QuarkNet

Evaluation of the QuarkNet Program:
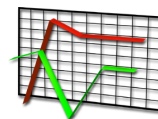# Final Evaluation Report 2018-2023
Executive Summary

Prepared by:

Kathryn E. H. Race
Race & Associates, Ltd.
4430 N. Winchester Avenue
Chicago, IL 60640
(773) 878-8535
www.raceassociates.com

Prepared for:

National Science Foundation
and
The QuarkNet Collaboration

August 2023

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Executive Summary

Kathryn Race
Race & Associates, Ltd.

The QuarkNet Collaboration, referred to as QuarkNet, "is a long-term, national program that partners high school science teachers with particle physicists working in experiments at the scientific frontier." QuarkNet is a professional development program that "immerses teachers in authentic physics research and seeks to engage them in the development of instructional strategies and best practices that facilitate the implementation of these principles in their classrooms; delivering its professional development (PD) program in partnership with local centers" (Program Theory Model, PTM, 2019). There are 52 QuarkNet centers in the United States (as of August 2023).

Program Goals

As articulated by the Principal Investigators (PIs) of the program and as stated in the Program Theory Model, the measurable program goals of QuarkNet are:

1. To continue a PD program that prepares teachers to provide opportunities for students to engage in scientific practices and discourse and to show evidence that they understand how scientists develop knowledge. To help teachers translate their experiences into instructional strategies, which reflect guided inquiry and NGSS science and engineering practices.

2. To sustain a national network of independent centers working to achieve similar goals. To provide financial support, research internships, an instructional toolkit, student programs and professional development workshops. To investigate additional funding sources to strengthen the overall program.

3. To reenergize teachers and aid their contributions to the quality and practice of colleagues in the field of science education.

4. To provide particle physics research groups with an opportunity for a broader impact in their communities.

Overview of Report

Each annual report prepared during this grant period represented a prototype of this final report. Thus, the present report and its review demonstrate the shift in evaluation efforts from formative (and summative) assessment to an outcomes-based evaluation. The early look at outcomes data provided the opportunity to test and support our approach to evaluation as a means of effectively measuring the impact of QuarkNet on teachers and

their students. Also, it offered opportunities for staff to identify principal needs and concerns that the evaluation should address; and it gave the evaluator time to adjust to these needs and suggestions proposed by staff to help aid in the usefulness of evaluation findings and recommendations.

Approach to Evaluation

The evaluation, during the 2018-2023 grant period focused on the following: (1) Develop (and use) a Program Theory Model (PTM); (2) Assess program outcomes at the national and center levels through teacher-level outcomes; and, (3) Assess the sustainability of program centers, based on center-level and sustainability outcomes.

The fully-articulated PTM was completed during the first year of this grant period. The process used to create the PTM has been described in this report and the model has been presented in detail. Ideally, a program theory model offers a cohesive and representative picture of the program, "an approximate fit" of the program as *designed*. We have sought consensus on the representativeness of this model with key stakeholders. Going forward, and if the renewal grant is awarded, the PTM will be updated as needed.

To a large extent the PTM elaborates on how change is expected to occur, based on the following QuarkNet Theory of Change:

By immersing teachers in doing authentic particle physics research and by engaging them in professional development that supports guided-inquiry and standards-aligned instructional practices and materials designed for the classroom, teachers become empowered to teach particle physics to their students in ways that model the actual practices of scientists and support instructional best practices suggested by the educational research literature. (Modified from Beal & Young, QuarkNet Summative Evaluation Report 2012-2017).

The development of a PTM and a Theory of Change is consistent with common guidelines proffered by the Institute of Education Sciences, U.S. Department of Education and the National Science Foundation (2013). Weiss (1995) noted that grounding evaluation in theories of change means integrating theory with practice. She postulated further that making assumptions explicit and reaching consensus with stakeholders about what they are trying to do, and why, and how, may ultimately be more valuable than eventual findings (Weiss, 1995), having more influence on policy and popular opinion (Rallis, 2013).

The PTM has been used to direct the development of evaluation measures and methods designed to address the remaining two goals. We have also used the PTM to compare the program as *designed* with the program as i*mplemented*. A Teacher Survey (full) and a Center Feedback Template have been designed to measure the teacher-level and center-level outcomes articulated in the PTM, respectively. The first administration of the Teacher Survey coincided with the start of summer workshops that occurred in 2019; and the roll-out of the Center Feedback Template began in September 2019. To coincide with

the 2020 program year, we added an Update: Teacher Survey (and continued its use in 2021 and 2023 program years) to capture information from participating teachers and to focus on classroom implementation of QuarkNet content and instructional materials.

Results

Based on 2019 through 2022 survey efforts, 483 teachers have completed the Full Teacher Survey (this represents a unique count). In addition, a total of 362 Update Surveys were completed (across a 3-year period); of, these, 327 (or 90%) were linked to full surveys to enable multiple-year comparisons. This represents a unique count of 208 teachers who completed their update survey at least once during this time period. Our approach to analysis has been to explore: teacher perspectives as to their exposure to core program strategies, perceived approach to teaching, student engagement, as well as the potential influence QuarkNet has had on teachers' approach to teaching and student engagement. These measures were based on scale scores generated from like items from the full Teacher Survey as well as self-reported use of activities from the Data Activity Portfolio. The Update Survey focused on reported classroom implementation of these activities.

The quantitative (and subsequent qualitative) analyses of teacher- and student-level outcomes were based on data from 24 (31 combined) centers, where a given center had at least 10 teachers participating at their center during the program years in question (to meet the requirements of hierarchical linear regression analysis).

These results are supplemented with information gathered from the QuarkNet Center Feedback process completed by 27 (31 combined) centers. [A total of 18 of these centers were among the centers included in the quantitative analyses.] This information helped to provide the program content in which the teachers engaged in the program and to assess center-level outcomes in their own right. In addition, we have focused on exploring consistent patterns in the data and have used multiple sources whenever possible (e.g., teacher responses, center responses, along with information from workshop agendas and annual reports of active centers). The level of documentation of workshop agendas, including details about embedded DAP activities and time for teachers to reflect and plan implementation options in their classrooms, has made the inclusion of this information in analyses possible. And, it made possible workshop site visits -- held virtually by the evaluator -- during teacher discussion of implementation plans.

In preliminary analyses ….

Single-variable analyses suggest that engagement in QuarkNet (the type and degree of program engagement is positively related to **Core Strategies** scores in a meaningful way. That is, more engagement by type and degree of QuarkNet opportunities was related to perceived higher exposure to core strategies; this was also the case for more reported use of activities from the Data Activities Portfolio in the classroom. This speaks to the fidelity of the *implemented* program as compared to the program as *designed* as perceived

by participating teachers; and, to the usefulness of this measure in subsequent outcomes analyses.

In preliminary multiple regression analyses (analyses based on 2019-2022 survey responses) Core Strategies scores, Use of activities from the Data Activities Portfolio, and Perceived Influence on QuarkNet on Teaching scores were related to teacher-level outcomes, that is **Approach to Teaching** scores.

Analysis of teachers from 24 centers (using hierarchical multiple regression) suggests that teacher outcomes (Approach to Teaching scores) are positively related to perceived QuarkNet's Influence on Teaching and Core Strategies scores. And the QuarkNet Center (as measured by Approach to Teaching center-level means) *matters* in this relationship.

Results from a hierarchical linear regression analysis show that student outcomes (student engagement scores as perceived by their teachers) are positively related to perceived QuarkNet's Influence on Student Engagement, Approach to Teaching scores (teacher outcomes) and QuarkNet's Influence on Teaching. And, again, the center *matters* in this relationship as supported by QuarkNet Center mean scores for **Student Engagement** and QuarkNet Influence on Teaching.

Although preliminary, the weight of these analyses suggests that our evaluation measures and methods have helped to ferret out the influence QuarkNet may have on participating teachers and their students, with caveats about causality links acknowledged. There is a positive relationship between engagement in QuarkNet (the type and degree of program engagement and use of activities from the Data Activity Portfolio); exposure to core program strategies; and perceived influence of QuarkNet on teacher outcomes (Approach to Teaching). Regarding the engagement of their students in inquiry-based science (that aligns with the NGSS Science and Engineering practices), QuarkNet's Influence on Student Engagement, along with Approach to Teaching and QuarkNet's Influence on Student Engagement, was shown to be related to Student Engagement. And of importance, the center in which a teacher participates in QuarkNet *matters* as related to teacher-level and student-level outcomes.

Center-specific tables, of which there is an example from two QuarkNet centers highlighted in the narrative of this report, provided opportunities to gauge teacher reported use of activities from the Data Activities Portfolio gauged by Teacher Survey (full) responses and in subsequent program years based on Update Survey responses. This descriptive analysis suggests that teachers from QuarkNet centers do vary in their reported use of DAP activities in their classroom. We have noted the importance of QuarkNet's efforts during this grant period to embed relevant DAP activities in workshops, provide time for teachers to engage in select DAP activities during the workshop, illustrate how to find and select DAP activities on the QuarkNet website, and provide workshop time for teacher implementation plan and discussion, supported by an implementation plan template to help teachers reflect on this planning.

To date, 27 (34 combined) centers have completed their Center Feedback Template. [A total of 18 out of the 24 centers reflected in the outcomes analyses have completed their feedback process. A few centers that completed their form did not meet the minimum requirement of 10 teachers per center to be included in quantitative hierarchical analyses.] Descriptive analyses based on information from these centers suggest that there is good agreement between individual teacher responses and center-level responses. That is, there is corroborative findings that teachers engage in QuarkNet as active learners, engagement through strategies that model the NGSS science practices, and provide opportunities for building collegial relationships with mentors, scientists, and other teachers.

We have supported these analyses using information obtained from workshop agendas and annual reports from active centers as well as virtual site visits of QuarkNet workshops during teachers' discussion of classroom implementation plans. In this report, we have also noted the impact COVID had on the implementation of QuarkNet especially during the 2020 and 2021 program years and its impetus for creating numerous DAP activities for online use. Also, of importance during the full grant period, a total of 71 presentations were given at professional conferences by QuarkNet staff and participating teachers.

Program Summary and Recommendations

The following program summary and recommendations are proffered:

1. The program has had a long-standing practice of holding regularly-scheduled staff meetings. One is staff-wide; one is specific to IT concerns; and, one is specific to program content and development. The evaluator has regularly attended the staff-wide meeting. These weekly staff-wide meetings provide a convenient and frequent means for staff and the evaluator to exchange ideas, such as opportunities to highlight evaluation results and for the evaluator to learn and respond to program needs when possible. This meeting structure turned out to be essential during the onset of COVID for the evaluator (and likely QuarkNet staff as well). Going forward the evaluator has attended weekly staff-wide meetings as her schedule has permitted; this open invitation is greatly appreciated.

   Recommendation 1: The frequent opportunity to exchange ideas among staff members as well as the evaluator is important and should be continued.

2. Over the course of the grant period, the collection of program operations data has improved substantially yet improvement is still needed. Although improved, the dispersed collection of this information can often make it difficult to determine simple counts, e.g., number of participating teachers during a given program year. (These responsibilities are shared across QuarkNet staff, rather than the main responsibility of a Project Coordinator and this dispersed responsibility may help aid in some of the challenges. QuarkNet staff have the responsibility of managing workshop RFP's and the award of monies to conduct these efforts as well as tracking

teachers to award stipends. These efforts are managed well as are attempts to gather a complete list of registered teachers. Comparisons of this information, however, often yield different totals of participating teachers across a program year. Adding to this complexity, this discrepancy in "total numbers" may be due to the bulk of workshop events occurring over the summer of a calendar year, which can straddle fiscal grant years.)

Recommendation 2: Continue to improve the collection of this information to help facilitate both program and evaluation efforts. In keeping with these efforts, improved program operations data will help provide running counts of *new* teachers in QuarkNet each year across participating centers. It also may help to provide insight into the outreach to additional teachers who are not as directly engaged in QuarkNet who nevertheless benefit from the program in other ways.

3. Starting in the 2019, and continuing during the 2020 through 2022 program years, there has been a concerted effort by QuarkNet staff to help nationally- and center-led workshops document the content of their workshops through the development and use of agenda templates. These agenda examples are readily available and offer a simple and pragmatic step that is very valuable; these agendas can and have been modified and used by QuarkNet centers. In many cases, agendas are modified during the event which memorializes the program in a just-in-time fashion. These documented agendas can help centers prepare their annual reports, which each participating center is asked to do.

   Recommendation 3: Continue to support these efforts.

4. Documenting workshop agendas and center annual reports – and posting these online -- have been extremely helpful in gathering information useful to the evaluation. Specifically, the workshop agendas improved the ability to identify which (and how) activities from the Data Activities Portfolio (DAP) have been incorporated into workshops, especially nationally-led workshops and to a lesser extent but still notable for center-led workshops. Other information gathered from these sources helps to summarize program year QuarkNet engagement by centers in general, and specifically in helping centers to complete the Center Feedback Template. We have also used this information for comparisons of the *designed* and *implemented* program; and in comparing individual teacher- and center-level response similarities/ differences.

   Recommendation 4: For these reasons (plus benefits noted in 3) continue to encourage centers to use the agenda template options to create their own and to post these on the QuarkNet website.

5. As evident in the narrative of this report, the Data Activities Portfolio has grown substantially during this grant period. Of importance DAP activities, collectively, have been shown to align well with Next Generation Science Standards Science and Engineering Practices. To this end, QuarkNet staff has provided operational

definitions to support how this alignment is determined. The DAP activities have also been aligned with the Enduring Understandings of Particle Physics. Noteworthy, these activities are a bridge for teachers to implement QuarkNet content and materials into their classrooms. During COVID, many of these activities were modified for online uses expanding implementation options for teachers; these options can now be used to support in-person instruction. Early efforts have translated several of these activities (and supportive resources) into Spanish. Teacher and student resources have been added; and older activities have been updated, modified, or even removed as scientific knowledge has advanced.

Recommendation 5: The dynamic effort that underlies the DAP is acknowledged and program support to maintain this effort is encouraged.

6. The number (and the quality) of activities in the DAP has increased dramatically from 2017 (the end of the past grant period) to the new program-award period. This has included applying the review and restructuring of previously developed activities, offering activities by graduated student skill sets, and separating activities by data strand and curriculum topics. As the number of these activities has grown so has the workload for their development and eventual use.

   Recommendation 6: Consider adding a select group of lead teachers or fellows to help in this process in the future. These individuals could help the education specialist with DAP activity development as well as have other responsibilities related to updating and augmenting resource information related to these activities.

7. During this grant period, and to this end, QuarkNet staff have demonstrated to teachers how to access DAP activities on the website; demonstrated search options and the availability of supportive resources such as teacher notes and student notes. Participating teachers often have had the opportunity to engage in these activities as active learners (as students) and to reflect on their possible use during implementation plan development and discussion that is part of the agendas of the workshops.

   Recommendation 7: Continue program efforts to maximize the use of Data Portfolio Activities by teachers at center-led and nationally-led QuarkNet workshops and meetings; and to encourage teachers' classroom implementation of these activities.

8. Starting with the 2020-2021 program year, staff created an implementation plan template to help teachers reflect on and develop implementation plans that can be incorporated into teachers' classrooms using QuarkNet content and instructional materials. Staff members have mandated this discussion in nationally-led workshops and they have strongly encouraged this inclusion in center-run workshops. Many of these implementation plans are posted on the QuarkNet website. Early results suggest that this structured approach, that is, time for planning and discussion as well as the implementation templates, -- has helped teacher frame their classroom plans in meaningful ways. It is likely that these program efforts have made it easier for teachers to respond to implementation questions asked in the Update Survey(s). These

efforts are valuable for the teachers and are very valuable for the outcomes evaluation. That said, the use of these implementation templates and posting these on respective webpages has remained "hit or miss."

Recommendation 8: Continue to incorporate the use of these templates and encourage teachers to post these on the QuarkNet website. Documenting these implementation plans will substantially help in providing the narrative as to the *how/what/why* QuarkNet content and materials are used in their classroom. In keeping with this, "coding camps" and workshops use a protocol of "share-out spreadsheets" where implementation plan coding projects are regularly posted by participating teachers. Adopting something similar to this protocol may aid in the consistent documentation of these proposed efforts across all QuarkNet workshops and programs.

9. Sustained duration is among the characteristics of effective professional development identified by Darling-Hammond et al (2017).

   Recommendation 9: QuarkNet has been a long-standing program. To support the sustained duration of the program for participating teachers throughout the year, encourage centers to meet during the school year in support of and to augment summer-led events. Although there are other issues such as time commitments and scheduling within a school year, the familiarity and necessity of online remote meetings during the 2020, 2021 (and 2022) program years may help centers move in this direction.

10. The Program Theory Model offers an approximate fit of QuarkNet as designed and provides a road map as to how change is expected to occur.

    Recommendation 10: Reflect on ways in which the Program Theory Model may be used to inform others in the program, those participating in the program (including centers), and those external to the program.

Although not recommendations per se a few additional thoughts are warranted.

Credit goes to QuarkNet staff for a roll-out of a series of mini-workshops for lead teachers at QuarkNet centers (started in the 2021 program year and again in the 2023 program year). Given that nearly all QuarkNet centers are mature (except for a few new centers), staff have taken this opportunity to clarify and expand the roles and responsibilities of lead teachers and to give these teachers a platform to exchange ideas on these possibilities.

QuarkNet staff has done outstanding work to support evaluation efforts and to help embed evaluation efforts and requirements within the structure and delivery of the program. This is reflected in a standing invitation for the evaluator to attend staff-wide weekly meetings, setting aside time during the workshop for the completion of Teacher Surveys (either the full or shorter update versions); as well as coordinating with centers for the Center Feedback process and the virtual workshop site visits by the evaluator

during teachers' discussions of implementation plans. The success of the evaluation's implementation is due to this cooperation by QuarkNet staff and is greatly appreciated. As is the participating teachers' willingness to complete the survey (both full and update versions) in a timely and frank manner.

Finally, QuarkNet staff have proposed during the next renewal grant to hold a series of focus groups across several participating centers to help broaden participation to reach more students who are underrepresented in STEM, either through their teachers or directly. These planned focus groups are intended to augment the in-roads made during this current grant period, through such outreach efforts as the development of STEP-UP classroom materials; or STEAM workshops intended to incorporate art with science concepts and Native American culture as well as increasing the number of schools that serve underrepresented students through representation by QuarkNet teachers.

Evaluation Summary and Recommendations

The following evaluation summary and recommendations are proffered:

1. The response rates for the Full Teacher Survey and the Update Survey remain high over the 2019 through 2022 program years (78%, 72%, 79% and 79%, respectively). Survey links have been embedded in the agendas of workshops to help facilitate a high response rate. This success is due to the commitment of QuarkNet staff teachers, fellows, and center mentors in allocating time during their workshops and meetings for this purpose. We acknowledge and are grateful for this commitment; and to participating teachers who complete it.

    Recommendation 1: Continue to work with QuarkNet staff in their support of evaluation efforts.

2. The Update Teacher Survey dovetails well with the in-workshop discussions by teachers about implementation plans. These discussions have served the evaluation well (and likely the program) as it provides teachers with a quick means to capture their thoughts in describing how and in what ways teachers plan to or have used QuarkNet program content and materials in their classrooms when completing the Update Survey. The template developed to augment implementation plan reflections (and their subsequent posting on the QuarkNet website has been used by teachers but this has remained "hit or miss" at best.

    Recommendation 2: With QuarkNet staff help, increase the number of teachers who use this template, or another means of memorializing these plans and then encourage that these are posted on the QuarkNet website.

3. The number of teachers who complete the Update Teacher Survey each year has grown. This has allowed a more in-depth descriptive analysis of the *how/what/why* of the use of QuarkNet content and materials in the classroom. The linking of these surveys (both full and updates) by individual teachers has provided a sense of how

these plans and QuarkNet content/material use may have changed over time as participation in QuarkNet continues. Both the review of posted implementation plans and responses from the Update Teacher Survey are expected to help provide the story or narrative behind the results of the quantitative analyses.

Recommendation 3: We anticipate that these qualitative analyses will be expanded during the renewal gran period to provide a more in-depth look at classroom implementation of QuarkNet content and materials across centers and the program overall. Qualitative analyses are expected to include the reported use of DAP activities by teachers in their classrooms based on various data sources (including the full survey, the update survey and posted implementation plans). In addition, we will explore the feasibility of using teacher interviews and/or testimonials, via a case study approach, to obtain more details on the *what/how/why* of classroom implementation based on QuarkNet program participation.

4. We anticipate the need for the Center Feedback Template process to be revised going forward. This revision is needed, in part, because the most active centers and those most likely to align their center-level efforts with the national program as well as the Program Theory Model have completed the process.

   Recommendation 4: Going forward, we will explore two ends; first, a quick and easy method to assess centers so that individual and center level responses can be compared. Second, it is expected that this revised process will be designed to help jump start or re-ignite centers to help increase their engagement in QuarkNet.

5. We have learned from preliminary, single-variable analyses (based on responses from the Full Teacher Survey) that the type and degree of program engagement is positively related to reported exposure to program core strategies. This is also the case for reported use of activities from the Data Activities Portfolio (DAP). Thus, we have used core strategies scores as a measure of program engagement by teachers. In support of this, results from multiple regression analyses, core strategy scores, use of activities from the DAP, and perceived Influence of QuarkNet on Teaching scores were positively related to teacher outcomes.

   Recommendation 5: Expand these preliminary analyses, per recommendations by NSF, to compare individual QuarkNet components to assess the unique contribution of each.

6. Teachers principally participate in QuarkNet through centers. This suggests the statistical need to use hierarchical linear regression analyses to help account for this nesting of teachers within these centers. Thus, using data from 24 (31 combined) centers (representing 80% of the teachers who completed the full survey and about 60% of QuarkNet centers), results from a hierarchical regression analysis show that perceived QuarkNet's Influence on Teaching and Core Strategies scores are positively related to teachers outcomes (Approach to Teaching scores). In other words, perceived influence of QuarkNet and program exposure are related to teachers

reported use of QuarkNet content and materials in their classrooms. And the QuarkNet Center (as measured by Approach to Teaching center-level means) *matters* in this relationship.

Recommendation 6: Continue to analyze teacher-level outcomes based on nested centers and increase the inclusion of as many teachers and centers in these analyses as is feasible and that meets analysis criteria.

7. Regarding Student Engagement, the center in which the teacher participates in QuarkNet *matters* as well. That is, a hierarchical linear regression analysis, based again on the same 24 (31 combined) centers, indicated that perceived QuarkNet's Influence on Student Engagement, Approach to Teaching scores (teacher outcomes) and QuarkNet's Influence on Teaching are positively related to student outcomes (student engagement scores based on teacher perceptions). Again, the center *matters* in this relationship as supported by QuarkNet Center mean scores for Student Engagement and QuarkNet Influence on Teaching.

Recommendation 7: Continue to analyze student-level outcomes based on nested centers and increase the inclusion of as many teachers and centers in these analyses as is feasible and that meets analysis criteria.

8. Descriptive analyses suggest agreement between center-level perceptions and teacher-level perceptions. This is based on information from centers -- 27 (34 combined) centers (this combined total represents about 71% of the centers) -- that participated in the Center Feedback Process. Results suggest that in the main there is good agreement between teacher-level responses and assessments by these centers; corroborating findings that teachers engage in QuarkNet as active learners, engagement through strategies that model the NGSS science practices, and provide opportunities for building collegial relationships with mentors, scientists, and other teachers.

Recommendation 8: Continue to explore individual-teacher and center-level comparisons looking for continuity (or not) across multiple data and information sources.

9. We have shown that activities from the Data Activities Portfolio, *as designed*, align well with the Next Generation Science Standards Engineering Practices and *as implemented* based on workshop agendas as well as the perceptions of participating teachers and feedback from QuarkNet centers.

Recommendation 9: Continue to compare the program as designed and as implemented.

10. Continue to work with program staff to help articulate ways in which the PTM can be used and how to facilitate this use. This includes seeing the PTM as representative of the program (as an "approximate fit") and the value of its Theory of Change.

Recommendation 10: It is important for evaluation efforts that the evaluator is mindful of the many responsibilities of QuarkNet program staff, mentors and teachers. Work to ensure that evaluation requests are reasonable and doable in a timely manner. And to the extent possible, embed evaluation requests and efforts within the structure and delivery of the program as has been done during this grant period. In addition, work to ensure that evaluation efforts and results are of value (or of potential value) to all those involved in the process. This includes QuarkNet staff and network of partners, advisory board members, participating teachers, NSF and others who may be interested in QuarkNet.