Evaluation of the QuarkNet Program: Evaluation Report 2023-2025 Executive Summary

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Abstract. 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. 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.

Since the start of the 2019 QuarkNet program year, the evaluation themes are: (1) (Develop and) Use a Program Theory Model (PTM); (2) Measure Outcomes (teacher, student and long-term); and (3) Measure Center-level Program Outcomes. During the previous grant period, new evaluation measures based on the PTM were created; these were combined with select previously used evaluation measures. We seek to link program engagement, as articulated through program strategies, to measurable program outcomes (see Figure 1 repeated here).

Program Strategies → **Measurable Program Outcomes**

Figure 1. Throughout the evaluation, program engagement (i.e., specifically exposure to core program strategies) provides the context in which assessment has occurred.

Program Theory Model (PTM): What's New and What's Kept

QuarkNet's PTM was reviewed and revised (in small but important ways) to coincide with the current renewal grant. To this end, a new partner (i.e., the Institute for Research and Innovation in Software for High Energy Physics, IRIS-HEP) was added; we added new program components; and, reviewed, updated and revised descriptions of other programs, as needed. The programmatic anchors of the PTM focus on: characteristics of effective professional development (Darling-Hammond, Hyler and Gardner, 2017); NGSS Science and Engineering Practices (NGSS, April 2013); and an operational definition of inquiry (Herron, 1971 as modified by Jan-Marie Kellow, 2007). Also, the PTM details the major partners, program goals, program components of QuarkNet, articulating program strategies and their linkage to expected outcomes as well.

Evaluation Measures and Sources of Information

Exhibit F provides an overview of the program and evaluation outcomes data. The evaluation measures and sources of information used to inform the evaluation is shown in Exhibit G (both are repeated here). These measures align with the PTM.

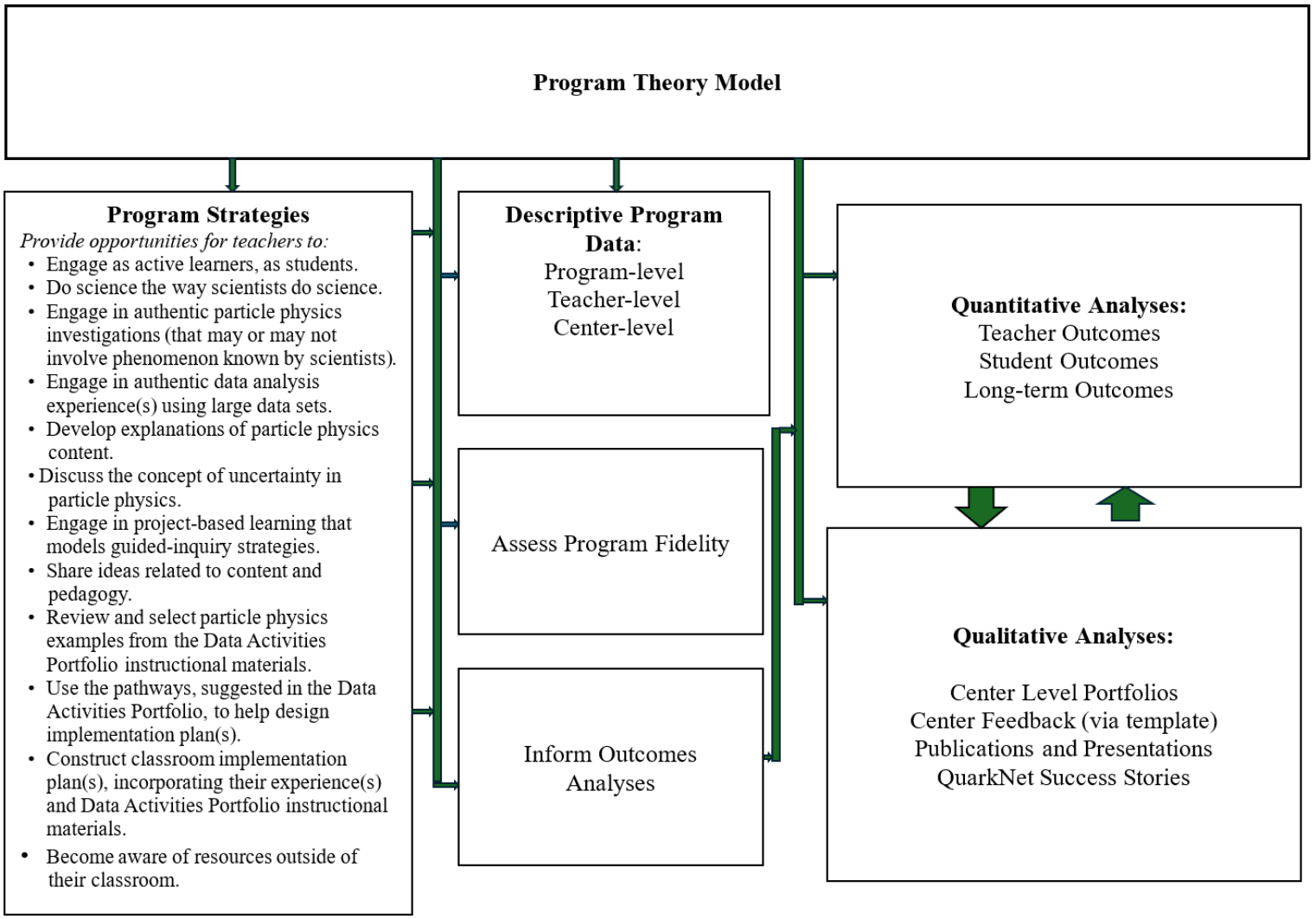

Exhibit F. Overview of Program and Outcomes Data

Sources of Outcomes Data

Teacher Full Survey
Primary Focus: Quantitative analyses of teacher, student, and long-term outcomes
Update Survey
Primary Focus: Qualitative analyses of QN content and material use in classrooms
Center Feedback Process and Template
Primary Focus: Comparing center-level and teacher-level responses
Virtual Workshop Visits by Evaluator
Primary Focus: Implementation plan discussions

Multiple Sources of Information: Evidence of Program Engagement/ Alignment with PTM

Workshop Summary Table compiled from:
Workshop Agendas
Annual Reports from Centers
Data Activities Portfolio alignment with:
NGSS Science Practices
Workshop Engagement
Enduring Understandings
Acknowledge and Review other Information
(e.g., cosmic ray studies, use of comic watches, professional presentations; masterclasses; student-collected data)

Exhibit G. Summary and Overview of Evaluation Measures and Program Engagement

Summary of Evaluation Results

The summary of evaluation results is highlighted in Table 15, using the outline highlighted below to achieve this purpose. The narrative of the evaluation report uses this organization and has detailed support for the conclusions presented for each of the following:

1. QuarkNet: Professional Development for HS Teachers
2. (Develop and) Use a Program Theory Model
3. Program Organization
4. Data Activities Portfolio: Brief History and Development
5. Program Implementation and Measuring Fidelity (*Designed* vs. *Implemented* Program)
6. Linking Program Strategies to Outcomes
7. Survey Implementation and Response Rates
8. Summary of QuarkNet Teachers: Demographics
9. School Characteristics and Student Demographics
10. Overview of Analyses: Teacher (and their Students) and Long-term Outcomes
11. Unique Contribution of Major QN Program Components
12. How QuarkNet Engagement is Related to Outcomes: QuarkNet Centers *Matter*
13. Qualitative Analyses: Center-level Portfolios A Narrative Picture of QuarkNet's Influence
14. Center-level Outcomes and Effective Practices
15. Getting the Word Out
16. QuarkNet Success Stories: Case Studies
17. Program and Evaluation Recommendations

Table 15
QuarkNet Evaluation: Summary of Major Efforts and Results

Evaluation Effort	Source(s) of Information	Highlighted Major Results
1. QuarkNet: Professional Development for HS Teachers Appendix A highlights program history.	• Review of previous program and evaluation documents • QuarkNet staff expertise	• Brief program history presented. • Importance of Centers noted. • Four Program Goals presented. • Approach to evaluation provided (three themes).
2. (Develop and) Use a Program Theory Model Appendix B summarizes the protocol used to develop this model. Appendix C presents the full model (PTM).	Created by working groups based on: • Structured interviews with key QuarkNet staff • Relevant literature • QuarkNet staff expertise PTM is intended to reflect that *context matters* in the implementation of the program providing a representative picture of how *change* is expected to happen.	• In detail (7 pages) PTM outlines the links between core program strategies, program structure and major program outcomes. (See Appendix C.) • Offers a 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.*
3. Program Organization (See Figure 2 for chart.) (See Table 1 for list of QuarkNet centers.)	• Organization and Implementation chart (developed by QuarkNet staff) • Program's website https://quarknet.org/	• Overviews the administration and implementation of the program. • Key role of centers noted (presently 55 centers). • Importance of QuarkNet's website presented.
4. Data Activities Portfolio: Brief History and Development Appendix D overviews protocol. Appendix E presents a brief history of Data Activities Portfolio (DAP) growth. (See Tables 2-4.)	• *The Data Portfolio is a compendium of particle physics classroom activities organized by Data Strand, Level of student engagement, Curriculum Topics and NGSS Standards*. (Data Activities Portfolio QuarkNet) • Organized by key search options • Pathway and Template documents created to support development of activities • Supported with resources (e.g., teacher/student notes)	• Organized by required student skills sets (Levels 0-4) (developed by QuarkNet staff). • Criteria used to determine the alignment of DAP with Next Generation Science Standards (NGSS) defined by QuarkNet staff. (See Table 2 in full report.) • DAP *as designed* aligns well with Next Generation Science Standards (NGSS), (see Table 3) and • QuarkNet's defined Enduring Understandings (see Table 4). • Grown to include 40 plus activities, designed to be implemented in the classroom. Several can be implemented online and several are in Spanish.

Table 15 (con't.)
QuarkNet Evaluation: Summary of Major Efforts and Results

Evaluation Eff ort	Source(s) of Information	Highlighted Major Results
5. Program Implementation and Measuring Fidelity (*Designed* vs. *Implemented* Program) Previous program years are highlighted in a series of tables in Appendix F. (See Table 5 in evaluation report for 2024 program year summary.)	• Program Theory Model • Workshop Agendas • Center Annual Reports • Virtual site visits by the evaluator	• Workshop summary tables highlight the *implemented* QuarkNet program. (See Table 5.) • Workshop agendas incorporate DAP activities offering opportunities for teachers to engage in these as active learners. • *Implemented* activities align well with NGSS Science Practices (see Figure Set 14). • Creates predicate to compare program engagement to program outcomes (presented here shortly).
6. Linking Program Strategies to Outcomes Appendix G presents a series of tables that link core program strategies to relevant education literature, followed by linking core strategies to program outcomes. Appendix H presents Full Teacher Survey. Appendix I presents Update Survey. Appendix J presents Center-level Feedback Template.	• Program Theory Model • Linking Program Engagement to Outcomes (evidence of program engagement) • Sources of Outcomes Data delineated • Appendix K shows statistical support for use of scale scores	• Overview outcomes data sources: • Teacher Full Survey • Update Survey (Spanish language version also) • Center Feedback Process and Template • Virtual Workshop Visits by Evaluator
7. Survey Implemented and Reponses Rates (See Table 6.)	• Teacher surveys (full/update) were conducted during 2019-2024 program years • Survey implemented during workshop participation with follow-up email as necessary • Raw data from the full teacher survey and the update survey • Data retrieved from Survey Monkey • Raw data cleaned and multiple data calculations and all analyses conducted using IBM SPSS version 28	• Annual survey responses (including combined full and update versions for years when relevant) range from a low of 72% (during COVID) to 80% during the 2019-2023 program years. • 83% response rate for 2024 program year.

Table 15 (con't.)
QuarkNet Evaluation: Summary of Major Efforts and Results

Evaluation Effort	Source(s) of Information	Highlighted Major Results
8. Summary of QuarkNet Teachers: Demographics		
a. Gender of Teachers (not statistically related to outcomes) (See Table 7.)	Full Teacher Survey	• The number and percent of women who participate in QuarkNet has increased over recent program years. • Over the 2019-2024 program years program engagement is close to parity: 50% for men; 43.6% for women; and 6.4% not specified (based on survey data). • From 2024 program registration information, 48% are men. 47% are women and 5% preferred not to answer.
b. Teachers *New* to QuarkNet Appendix L presents these data by QuarkNet center and program years.	• Full Teacher Survey • Operations Data (teachers receiving stipends)	• For 2019-2022 program years, 36% of teachers were new/1-year in program. • For the 2023 program year, this percent was 33%. • In 2024 program, 33% of teachers were new/1-year in program (information from attendance records and survey responses).
c. Years in QuarkNet, Years Teaching and Years at Current School (See Figure Set 4.)	• Full Teacher Survey (at the time teachers completed their survey)	• Based on teacher reports, the mean number of years in QuarkNet is 4.62 years (median 2.0 years). • Mean number of years teaching is 16.12 years (median 15 years). • Mean number of years at current school is 9.09 years (median 7 years).
d. School Location (See Table 8.)	• Full Teacher Survey	• Over 50% (51.3%) of schools where participating teachers teach are in urban/urban central city locations. • 29.5% of schools are in suburban locations. • 19.2% of schools are in rural locations.
e. Teaching Physics (See Table 8.)	• Full Teacher Survey (at the time teachers completed their survey)	• A total of 74.8% of teachers reported teaching physics. • Over time, there has been a tendency for more teachers to report that they are not teaching physics. • Other fields mentioned include Chemistry, Physical Science, Earth Sciences, Biology, Statistics, Math. • Slightly more women report that they do not teach physics as compared to men.

Table 15 (con't.)
QuarkNet Evaluation: Summary of Major Efforts and Results

Evaluation Effort	Source(s) of Information	Highlighted Major Results
8. Summary of QuarkNet Teachers: Demographics (con't.)		
f. QuarkNet Participation (See Tables 9-10.) (See Figure 6.)	Full Teacher Survey	• Any and all programs (as reported when survey was completed) that teachers participated in at the time they completed their full survey. • Program engagement linked to exposure to core program strategies.
g. QuarkNet Participation and Program Year (See Table 11.)	Full Teacher Survey	• Outcomes do not vary by which year a teacher participates in QuarkNet.
9. School Characteristics and Student Demographics (based on publicly available school-level information) **a. Location** **b. Enrollment size** **c. Student: Gender (%), Ethnicity/Race (%); Free or Reduced Lunch (%)**	• Large scale case study • Either www.publicschoolreview.com or www.privateschoolreview.com • Information accepted at face value. • Based on teachers enrolled in QuarkNet during the 2022 program year. • ~ 250 teachers from ~120 schools.	• Organized by center. • Schools represented by QuarkNet teachers are varied; representing mostly public schools both large and small; and, to a lesser extent, private schools. Some centers show evidence that students represented by schools are diverse in ethnicity and represent notable percents of low-income students (e.g., free or reduced lunch eligibility). Other centers less so.
10. Overview of Analyses: Teacher (and their Students) and Long-term Outcomes (See Figure 7.)	• Full Teacher Survey: Quantitative Data Analyses	• Maps out key outcomes analyses • Statistical analyses support the use of scale scores as program exposure/outcome measures. • Outcomes measures are: Core Strategies (exposure), Approach to Teaching, QuarkNet's Influence on Teaching, Student Engagement (as perceived by teachers), QuarkNet's Influence on Student Engagement and Long-term Outcomes.

Table 15 (con't.)
QuarkNet Evaluation: Summary of Major Efforts and Results

Evaluation Effort	Source(s) of Information	Highlighted Major Results
11. Unique Contributions of QuarkNet Program Components **a. Data Camp** **b. (Variety of) Workshops** **c. Masterclasses** (See Table 12 in full report.) Appendix L presents summary of results and analysis details.	• Full Teacher Survey (Program Exposure and Outcome Scale Scores: Core Strategies, Approach to Teaching, QuarkNet's Influence on Teaching, Student Engagement, QuarkNet's Influence on Student Engagement, and Long-term Outcomes: Teachers.) • Requested by NSF. In response, conducted a series of simultaneous Analysis of Variance (ANOVA) analyses	• Analyses suggest that Data Camp and Variety of Workshops each contribute to teachers' reported engagement in Core Strategies, and that • Each major program component of QuarkNet contributes uniquely to at least one or more outcome measures: Approach to Teaching; QuarkNet's Influence on Teaching, Student Engagement (as reported by teachers), QuarkNet's Influence on Student Engagement; and Long-term Teacher Outcomes. (See Table 12 in full report.) • Thus, analyses suggest that each of the major components of QuarkNet contribute *uniquely* to outcomes as measured. • Analyses do not take into consideration the role that centers play in engagement and outcomes (do not meet statistical requirements for such analyses).
12. How QuarkNet Engagement is Related to Outcomes: QuarkNet Centers *Matter*	• Full Teacher Survey • Hierarchical linear regression analyses that account for teachers nested in QuarkNet Centers. • Using scale scores to measure outcomes.	• See Figure 8 for a schematic on the relationship between program engagement and exposure to core program strategies. • QuarkNet Centers *matter* when assessing teacher, student, and long-term outcomes. (See below for short summary of each.)
a. Approach to Teaching (See Figure 9-10.)	• Scale Scores: Core Strategies, Approach to Teaching, QuarkNet's Influence on Teaching and Center-level Mean Scores (Approach to Teaching)	A hierarchical linear regression analysis based on 26 centers (34 combined) 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' use of content and instructional practices in their classrooms (i.e., Approach to Teaching). These results are statistically significant [$F_{(3, 424)} = 77.32$, $p < .001$]. See Figures 9-10.

Table 15 (con't.)
QuarkNet Evaluation: Summary of Major Efforts and Results

Evaluation Effort	Source(s) of Information	Highlighted Major Results
12. How QuarkNet Engagement is Related to Outcomes: QuarkNet Centers *Matter* (con't.)	• Full Teacher Survey • Hierarchical linear regression analyses that account for teachers nested in QuarkNet Centers. • Using scale scores to measure outcomes.	
b. Student Engagement (See Figure 11-12.)	• Scale Scores: Student Engagement, QuarkNet's Influence on Student Engagement, Approach to Teaching and Center-level Student Engagement Mean.	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 this Student Engagement. These results are statistically significant [$F_{(3, 383)} = 94.43$, $p < .001$].
c. Long-Term Outcomes (See Figure 13.)	• Scale Scores: QuarkNet's Influence on Teaching, Student Engagement and Long-term Outcomes	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 [$F_{(3, 386)} = 66.64$, $p < .001$].
13. Qualitative Analyses: Center-level Portfolios A Narrative Picture of QuarkNet's Influence Compiled for 26 (34 combined) centers included in the quantitative analyses.	• Full Teacher Survey (open-ended questions) • Update Survey (open-ended questions) • Virtual workshop site visits by evaluator • Teacher Implementations Plans (workshop agendas/center annual report) • Examples of teachers' work • Examples of student work	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). When available: • Implementation plans prepared by teachers or groups of teachers and posted on QuarkNet website are included. • Examples of teacher work (during workshops, science fairs, presentations at workshops/ professional conferences) are included. • Examples of student work are included.

Table 15 (con't.)
QuarkNet Evaluation: Summary of Major Efforts and Results

Evaluation Effort	Source(s) of Information	Highlighted Major Results
14. Center-level Outcomes and Effective Practices (See Figure Set 14 for comparisons of designed vs. implemented and teacher-level and center-level responses.)	• Center Feedback Template • Effective Practices (M.J. Young & Associates (2017, September). *QuarkNet: Matrix of Effective Practices*	• Center-level responses from Center Feedback Templates indicate that QuarkNet teachers engaged in NGSS Science Practices as part of their work-shop engagement; and this experience has a noted influence on teachers related to these practices. • Comparisons suggest good agreement on select responses by individual QuarkNet teachers and QuarkNet centers [26 (34 combined) centers]. • Results suggest good alignment of centers to meet the criterion of each of 10 effective practices. • Offers a suggestion of program sustainability (i.e., what is being sustained).
15. Getting the Word Out Compiled by K. Cecire and S. Wood	• https://quarknet.org/content/publications-presentations-and-posters-sept-2018-sept-2023 • Publications, Presentations, and Posters June 2023-Present | QuarkNet	• As of the 2023 program year (Sept), QuarkNet has posted a total of 72 presentations, posters, and publications by staff, teachers and/or students. • From June 2023 to present, an additional 35 presentations, posters, and publications by staff, teachers and/or students have been posted.
16. QuarkNet Success Stories: Case Studies **Supplement I Final | QuarkNet** **Supplement II Final | QuarkNet**	• Testimonials • Interviews with select staff, teachers and former students • Emails from staff about former students • Evaluation Team | QuarkNet	• In more detail, how QuarkNet has influenced teachers, students as well as its staff, a series of two supplemental reports were created in support of these quantitative and qualitative analyses • Each vignette prepared with the active participation of the individual highlighted. • The first report highlights individuals from four QuarkNet centers. The second report highlights individuals from one QuarkNet center. • Staff, teacher and student work examples are proffered including publications, and presentations.
17. Program and Evaluation Recommendations	• Culmination of information sources contained in this evaluation	• A total of 10 program recommendations and • 10 evaluation recommendations are proffered.

Program Summary and Recommendations

The following program summary and recommendations are proffered:

P1. 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 was essential during COVID for the evaluator (and likely QuarkNet staff as well). The evaluator has attended weekly staff-wide meetings as her schedule has permitted; this open invitation is greatly appreciated.

Recommendation P1: The frequent opportunity to exchange ideas among staff members as well as the evaluator is important and should be continued.

P2. Over the course of the grant period, the collection of program operations data has improved substantially including, for example, simple counts, e.g., number of participating teachers during a given program year. 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, although these responsibilities are shared across QuarkNet staff rather than the responsibility of one individual.

Recommendation P2: Continue to improve the collection of program operations data to help facilitate both program and evaluation efforts. In keeping with these efforts, improved program operations data has helped with a running count 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 directly engaged in QuarkNet who nevertheless benefit from the program in other ways.

P3. Starting in 2019, and continuing during the 2020 through 2024 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 P3: Continue to support these efforts.

P4. 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 a growing number of 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 P4: 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.

P5. As evident in the narrative of this report, the Data Activities Portfolio has grown substantially during this past grant period and into this new grant period. Of importance, collectively DAP activities have been shown to align well with Next Generation Science Standards Science and Engineering Practices. To this end, QuarkNet staff have 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. Many of these activities were modified for online uses expanding implementation options for teachers (with COVID the impetus for this effort). 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 P5: The dynamic effort that underlies the DAP is acknowledged and program support to maintain this effort is encouraged. The DAP may be the lasting legacy of the QuarkNet program.

P6. The number (and the quality) of activities in the DAP has increased dramatically from 2017. 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 P6: 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.

P7. During the past and present grant period, 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 P7: 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 to implement these activities in their classrooms.

P.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 or a variation of it, has helped teachers 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 evaluation. Because of these efforts, many implementation plans created by teachers have been incorporated into center-level portfolios that include other qualitative data as well.

Recommendation P8: Continue to incorporate the use of these templates (or a variation of it) 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. Regularly posting implementation plans may encourage teachers to post other examples of how QuarkNet content and materials are incorporated into their classrooms.

P9. Sustained duration is among the characteristics of effective professional development identified by Darling-Hammond et al (2017).

Recommendation P9: 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 2020-2023 program years may help centers move in this direction.

P.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 P10: 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 have proposed during this grant period to hold a series of needs assessment workshops across participating centers. Each such workshop was named *Physics Education Forum* and sub-titled as *Helping Share the Future of Physics Education in Our Schools*. The first was held at Rice University/University of Houston QuarkNet Center on December 16, 2023 (Rice QuarkNet Physics Education Forum - December 16, 2023 | QuarkNet). The second was held at the University of Minnesota QuarkNet Center on February 1, 2025 QuarkNet - U of M Physics Education Forum - February 1, 2025 | QuarkNet. The purpose of these forums was to help broaden participation to reach more teachers and students in STEM, to learn about the program needs and interests of teachers who are not yet engaged in the QuarkNet program and to help inform the program as to possible options to help expand the program's outreach.

Finally, 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.

Evaluation Recommendations

The following evaluation summary and recommendations are proffered:

E1. The response rates for the Full Teacher Survey and the Update Survey remain high over the 2019 through 2024 program years (ranging between 72% to 83%). 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 their surveys.

Recommendation E1: Continue to work with QuarkNet staff in their support of evaluation efforts.

E2. 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. During the 2023 and 2024 program years, there has been an important uptick of teachers posting implementation plans. This is very important to help qualitatively describe implementation in-roads of QuarkNet content and materials in the classroom.

Recommendation E2: With QuarkNet staff help, increase the number of teachers who post their implementation plans or ideas on the QuarkNet website.

E3. The use of the Update Teacher Survey has allowed a more in-depth descriptive analysis of the *how/what/why* of the use of QuarkNet content and materials by teachers in the classroom (and reduces the ask of teachers to supply evaluation information) over time. The linking of these surveys (both full and updates) by individual teachers has provided a valuable picture 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 have helped to provide the story or narrative behind the results of the quantitative analyses; this information is now captured in center-level portfolios along with examples of teacher/student work, when available. (These portfolios are 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.)

Recommendation E3: These qualitative analyses have been expanded during this grant period to provide a more in-depth descriptive look at classroom implementation of QuarkNet content and materials across centers and the program overall. This effort should be continued as these qualitative analyses help to provide a narrative of what

classroom implementation of QuarkNet content and materials looks like. Add examples of teacher work, student work, and presentations/posters given at professional conferences when available.

E4. The Center Feedback Template process continues to provide valuable information to compare individual teacher- and center-level views on teacher engagement and on center-level outcomes. For the near future this effort may be put on the back burner and revisions to this process may be explored. This is the case, 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 E4. Although not an active part of the current evaluation efforts, 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 and/or to document these efforts.

E5. Per a recommendation by NSF, we revamped the preliminary quantitative analyses to investigation the unique contribution major QuarkNet components play in the measurement of program engagement and outcomes. These analyses suggest that Data Camp and Variety of Workshops each contribute to teachers' reported engagement in Core Strategies, and that each major program component of QuarkNet contributes uniquely to at least one or more outcome measures: Approach to Teaching; QuarkNet's Influence on Teaching, Student Engagement (as reported by teachers), QuarkNet's Influence on Student Engagement; and Long-term Teacher Outcomes. Thus, these analyses suggest that each of the major components of QuarkNet contribute uniquely to outcomes as measured.

Recommendation E5: The unique contribution of major QuarkNet program components has been noted but these analyses do not take into consideration the center in which teachers engage in the program (because of sample size limitations). Thus, these analyses will not be explored further unless recommended by NSF.

E6. *Centers Matter.* Teachers principally participate in QuarkNet through centers suggesting the statistical need to account for this nesting of teachers within these centers. Thus, a hierarchical linear regression analysis based on 26 centers (34 combined) explored the relationship between core program strategies, perceived influence QuarkNet has had on classroom teaching practices and implemented instructional practices (Approach to Teaching). The results of this analysis show 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 teacher use of content and instructional practices in their classrooms (i.e., Approach to Teaching). These results are statistically significant.

Recommendation E6: 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.

E7. Similarly for Student Engagement, the center in which the teacher participates in QuarkNet *matters*. Thus, a hierarchical linear regression analysis [based on 26 (34 combined) centers] was conducted where QuarkNet's Influence on Student Engagement, Approach to Teaching and Centers (as measured by mean Student Engagement scores) were shown to be positively related to Student Engagement.

Recommendation E7: Modelling student-level outcomes through analyses continue to be challenged where a wide variety of possible relationships may exist but recent data suggest that this model may be becoming a more stable, reliable model. That said, continue to explore student level outcomes analyses based on nested centers with the hope that additional data will help to stabilize these results. And continue to supplement these quantitative results with qualitative examples of student work as well as former QuarkNet student achievement through success story vignettes.

E8. Long-term outcomes by participating QuarkNet teachers were measured quantitatively as well. That is, perceived QuarkNet's Influence on Teaching, Student Engagement and Center-level means scores are positively and statistically related to Long-term Outcomes: Teachers.

Recommendation E8: These results have been replicated with additional data based on 2024 program year.

E9. Qualitative analyses have supported the results of these quantitative analyses by providing descriptive details including examples of classroom implementation plans of QuarkNet content and materials by participating teachers. This information has been compiled in center-level portfolios (as already mentioned) which have included: teacher responses to open-ended survey questions over time as to the *what/how/why* of classroom implementation; examples of implementation plans created by teachers, as well as examples of teacher work, and student work. Examples of presentations at professional conferences are included as well, when available. And highlighted through success story vignettes.

Recommendation E9: Continue to explore the development and use of these center-level portfolios.

E10. 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 E10: It is important that the evaluator remains 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.