QuarkNet Evaluation Recap

The current evaluation efforts focused on quantitative and qualitative analyses that covered data collected during the 2019-2026 program years and included teacher responses to a full survey (a unique count of 780 teachers) along with nearly 2,000 follow-up survey responses, as well as examples of teacher and student work described shortly. (Yearly survey responses rates range from 72 to 83% over this time period.)

QuarkNet teachers are both new to the program (about one-third each year) and returning teachers offering opportunities for sustained duration a characteristic of effective program professional development (Darling-Hammond et. al., 2017), and a program anchor of QuarkNet. Over this time period, the program has reached near parity of teacher gender, about three-quarters of teachers report teaching (or have taught) physics, from schools in urban, suburban, or rural locations, representing mostly public schools both large and small (with some private schools). Students represented by these schools are diverse in ethnicity, notable percents of low-income student (e.g., free, or reduced lunch eligibility); these school-wide statistics vary by centers.

QuarkNet Centers Matter in the Delivery and Impact of the Program

Program Delivery: Implementation

QuarkNet supports Centers through:

- A menu of available workshops to select, plan, and implement program year event(s).
- Workshop agenda template options to help in program planning.
- Workshops facilitated by QuarkNet staff and/or locally-run by individual centers through fellows or lead teachers.
- Workshops model best practices and are of a sustained duration.
- Leadership skill development through workshops for fellows.
- A compendium of participle physics classroom activities and resources (Data Activities Portfolio, DAP) to support classroom implementation that align with NSGSS and other standards as well as the Enduring Understandings of Particle Physics (Young, Bardeen, Roudebush, Smith and Wayne, 2019).
- Implementation plan template options offered to help teachers plan (and to post these on the website), time allocated during the workshops to plan and follow with discussions.
- Masterclasses conducted within and across centers as well as events such as World Wide Data Day.
- Opportunities to engage students in research, experience scientific collaboration, and analysis of authentic data from large data sets through CMS and Cosmic Ray e-labs and through the distribution of cosmic ray detectors and cosmic watches.
- A framework of the program's major components linked to outcomes through a Program Theory Model.
- Supporting centers in their participation in outcomes-based evaluation efforts (e.g., full and update surveys).

Workshop agendas and center reports are used to prepare workshop summary tables created each program year to provide evidence of fidelity of the implemented program compared to the program as designed. These tables focus on workshop content and embedded activities from the DAP. Center-level responses (from center-level data) indicate that QuarkNet teachers engaged in NGSS Science Practices as part of their workshop engagement; and this experience has a noted influence on teachers related to these practices. Survey response comparisons suggest good agreement on select responses by individual QuarkNet teachers and QuarkNet centers [26 (34 combined) centers]. Results also suggest centers align well with 10 effective practice criteria created by Young (2017).

Program Impact: Quantitative Analyses

We looked at the cumulative experience of engagement over many and varied QuarkNet program opportunities based on exposure to core program strategies. We attempted to logically link this cumulative exposure to teacher-, student-, and long-term outcomes through a series of hierarchical statistical analyses that take into account the importance that centers play in these relationships. These quantitative analyses can be interpreted as analogous to the analytic approach used in epidemiological investigations where statistical relationships are posited through exploration of key variables.

Teacher Outcomes: Approach to Teaching. Scale or composite scores were created based on the rating of core strategies from self-reported perceptions of teachers obtained from survey responses.

• Discuss and explain concepts in particle physics. • Engage in scientific practices and discourse. • Use physics examples including authentic data when teaching subjects such as momentum and energy. • Review and use instructional materials from the Data Activities Portfolio. • Selecting these lessons guided by the suggested pathways. • Facilitate student investigations that incorporate scientific practices.	• Use active guided-inquiry instructional practices that align with science practices standards (NGSS and other standards). • Use instructional practices that model scientific research. • Illustrate how scientists make discoveries. • Demonstrate how to use, analyze and interpret authentic data. • Demonstrate how to draw conclusions based on these data. • Become more comfortable teaching inquiry-based science.

First teachers rated their exposure to these strategies during participation in QuarkNet programs (Core Strategies). Then, teachers rated the use of these practices in their classrooms (Approach to Teaching); and the degree to which QuarkNet has influenced these practices (QuarkNet's Influence on their Teaching).

Results show that QuarkNet program engagement is **positively** related to teachers reporting the use of these practices in their classroom, QuarkNet influence on these practices, and the center in which the teacher experienced program events.

- A hierarchical linear regression analysis based on 26 centers (34 combined)[1] explored the relationship between QuarkNet program engagement and Approach to Teaching. The results of this analysis suggest that QuarkNet's Influence on Teaching, Core Strategies and Centers (as measured by mean Approach to Teaching Scores) are shown to be positively related to teachers' reported use of content and instructional practices in their classrooms (i.e., Approach to Teaching). These results are statistically significant [$F(3, 427) = 85.34$, $p < .001$].

Student Outcomes: Student Engagement. Scale or composite scores were created based on teacher ratings of their students [Student Engagement: My students are able to …. Discuss and explain concepts in particle physics; Discuss and explain how scientists develop knowledge; Engage in scientific practices and discourse; Use, analyze and interpret authentic data; and Draw conclusions based on these data.]

Results show that Student Engagement, as measured by teachers' perceptions, is **positively** related to the perceived influence QuarkNet has had on these practices (QuarkNet's Influence on Student Engagement), their classroom practices (Approach to Teaching), and the center in which the teacher experienced program events.

- This hierarchical linear regression analysis was based on 26 (34 combined) centers. The results of this analysis suggest QuarkNet's Influence on Student Engagement, Approach to Teaching and Centers (as measured by mean Student Engagement scores) have a positive relationship on Student Engagement. These results are statistically significant [$F_{(3, 383)} = 94.43$, $p < .001$].

Long-term Outcomes: Teachers. Scale or composite scores were created based on teacher ratings of a set of survey items [Long-Term: I use resources (including QuarkNet resources) to supplement my knowledge and instructional materials and practices. I have increased my science proficiency; I have developed collegial relationships with scientists and other teachers. I think my students have become more comfortable with inquiry-based science.]

Results show long-term outcomes by teachers are **positively** related to their perception of QuarkNet's Influence on their teaching, measures of student engagement and the center in which the teacher experienced program events.

- Again, using a hierarchical linear regression analysis, perceived QuarkNet's Influence on Teaching, Student Engagement and Center-level Means (Long-term Outcomes) are positively and statistically related to Long-term Outcomes: Teachers [$F_{(3, 386)} = 66.64$, $p < .001$].

[1]Only centers that have a large number of teachers participate in QuarkNet (at least 10 teachers) were included in these analyses to meet statistical requirements.

Why did we Use Core Strategies rather than Focus on Major QuarkNet Program Components in these Analyses?

Bringing current evaluation efforts into the program midstream made it difficult to capture data that could have been interpreted as a baseline for any subsequent analyses. Retrospective analysis were hampered by insufficient program operations data that could pinpoint past enrollment by specific program event engagement. Teachers were asked, when completing their surveys, to identify past and present engagement in QuarkNet by program name (e.g., Data Camp, Specific Workshops, Masterclasses) to get a sense of their cumulative engagement. We reasoned, however, that teachers were more likely to remember the content and instructional practices present over the course of multiple QuarkNet program engagement rather than the specific name of those events. Of importance, these practices should be evident across program workshops or events. This cumulative engagement is in keeping with sustained duration, a characteristic of effective professional development posited by with Darling-Hammond, et al. (2017), when classroom practices or implementations are assessed.

That said, analyses that investigated the influence of individual QuarkNet events (Data Camp, Workshops, and Masterclasses) did show that each contribute uniquely and positively to one or more of the above outcomes but these analyses did not take into account the significant role that centers play in these relationships because of data size limits.

Program Impact: Qualitative Analyses

To support quantitative analyses, we conducted qualitative analyses highlighting information from the same 26 (34 combined) centers included in the hierarchical regression analyses just described. Our evaluation approach is consistent with the use of *authentic assessment* as a means to evaluate performance, "teaching for understanding and application rather than for rote recall" (Darling-Hammond & Snyder, 2000, p. 523).

Organized by center, portfolios are comprised of:

- Teachers reported planned or actual use of QuarkNet content and materials in their classroom over **time** (based on survey responses to open-ended questions).

Captured over a 3-year period:

- Implementation plans[2] prepared by teachers or groups of teachers and posted on QuarkNet website are included, when available.
- Examples of teacher work (e.g., exercising done during workshops or presentations based on posters; conducting an experiment, presentations, or posters at professional conferences) are included.
- Examples of student work, when available, includes presentations by students at science fairs or presentations at a QuarkNet workshop, data gathered by students during a Masterclass as well as presentations at professional conferences.

[2] Virtual visits by the evaluator often occurred during the discussion by teachers of their implementation plans.

Each center-level portfolio is posted on the individual center webpage of the QuarkNet's website.

In further detail as to the nature of how QuarkNet has influenced teachers, students as well as its staff, two supplemental reports were created in support of these quantitative and qualitative analyses. Each vignette is organized by the QuarkNet Center represented for that individual and each individual was actively engaged in the effort to create his/her vignette. Each report contains several examples of how QuarkNet engagement has benefited the classroom teaching and instructional practices of QuarkNet teachers and in turn, how these teachers, fellows and staff have influenced QuarkNet. First-hand accounts of how QuarkNet has influenced the academic plans and career choices of former high school students who have engaged in QuarkNet directly and/or through the instructional support of their teachers have been included as well.

The accomplishments of QuarkNet teachers are noteworthy including presentations at regional and/or national conferences, as well as exploring the impact of QuarkNet's masterclass in partial fulfillment of a doctorate in education. Teachers are often cited as playing an important role in notable accomplishments of former QuarkNet students. These former students include, for example, Fulbright awardees, pursuing and obtaining a PhD in physics or related field, co-authors of published articles, and working in the field as researchers or as a physics high school teacher.

As of the 2023 program year (Sept 2018-Sept 2023), QuarkNet has posted a total of 72 presentations, posters, and publications authored by teachers, students, or QuarkNet staff. From June 2023 through June 2026, an additional 35 presentations, posters, and publications authored by teachers, students, and QuarkNet staff have been posted.

In Sum. Using various sources of information, the evaluation attempts to provide a cohesive look, based on quantitative and qualitative analyses, at the impact QuarkNet (exposure to core strategies that run throughout the major components of the program) has on teacher, student, and long-term outcomes. Results suggest that QuarkNet engagement is statistically associated with each of these outcomes and that QuarkNet Centers play a key role in program delivery and impact. Teacher-level and center-level data tend to agree on fundamental metrics (e.g., active engagement, science practices). Qualitative analyses attempt to tell the story behind these data and include examples of implementation plans, teacher work, and student work including presentations at national and/or regional professional meetings as well as vignettes of individual success stories.