Evaluation of the QuarkNet Program: Evaluation Report 2021-2022 Executive Summary

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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 approximately 50 plus such centers across the United States.

Program Goals

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

This report is a prototype of the final evaluation report that will be submitted at the end of this award period; as such, it presents a draft of the final evaluation report (although it is final as an interim report). In serving as a prototype, the present report and its review demonstrate the shift in evaluation efforts that have occurred from formative (and summative) assessment to an outcomes-based evaluation. One intent of this early look

is that it has provide opportunities to help QuarkNet program staff members better understand this shift. And, it has offered opportunities for staff to identify principal needs and concerns that the evaluation may be able to be responsive to; and to give the evaluator time to adjust to these needs and suggestions proposed by staff to aid in the usefulness of evaluation findings and recommendations.

The evaluation 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 is complete. The process used to create the PTM has been described in this report and the model has been described 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 and will revisit the PTM over the course of the award period, as this is 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).

We have used the PTM to direct the development of evaluation measures and methods designed to address the remaining two goals. 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 years, we have added an Update: Teacher Survey (and continued in 2021) to

capture information from participating teachers and to focus on classroom implementation of QuarkNet content and instructional materials.

Based on 2019, 2020 and 2021 survey efforts, 406 teachers have completed the Full Teacher Survey (this represents a unique count). A total of 82 Update Surveys from 2020 and 107 Update Surveys from 2021 were matched with teachers who completed the full survey and self-identified on all survey forms. Our approach to analysis has been to explore, preliminarily, teacher perspectives as to their exposure to core program strategies, perceived approach to teaching, student engagement, the potential influence QuarkNet has had on teachers' approach to teaching and student engagement (based on scale scores generated from like items on the full Teacher Survey); as well as self-reported use of activities from the Data Activity Portfolio (DAP). The Update Survey focuses on reported classroom implementation of these activities. The analyses of teacher- and student-level outcomes were based on data from 21 centers, where a given center had at least 10 teachers participating at their center during the three program years in question.

These results are supplemented with information gathered from the QuarkNet Center Feedback process (completed by 18 out of these 21 centers included in the analysis mix) to help provide the program content in which the teachers engage in the program and to assess center-level outcomes in their own right. (Additional centers are expected to be added into these analyses in 2023.) 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.

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; and 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 multiple regression analyses (analyses based on 2019, 2020 and 2021 survey responses) Core Strategies scores, Use of activities from the Data Activities Portfolio, and Perceived Influence on QuarkNet on Teaching scores are related to teacher-level outcomes, that is **Approach to Teaching** scores.

Analysis of teachers from 21 centers (using hierarchical multiple regression) suggests that the center in which the teacher participates in QuarkNet *matters*, that is, teacher-level

outcomes are statistically related to the center in which the teachers engage in the program as measured by the perceived QuarkNet's Influence on Teaching and Approach to Teaching center mean scores.

Regarding **Student Engagement** scores, the center in which the teacher participates in QuarkNet *matters* as well. That is, teachers perceived influence of QuarkNet on Student Engagement, and center mean scores of Student Engagement are positively related to student-level outcomes (as perceived by their teachers).

Although preliminary, the weight of these analyses suggests that our evaluation measures and methods are on track to help us 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 were shown to be related to Student Engagement. And, the center in which a teacher participates in QuarkNet *matters* as related to teacher-level and student-level outcomes.

To date, 26 centers have completed their Center Feedback Template; 18 out of the 21 centers reflected in the outcomes analyses have completed their feedback process. (A few centers that completed their form do not meet the minimum requirement of 10 teachers per center to be included in these analyses.) At least one center now meets this requirement and will be added to future analyses. We plan to work with additional centers to obtain their templates an effort to be scheduled in fall 2022. Using information from these centers, descriptive analyses suggest that there is good agreement between individual teacher responses and center-level responses. We have supported this feedback using information obtained from workshop agendas and annual reports from active centers.

Center-specific tables, of which there was an example from two QuarkNet centers highlighted in the narrative of this report, provide 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.

Program Summary and Recommendations

With few exceptions, nearly all of the 2020 workshops and masterclasses were conducted in a virtual environment – and all occurred during a turbulent time of considerable uncertainty as to the severity and longevity of the COVID-19 pandemic. We have described how COVID-19 (coronavirus) has impacted the implementation of the 2020 QuarkNet program year; and how this has continued into the 2021 program year. Virtual workshops held in 2020 were reduced in scope focused on core concepts; and converted, for example, to half-day sessions with small-group breakout sessions, separate off-line time to work on specific tasks, and breaks built into the agenda. Programs in 2021 were held in in-person and/or virtual environments or a mix of the two. With important input from QuarkNet staff, we have outlined the long-term possible implications of many of these program modifications. It is important to acknowledge and underscore that QuarkNet staff sustained the high quality of implemented workshops and meetings during these very turbulent times.

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 meeting has provided 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; and has been essential to understanding how COVID has necessitated changes in the implemented program.
2. Starting in the 2019, and continuing during the 2020 and 2021 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. This is 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.
3. Documenting workshop agendas and center annual reports – and posting these on-line -- have been extremely helpful in gathering information useful to the evaluation. Specifically, the workshop agendas improved our 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 *designed* and *implemented* comparisons; and in comparing individual teacher- and center-level response similarities/differences. For these reasons (plus benefits noted in 2) continue to encourage centers to use the

agenda template options to create their own and to post these on the QuarkNet website.

4. DAP activities, collectively, have been shown to align well with Next Generation Science Standards Science and Engineering Practices. QuarkNet staff has provided operational definitions to support how this alignment is determined and has also shown the alignment of these activities with Enduring Understandings of Particle Physics. Of importance, these activities are a bridge for teachers to implement QuarkNet content and materials into their classrooms. As a result of COVID-needed modifications, many of these activities can now be implemented in on-line environments expanding implementation options for teachers. 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 either in-person, on-line (or both).
5. Starting with the 2020-2021 program year, staff created a 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 its use in center-run workshops. Many of these implementation plans are posted on the QuarkNet website. Early results suggest that this structured approach has helped teacher frame their classroom plans in meaningful ways and may have made it easier for teachers to respond to implementation questions asked in the Update Survey(s). These efforts are very valuable for the outcomes evaluation and we hope these are helpful in guiding QuarkNet staff's thinking about subsequent workshops as well.
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. Consider adding a Project Coordinator position to QuarkNet staff in the future renewal funding. This person could help the education specialist with DAP activity development as well as have other responsibilities related to gathering and updating program-operations data such as helping to track participation related to registration, updating teacher profiles on the QuarkNet website; and subsequent stipend payment.
7. 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 remote meetings via Zoom during the 2020, 2021 (and 2022) program years may help centers move in this direction.
8. 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 program.
9. 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 planned to be continued in subsequent program years). Given that all QuarkNet centers are mature,

staff realized that there was need to clarify the roles and responsibilities of lead teachers and to give these teachers a platform to exchange ideas on these possibilities.

10. Continue to support the evaluation and its efforts as reasonable; and continue to work with the evaluator, as planned, to help embed evaluation efforts and requirements within the structure and delivery of the program. QuarkNet staff have encouraged evaluation relevant conversations during weekly staff meetings and designated time for evaluation discussion during in person staff meetings. This is greatly appreciated as it helps to inform QuarkNet staff and provides valuable feedback in how to improve imparted evaluation findings.

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, 2020 and 2021 program years (78%, 72% and 79%, respectively). 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.
2. Working with QuarkNet staff, the Update Teacher Survey(s) dovetails well with the template that teachers use to develop classroom implementation plans. As the number of teachers who completed the Update Teacher Survey has grown, we have used this information to help illuminate how and in what ways teachers have planned or have used QuarkNet program content and practices in their classrooms. We think these descriptive analyses may help to explain the center-level differences found in teacher-level and student-level outcomes linked to the type and degree of engagement by teachers in QuarkNet.
3. Continued efforts to distribute and collect center-level information through the Center Feedback Template suggest that this process has been helpful for QuarkNet staff, Center level mentors and lead teachers, and the evaluation. To date, we have information from 26 Centers; 21of which have been incorporated into outcomes analyses (18 of these have completed their form) and 22 Center forms used in descriptive analyses. We anticipate additional centers will be added to this analysis mix in the subsequent program year.
4. Single-variable analyses from the Full Teacher Survey suggest that engagement in QuarkNet (the type and degree of program engagement) is positively related to program core strategies; and the use of activities from the Data Activities Portfolio (DAP) is positively related as well. In multiple regression analyses, Core Strategies, Use of activities from the DAP, and Perceived Influence of QuarkNet on Teaching scores were positively related to teacher outcomes. And of importance, hierarchical multiple regression analysis from 21 centers suggests that the center in which the teacher participates in QuarkNet *matters* as teacher-level outcomes were shown to be related to perceived QuarkNet's Influence on Teaching and center mean scores. Regarding Student Engagement, the center in which the teacher participates in QuarkNet *matters* as well; that is, teachers' perceived influence of QuarkNet on

Student Engagement and center mean scores of Student Engagement are positively related to student-level outcomes (as perceived by their teachers).

5. Data analyses suggest agreement between center-level perceptions and teacher-level perceptions. This is evident when looking at information about teachers experiencing activities as active learners (as students); and, exposure to opportunities to develop and maintain collegial relationships with other teachers, mentors and other scientists. 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.
6. Continue to incorporate center-level outcomes data (from the Center Feedback Template process), in analyses of teacher-level and student-level outcomes as the QuarkNet center *matters*. An early look at center success factors suggests the importance of adding sustainability outcomes into the analysis mix especially in answering the question, *What is likely to be sustained*?
7. 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.
8. Continue to be mindful of the many responsibilities that program staff, mentors and teachers have. 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.
9. Work to ferret out the benefits and challenges of implementing QuarkNet programs (workshops, masterclasses) in a virtual environment and work with QuarkNet staff to highlight positive long-term implications of this over time and/or joint-center QuarkNet opportunities.
10. 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, participating teachers, NSF and others who may be interested in QuarkNet.