450 Summer METS students and 64 teachers, observers recorded notes using the first pilot version of the DoS tool (Noam, Schwartz, Bevan, & Larson, 2007). Based on these observation data, the tool was further developed in 2008, when 10 programs in Kansas City began using DoS to observe one another in a peer-to-peer evaluation network (Dahlgren, Larson, & Noam, 2008). Though the programs were all STEM-focused, they were diverse in many ways. For example, they used different curricula and served different student populations; they worked in a variety of configurations, whether school-based or community-based, free-standing or part of a bigger network. Therefore, researchers' biggest challenge was to standardize DoS to be applied in a wide variety of programs while still using the same rubrics so that the results could be compared across sites (Dahlgren et al., 2008).

After incorporating feedback from the Summer METS project, developers worked to expand the usability of the DoS tool and to pilot it in a wider sample of afterschool programs, starting with the Informal Learning of Science Afterschool (ILSA) project. As part of ILSA's in-depth case studies, trained observers used DoS in eight afterschool sites in California and Massachusetts, conducting 115 observations from January 2008 to August 2010. To triangulate DoS with previously validated observation tools, researchers also collected data on these programs using the

Promising Practices Rating Scale (PPRS, Wisconsin Center for Education Research & Policy Studies Associates, 2005) and the Classroom Observation Protocol (Weiss et al., 2003). PPRS is a general afterschool observation tool, while the Classroom Observation Protocol, originally designed for use in schools, provided a science-specific framework. This process led to further revisions of the DoS tool.

Alignment with Nationally Recognized Frameworks

Two recent documents were fundamental in shaping quality indicators for OST STEM learning and accelerated the need for a quality assessment tool specific to this field. In 2008, the National Science Foundation (NSF) developed *Framework for Evaluating Impacts of Informal Science Education Projects* (Friedman, 2008), which outlined the main areas in which OST STEM programs should be evaluated. Additionally, the National Research Council (NRC, 2009) introduced six strands that describe goals and practices for informal science learning. The NRC strands, like the NSF domains, offer a framework for designing quality STEM experiences in OST and for identifying possible outcomes. Specifically, the NRC framework highlights the importance of students' excitement and interest; their ability to use models and build explanations, explore and test questions, reflect, and use scientific language and tools; and their ability to identify as people who can learn, use, and contribute to science (NRC, 2009).

The NSF framework (Friedman, 2008) defines five impact categories for assessment:

- Awareness, knowledge, or understanding of STEM concepts, processes, or careers
- Engagement or interest in STEM concepts, processes, or careers
- Attitude toward STEM-related topics or capabilities
- Behaviors related to STEM concepts, processes, or careers
- Skills based on STEM concepts, processes, or careers

The researchers' goal was to align DoS with the NSF framework and the NRC strands. At the time, three of the four DoS domains were Engagement or Interest, Content Knowledge & Competence and Reasoning, and Career Knowledge/Acquisition & Attitude/Behavior. All three domains are closely related to both the NSF framework and the NRC strands. As a result of numerous observations, the researchers felt the need for an additional domain to describe the curricula, materials, and space offered by afterschool programs, so they created a fourth domain, Programmatic Features. Over time, as researchers observed more STEM programs, dimensions within these domains were modified.

Validation

In order to make DoS available to a wide spectrum of OST programs, the development team needed to validate the tool by studying and reporting its psychometric properties. To accomplish this goal, PEAR teamed up with Educational Testing Services (ETS) in 2010 under NSF's Research and Evaluation on Education in Science and Engineering program. A team of observers was trained to use DoS in more than 300 STEM programs across seven states.

Teams of two trained observers, who had established initial inter-rater reliability with each other and with the pool of observers, observed STEM activities using DoS. These data were then analyzed to build a validity argument for the tool. Specifically, developers looked at the distribution of scores for each dimension, the rater reliability of observers, and the average scores for each dimension. They also looked for significant differences in scores from different kinds of programs—school-based, community-based, museum-sponsored, and so on. These details established the validity of the DoS tool; they are available in the NSF final technical report (Shah, Wylie, Gitomer, & Noam, 2013).

The Final DoS Tool

As illustrated in Figure 1, the current version of DoS has 12 dimensions in four domains: Features of the Learning Environment, Activity Engagement, STEM Knowledge and Practices, and Youth Development in STEM. Together, the twelve dimensions capture key components of what makes a quality STEM activity in OST.

The current DoS domains continue to be aligned with NSF categories and NRC strands, though they are arranged in different "bins." For example, the NSF category Engagement and Interest is now covered by several DoS dimensions including Participation, Engagement with STEM, and Relevance. The NSF category Skills and Awareness, Knowledge, and Understanding is reflected in such DoS dimensions as STEM Content Learning, Inquiry, and Reflection. Similarly, the DoS dimension Inquiry aligns with the NRC strand "Manipulate, test, explore, predict, question, observe, and make sense of the natural and physical world." The DoS dimensions Relevance, Engagement with STEM, Relationships, and Youth Voice contribute toward NRC strand 1, "excitement, interest, and motivation." The 12 DoS dimensions work together to cover the range of outcomes in both the NRC and NSF frameworks.

The DoS protocol consists of a short description of each dimension, a more elaborate description, commentary for training, and a four-point rubric. The description defines the dimension; the elaboration provides more details, presents

FEATUES OF THE LEARNING ENVIRONMENT	ACTIVITY ENGAGEMENT	STEM KNOWLEDGE AND PRACTICE	YOUTH DEVELOPMENT IN STEM
Organization	Participation	STEM Content Learning	Relationships
Materials	Purposeful Activities	Inquiry	Relevance
Space Utilization	Engagement with STEM	Reflection	Youth Voice

Figure 1. The Final DoS Domains and Dimensions

examples from the field, and provides tips on scenarios that commonly occur while observing STEM activities in OST. The commentary for training highlights key issues for trainees as they learn how to use the tool. The summary of the rubric provides examples of numerical ratings on a scale of 1 to 4, where 1 indicates little evidence and 4 indicates strong evidence of quality in that dimension. Each level is defined carefully in the rubric so that observers can distinguish the levels during their observation of an activity. The rubric for one dimension, Inquiry, is summarized in Figure 2.

DoS Training

To one observer, "inquiry" may mean "experiments," while to another it may mean "rich discussions." Simply reading rubrics and watching science activities is not enough to make someone a proficient DoS observer. The text in the rubric helps to guide observers, but they need training to learn the meaning of each of the 12 dimensions and how to identify each of the four levels.

DoS training familiarizes participants with the DoS tool and prepares them to conduct observations in the field. It also calibrates observers' ratings so that the results are reliable and valid. The basic training consists of four steps:

- Eight hours of content training, online or in person
- Four to six practice observations in local afterschool STEM programs, in pairs
- A one-hour online calibration session with PEAR
- Certification for two years, with technical assistance and coaching as needed

The training materials include case studies of real afterschool science programming, exercises asking observers to critique evidence from real DoS observations in the field, and observation simulations using videos of science activities of various levels of quality.

After completing all the parts of DoS training, new observers are certified for two years. One training fee covers all four steps, including continued coaching and technical assistance for two years to support the successful use of DoS in the field. Certified DoS observers can use the tool at no additional cost as frequently as needed to meet their program goals.

Why Use DoS

DoS can be used in flexible ways based on the needs of a program. Some reasons to use DoS include:

HOW TO BE CERTIFIED AS A DOS TRAINER

Researchers or practitioners can become certified DoS observers by completing the certification process outlined in this article. Contact PEAR to schedule a training. Training sessions are held year-round; the schedule can be adjusted to accommodate the needs of the organization. In-person trainings are great for large state networks or organizations looking to train their whole team, while online webinars accommodate participants from different locations.

EVIDENCE ABSENT	INCONSISTENT EVIDENCE	REASONABLE EVIDENCE	COMPELLING EVIDENCE
There is minimal evidence that students are engaging in STEM practices during activities.	There is weak evidence that students are engaging in STEM practices during activities.	There is clear evidence that students are engaging in some STEM practices during the activities.	There is consistent evidence that students are engaging in a range of STEM practices during the activities.
1	2	3	4
Students observe experiments demonstrations, or are given data, but do not participate in inquiry practices on their own.	Students follow cookbook experiments where they are given step-by-step directions, or may be given data or facts instead of collecting them. Some aspects of the activity will support students engaging in STEM practices, but it is quite scripted or unnatural.	Students engage in STEM practices; however, there may be uneven use of these practices by students or the level of support during inquiry may not be appropriate for the group of students.	Students have multiple opportunities to ask questions; to think like scientists, mathematicians, and engineers; and to engage in STEM practices that allow them to investigate questions as they are appropriately guided by the facilitator.

Figure 2. Summary of the DoS Rubric: Inquiry Dimension

- To help individual programs track their progress over time
- To encourage self-reflection among program staff, who can use DoS as a common language to discuss the quality of their activities and to pinpoint areas for improvement
- To aggregate information across individual sites for large youth-serving organizations such as Ys or for city or state afterschool networks
- To integrate DoS observations into an experimental evaluation design using pre- and post-participation assessments whose findings can be connected to the quality of the inputs observed using DoS

DoS can be used to help identify the areas where professional development or coaching may be needed. It provides a common language that staff members can use as they reflect on the quality of their science activities. Observers engage in consensus discussions in which they compare their field notes and ratings to make sure they have covered all aspects of the activities they observe and that they leave no room for misinterpretation. They then use the results of that discussion to frame the feedback given to staff members to help them improve their activities. DoS scores, along with the ensuing discussion and feedback, can help programs improve their curricular activities and pedagogical approaches.

Because DoS training involves several steps, OST programs will benefit most if they send staff members or leaders who are committed to the organization and are likely to stay for at least a year. Despite the high turnover in afterschool settings, DoS can become an integral part of a program's planning, monitoring, and evaluation process. Its dimensions and quality indicators can be passed on to new staff members as a common framework for discussion when, for example, staff participate in curriculum design or undergo observation to help them improve their facilitation of activities. We are currently working on a train-the-trainer model so that program, curriculum, and training directors can begin to train their own staff and therefore make DoS an integral part of their program.

A Case from the Field

To illustrate how DoS can be applied in the field and to provide practical details on DoS training, we next describe a case study of DoS observations conducted from summer 2009 to spring 2010 at East End House, a community center in Cambridge, Massachusetts. At the time of the study, East End House served 100 youth, ages 11–14, the majority of whom were eligible for free or reduced-price lunch. Approximately 60 percent of the participants were male and 40 percent female. The racial and ethnic composition of the student population was 35 percent African American, 25 percent Caucasian, 20 percent Hispanic, 10 percent Asian, and 10 percent other.

DoS was applied in this program both as a quality observation tool to pinpoint strengths and weaknesses and as a professional development tool to help the staff plan and revise their activities. PEAR trained the afterschool staff to use DoS, conducted observations of STEM activities, and provided feedback and recommendations that staff incorporated into their STEM curricula. In total, 19 one-hour observations were conducted, eight before the afterschool staff received DoS training and 11 after the DoS training.

The one-day training included information about existing quality frameworks in OST science, including the NSF framework and the NRC strands; approaches to quality in OST STEM instruction; and the development of DoS. More importantly, participants practiced applying the tool by watching videos of STEM activities, rating them, and reaching consensus on the ratings in small groups. Later, their ratings were calibrated with those of PEAR observers to establish inter-rater reliability with the tool's developers. Inter-rater reliability was also established during practice field observations by comparing the ratings of pairs of newly trained observers. This process ensures that DoS is being used consistently and accurately, regardless of who the observer is.

After the East End House staff received training in DoS, PEAR and East End House staff began conducting observations together. PEAR observers were paired with the East End House middle school program director and the curriculum director. Each pair observed one activity at a time and then discussed their ratings to reach consensus. The feedback was communicated to the facilitator of the observed activity. At the beginning of each curricular unit, the two directors worked with front-line staff to develop new curricula, incorporating the findings from the DoS observations. PEAR also used observation data to recommend ways that East End House could improve its programming.

The observed curricula were developed by the afterschool staff. Some examples of curriculum units included Numbers Behind Sports, Body Movement, Music by Me, and Green Thumbs Club. On average, the units were offered three times a week for four weeks. Typically one facilitator taught each unit, while groups of students rotated, so that all students got through all of the available curricular units during the academic term. During our study, four facilitators were teaching the units; there was no facilitator turnover. All facilitators had or were working toward bachelor's degrees. Only one had a science background.

Figure 3 compares the findings of the eight pre-training observations with those of the 11 post-training observations, using the dimensions that comprised the DoS domains at the time of the East End House case study. (See Figure 2 for the current domains and dimensions.) Post-training quality ratings for each of the 11 dimensions[1] increased relative to pre-training observations. The mean difference between pre-training and post-training scores was significant for nine dimensions: Planning and Preparation, Materials, Space, Engagement, Interest, Exploration, Investigation, Broadening Perspective, and Relevance. The only dimensions that did not show significant gains were Content Learning and Structure.

This case study suggests a correlation between use of the DoS tool and quality improvement. The study was not designed to confirm a causal relationship between the DoS training and an increase in quality of STEM programming. It used DoS as a *formative* instrument to help East End House improve its training and programming. A *summative* study, by contrast, would separate the external evaluators from the observers; the evaluators would analyze the observers' data. Moreover, an experimental design with treatment and control groups would be the only way to establish a causal relationship between DoS and STEM quality. Thus, this case study cannot pinpoint exactly what influenced the quality improvement. However, it does suggest that the focused training and feedback DoS provides were associated with positive trends in quality.

Staff interviews confirmed the importance of DoS to the STEM programming at East End House. DoS training enabled afterschool staff members to look at the program from an outsider's perspective and to strive to achieve quality. They also became familiar with national frameworks of STEM quality assessment and with the dimensions of STEM quality in OST. In follow-up interviews, front-line staff reported feeling more confident in their STEM teaching and in their understanding of what quality STEM activities look like. Staff members stated not only that the DoS training was important but also that actual use of the tool, with time for reflection and planning, greatly enhanced their ability to develop and implement quality STEM activities. One activity facilitator said:

> When we started doing science in our afterschool program, before being trained on DoS, we didn't do inquiry; we didn't know how to teach content. We did a lot of projects without a lot of depth. But now, we build lessons around student voice that engage kids in really understanding science, making meaning of their world, and using critical thinking skills.

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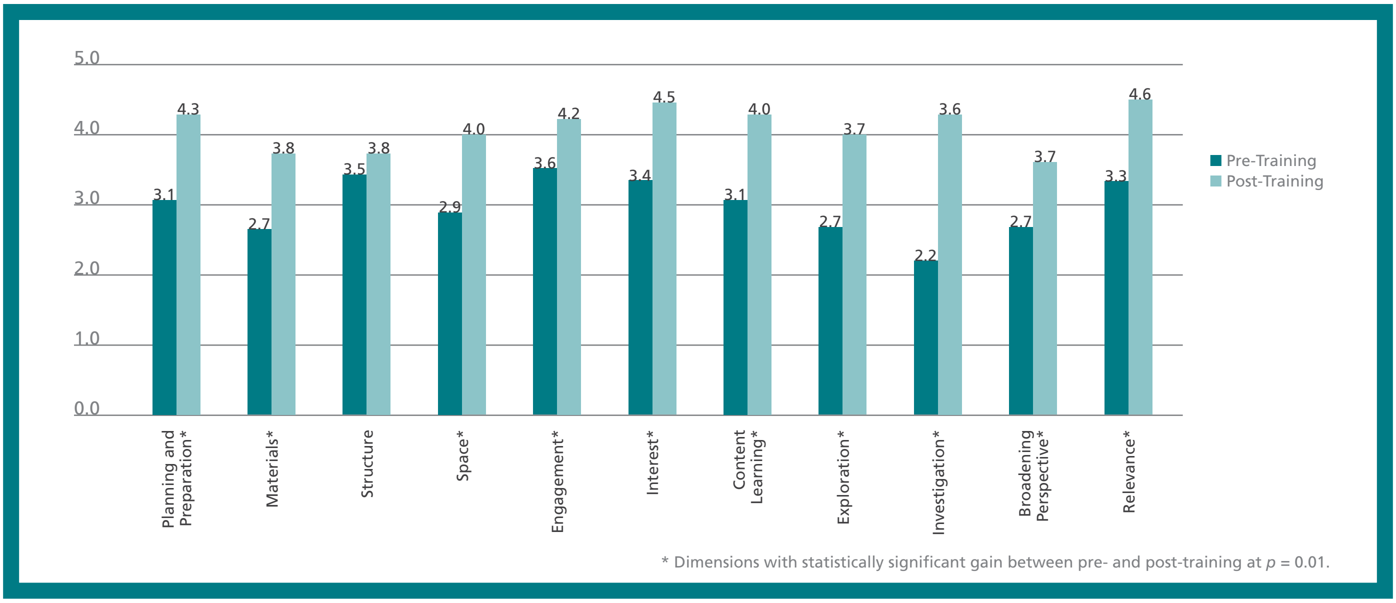

Figure 3. Comparison of DoS Dimension Average Scores, Pre- and Post-Training

The staff also reported that they were able to use their newly acquired skills to engage students in better science experiences. This improvement is exemplified in the words of another facilitator, who said, "One of the things we're best at now is helping kids to make their own meaning and draw their own conclusions. Now they get to do the thinking."

Strengthening the Investment in Afterschool STEM Quality

Our findings extend the creative work of a number of program assessment and quality observation tools by helping to define quality STEM education and enabling practitioners to observe STEM activities systematically. The DoS platform of observation and data-driven professional development can support programs to build practices that foster student interest and engagement in STEM.

Findings from the case study of East End House can be generalized to a wide spectrum of afterschool science programs. Although each program is unique, the DOS tool is designed to help afterschool staff identify the strengths and weaknesses in their STEM instruction so that, through consensus discussions, they can work to improve the program.

As a next step, the Mott Foundation, in collaboration with the Noyce Foundation, has created a technical assistance team to support nine state afterschool STEM networks. In each state, we will train teams to use DoS and certify them when they have reached acceptable levels of reliability. This large-scale project has several components, including training professionals to use DoS and comparing DoS observation data with students' expressions of science interest and facilitators' self-reports on their science programming. We are also planning to give DoS training to afterschool providers across California. In the meantime, the DoS tool has been adopted successfully in many afterschool networks. We have built the infrastructure to serve many regions and organizations across the country.

We have collected valuable data describing quality across a range of sites and have seen improvement when OST staff systematically observe their STEM activities. Through continued analysis of the data, we are able to improve our training process and prepare observers to achieve the most accurate ratings possible. The practical feedback provided by certified observers can immediately be used to improve OST STEM programming.

Public and private funders are investing millions of dollars to get students interested and engaged in science outside of school. Use of DoS helps the OST field to demonstrate that the quality of our STEM instruction is strong and that it can lead to the student outcomes that funders, researchers, and practitioners alike are working to achieve.

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Notes

[1] Data from the Belonging/Relationship dimension were removed from analysis. During development, the protocol for this dimension was changed several times. This dimension therefore was not deemed consistent enough for the purpose of this paper.