Evaluation of the QuarkNet Program: Final Evaluation Report 2018-2023

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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 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.

Evaluation of the QuarkNet Program: Final Evaluation Report 2018-2023

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This report highlights the cumulative evaluation, which began anew in 2018-2019 through 2021-2022, during the current funding cycle from the National Science Foundation (NSF). Portions of this report have drawn from annual evaluation reports prepared during this grant period to reflect the continuity of these efforts (Race, 2019-2022).

QuarkNet: Professional Development for HS Teachers

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).

QuarkNet program efforts began in 1999; a brief history of the program is described in Appendix A. The QuarkNet program is not static but reflects changes in particle physics, such as neutrinos, and improved approaches to professional development over time. As noted by Beal and Young (2017), "For nearly two decades, QuarkNet has been fully engaged in establishing a national community of researchers and educators associated with particle physics experiments" drawing from the professional development literature. These past evaluators noted that QuarkNet has "evolved to reflect changes in the education context in which the program operates, and in response to findings from formative evaluation."

It is the current program that is the focus of present evaluation efforts, but we have drawn on the program's rich history when relevant.

Importance of Centers

In current form, QuarkNet[1] is "first and foremost, a teacher professional development program" (personal communication, email December 11, 2018), with 52 centers across the United States, where these centers "both form the essential backbone and are partners in the QuarkNet collaboration" (PTM, 2019). These centers are housed at a university

[1]Until this award period, QuarkNet had been co-sponsored by the National Science Foundation and the Department of Energy. In addition to NSF funding, funding is also provided by U.S.CMS and U.S. ATLAS. In-kind support is provided by Fermilab during this current award period as well.

or laboratory, serving primarily high school teachers who live in the nearby catchment area. Included in this number of in-person centers, there is the Virtual Center, which provides a home for teachers who do not live proximal to a particle physics research group. At these centers, program leaders include one or two physicists who serve as mentor(s) and team up with one or two lead teacher(s). Each center seeks to foster lasting relationships through collaboration at the local level and through engagement with the national program (PTM, 2019).

During this award period, a center has been defined as "active" if it provides at least one day of teacher development and "semi-active" if the center and its teachers participate in only International Masterclasses, or another promotional event-program such as International Muon Week, Word Wide Data Day, International Cosmic Day or an equivalent activity (email blast sent by the PIs, email December 11, 2018). At the time of this writing there are 52 "active" QuarkNet centers, which will be presented later in this report. Two of these centers are very new.

In addition, later in this report, we will discuss the effect the COVID pandemic had on the QuarkNet program and modifications made during the summer of 2020 (and the 2021 program year) and its potential impact on the implementation of program going forward.

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.

Approach to Evaluation

As already stated, the QuarkNet program is not new, but the external evaluator is -- starting with the 2018-2019 program year. Accordingly, a new direction focused the evaluation 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. Based on the PTM, new evaluation measures were created and, when relevant, existing evaluation measures from previous evaluation efforts were modified and included; these have been implemented to assess teacher-level program outcomes, center-level outcomes and program-center sustainability. These data are supported by program-operations data obtained from program resource documents (such as agendas and annual reports) and, other teacher- and center-level information (such as teacher implementation plans and center feedback forms). We drew from QuarkNet program and evaluation history when relevant (e.g., QuarkNet Proposal to NSF, 2018).

Develop (and Use) a Program Theory Model (PTM)

A Program Theory Model (PTM) was developed during the first year of this funding cycle. Because of its significance, we present the rationale for why it was developed and highlight the important components of the program (and its model). The process used to develop the model is described in Appendix B. In short, we drew from the relevant literature; Next Generation Science Standards (especially the Practices); and, defined our use of the term "Guided Inquiry." We developed the content of the model through structured interviews with key stakeholders; held a face-to-face meeting with past evaluators; and through working meetings with PIs and stakeholders developed a detailed, pictorial representation of the program.

Why a Program Theory Model Was Developed

Often the term "logic models" and "program theory models" are used interchangeably. We intentionally use the later term for a variety of reasons. Although logic models often distinctly focus on describing the program as *it is in operation* -- offering an advantage if this is desired -- these models often blur the lines between the designed and implemented program. By developing and using a PTM, we intended to offer a representative picture of how *change* is expected to happen -- at least in theory -- by describing in detail the program *as designed.* PTM models differentiate between the program *as designed* from the program *as implemented* helping to underscore the importance of measuring program fidelity, program "dosage" or participation levels, as well as other operational variables and suggesting at least what, if not how these, might be measured. It also underscores that variations between the *designed* and *implemented* program are expected and that these variations are worth knowing and noting.

Of importance, PTM's often underscore that the *context* in which the program is implemented *matters*, including program partnerships and supporting institutions. This context can be particularly helpful in suggesting, perhaps the type and continuum of engagement, whether or not to scale-up the program, and, whether replicating or generalizing of the program will work in other settings or situations. And in the case of QuarkNet, the PTM has underscored factors related to the sustainability of the program.

We see the following benefits and uses derived by creating a PTM:

- The program is articulated in a representative way reflecting its integrated components.
- Program strategies and measurable program outcomes logically link together.
- Identified indicators and proposed measures align with priority outcomes.
- Future program modifications, if any, adhere to strategies identified as core to the program.
- Program staff, key stakeholders and the evaluator have a common understanding of the program. (Donaldson, 2007)
- The potential to facilitate the generalization of program and evaluation efforts to other programs with similar goals and outcomes, including participating QuarkNet centers.

These evaluation efforts are consistent with program models or theory of change models that are often developed by evaluators and stakeholders to articulate how program outcomes link to specific program strategies and activities (Brett & Race, 2004; Rogers, Petrosino, Huebner & Hasci, 2000; Race & Brett, 2004; Renger, 2006). As already stated, such models facilitate the achievement of a common understanding of the program by stakeholders and the evaluator (Donaldson, 2007), and serve to conceptualize a program relative to its operation, the logic that connects its activities to the intended outcomes, and the rationale for why the program does what it does (Rossi, Lipsey & Freeman, 2004).

Thus, QuarkNet's PTM:

1. Offers "an approximate fit" of the theory of the QuarkNet program as *designed.*
2. Allows for a comparison between the program as *designed* and as *implemented.*
3. Links core program strategies to program outcomes.
4. Directs evaluation efforts.

It is important to note that although the PTM is intended to be inclusive, both from the standpoint of providing a consensus as to the model's representativeness of the program among key stakeholders and a comprehensive picture of program outcomes, evaluation efforts will focus on key program outcomes and program sustainability efforts. Thus, not all articulated program outcomes are assessed.

Theory of Change

To a large extent the Program Theory Model (described shortly) elaborates on how change is expected to occur, based on 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).

PTM Program Anchors

The complexity of the program, its network of partners, and its longevity suggested that the development of a PTM was warranted. Largely, the creation of this Program Theory Model involved making key program components and strategies explicit, that have evolved and been implemented over time, and served to help link these to an outcomes-based evaluation. The PTM was anchored by relevant literature on effective professional development; the Next Generation Science Standards (and other relevant standards); and our defined use of the term “Guided Inquiry.” We also included a framework that adds program sustainability strategies and outcomes into the mix.

Effective Professional Development (PD)

In 2017, Darling-Hammond and her colleagues identified characteristics of effective professional development. Her work was based on the review of 35 studies that met their criteria of methodological rigor; studies, which they noted, built on an expansive body of prior research that has described positive outcomes based on teacher and student self-reports or observational studies. These reviewed studies showed a positive link between teacher professional development, teaching practices, and student outcomes (Darling-Hammond, Hyler & Gardner, 2017). Her work added to the contributions of Desimone (2009), which led to the identification of seven characteristics of effective PD. They posit that successful PD “will generally feature a number of these components simultaneously” (Darling-Hammond, Hyler & Gardner, 2017, p. 4). Table 1 provides a brief description of each of these characteristics.

As shown in this table, the seven characteristics of effective PD as proffered by Darling-Hammond, et al. (2017) are:

1. Is **content focused**.
2. Incorporates **active learning** utilizing adult learning theory.
3. Supports **collaboration**, typically in **job-embedded contexts**.
4. Uses **models and modeling** of effective practice.
5. Provides **coaching and expert support**.
6. Offers opportunities for **feedback and reflection**.
7. Is of **sustained duration**.

Given the overarching nature of this program anchor, Table 1 also briefly describes how each of these characteristics is integrated in the QuarkNet program. Similarly, Roudebush (2022) showed how these characteristics align with the Data Activities Portfolio activities of QuarkNet. Professional Learning Communities are seen by Darling-Hammond, Hyler and Gardner (2017) as an important means in which to embed these PD characteristics Later in this report, we will highlight how the implemented QuarkNet program facilitates building relationships among teachers, lead teachers, fellows, mentors, and other scientists through these collegial networks in pursuit of learning communities.

The remaining program anchors described in the PTM are introduced in this section as well; however, QuarkNet alignment with these anchors are presented in more detail in subsequent sections of this report.

Table 1
Brief Description of Characteristics of Effective Professional Development (PD)
Identified by Darling-Hammond, Hyler and Gardner (2017) and What Happens in QuarkNet

Characteristic of Effective PD	Brief Description	What Happens in QuarkNet
Content Focused	PD that is focused on a discipline-specific curricula or instructional materials; that is "both content specific and classroom based;" that promotes inquiry-based learning in a structured sequence of ideas; and, supported by standards-based instruction and practice. Such PD will provide teachers with opportunities, for example, to study their students' work, test out new curriculum, and study a particular element of pedagogy or student learning in the content area. It is most often job embedded (i.e., situated in the classroom). (pp. 5-6)	All QuarkNet opportunities are content focused and are an integral part of the larger QuarkNet program whether a workshop, masterclass, e-Lab or something else (focused on specific content i.e., particle physics or more general physics). The Data Activities Portfolio (DAP) activities, content-specific instructional materials designed for classroom use, support QuarkNet opportunities and are designed for classroom use. Each activity encompasses standards-based instruction and practice; each aligns with specific Next Generation Science Standards science practices. Some instructional materials build skills necessary to support subsequent content area(s). The need for diversity and inclusion in physics is addressed through specific activities.
Active Learning	PD that addresses "*how* teachers learn as well as *what* teachers learn;" engages teachers directly in the practices they are learning, and is connected to teachers' classrooms and students; where teachers use "authentic artifacts, interactive activities and other strategies;" teachers engage as learners often engaging in the same activities that they are designing for their students; and, where learning opportunities reflect their own interests, needs and experience; and where reflection and inquiry are central. (p. 7)	QuarkNet provides opportunities for teachers to engage in QuarkNet as active learners. Active learning typically occurs through the engagement in DAP activities by teachers, experiencing these as students, during all nationally-led workshops, and during most center-led workshops. Teachers may try out Masterclass materials, as active learners, during a center meeting prior to implementing the activity with their students. At specific centers, teachers participate in on-going research projects as active researchers.
Collaboration	Seen as an important feature of well-designed PD programs where collaboration can span a host of configurations "from one-on-one or small group interactions to schoolwide collaborations to exchanges with other professionals beyond the school." (p. 9)	QuarkNet provides a full array of opportunities to collaborate whether one-on-one engagement between teachers; working in small groups while engaged in an activity; or collaborating between centers. Teachers become familiar with large, international collaborations through physics talks and activities such as virtual tours of the experiments at CERN. Teachers exchange ideas with other teachers or fellows on classroom implementation, including the necessary collaboration to conduct very large particle physics experiments. QuarkNet encourages teachers to share their QuarkNet opportunities, such as participating in Data Camp or a visit to CERN, with teachers upon their return to the center.
Use of Models and Modeling	PD that uses models of effective practice, where "curricular and instructional models and modeling of instruction help teachers have a vision of practice on which to anchor their own learning and growth." (p. 11)	QuarkNet supports professional development by focusing on cutting-edge particle physics and by modeling the instructional practices that teachers are encouraged to use in their classroom, supported with standards-based instructional materials. Workshop facilitators and QuarkNet staff support these practices using standards-based instructional materials found in the DAP. Teachers engage in QuarkNet as active participants with ample time for reflection, feedback, and collaborations with others.

Table 1 (con't.)
Brief Description of Characteristics of Effective Professional Development (PD)
Identified by Darling-Hammond, Hyler and Gardner (2017) and What Happens in QuarkNet

Characteristic of Effective PD	Brief Description	What Happens in QuarkNet
Coaching and Expert Support	PD where experts help "to guide and facilitate teachers learning in the context of their practice" by "employing professional learning strategies" "such as modeling strong instructional practices, supporting group discussions," "share expertise about content and evidence-based practices;" "sharing their knowledge as workshop facilitators." Experts can range from "specially-trained master teachers and instructional leaders to research and university faculty." (pp.12-13)	There are a variety of ways in which QuarkNet draws on expert support, by a teacher reaching out to a mentor, to another teacher, to a lead teacher, fellow, or QuarkNet staff teacher. Often, these opportunities are a designated part of a workshop or a meeting as documented in the agenda. Opportunities can occur more informally such as through emails and one-on-one conversations as needed by individual teachers. QuarkNet encourages teachers to develop and practice leadership skills. These skills are fostered through specific workshops to help lead-teachers and fellows define their role, including how/and in what ways they can contribute to workshops. Lead teachers are encouraged and supported in coordinating logistics, serving as facilitators, or in giving presentations. Fellows are encouraged and supported in developing agendas and in facilitating and leading workshops. Fellows and, at times, teachers are encouraged and supported to present at local, regional, and national professional conferences.
Feedback and Reflection	Effective PD incorporates two distinct practices feedback and reflection -- that are seen as "powerful tools" and each of which are "critical components of adult learning theory." Effective PD provides "built-in time for teachers to think about, receive input on, and make changes to their practice by provides intentional time for feedback and/or reflection." (p.14)	Specific time is allocated during workshops and other QuarkNet opportunities for meaningful discussions based on the needs of teachers. Often, these sessions or opportunities focus on ways to incorporate QuarkNet content or instructional materials into the classroom. Teachers have time to reflect "as students" followed by a debriefing at the end of an activity after their engagement. A significant portion of nationally-led workshop agendas is devoted to the development of implementation plans by teachers. Feedback can come from other teachers who have implemented a particular activity or from workshop facilitators. Other opportunities to exchange ideas can occur through "share-a-thon' sessions, which can include QuarkNet and other resources. For example, QuarkNet Educational Discussions (QED) started during COVID to provide a small-group forum for teachers to discuss issues related to online teaching and the return to the classroom. This has evolved to a more general discussion and support group forum.
Sustained Duration	"(M)eaningful professional learning requires time and quality implementation." Effective PD is sustained, providing multiple opportunities for teachers to engage in learning around a single set of concepts or practices; providing the time necessary for learning that is rigorous and cumulative. (p. 15)	Typically, centers have been involved in QuarkNet for many years and individual teachers within centers continue to meet over many years. These efforts are wrapped in a larger program. Centers may meet annually, and some meet throughout the school year. Engagement may include: a workshop, a masterclass, and/or using cosmic ray detectors to collect and analyze data. QuarkNet offers many opportunities for teachers to engage, and the teacher (and the center) can select, from among these, opportunities that best fit the teachers or center needs. Not all centers or teachers engaged in the full spectrum of QuarkNet opportunities, but the center serves to build a supportive network of teachers, nonetheless. For example, teachers are supported through team building, networking, and supporting the social needs (e.g., sharing stories) of participating teachers.

Sources. Column two presents direct quotes and paraphrases descriptions proffered by Darling-Hammond, Hyler & Gardner (2017). The program descriptions of QuarkNet presented in column three were prepared by the QuarkNet PI, QuarkNet staff, and the evaluator (Roudebush, Bardeen, Cecire, Woods, LaMee, Pasero, Adams, Hoppert and Race). It is intended to provide a representative picture of the current program relative to these characteristics.

Program's Alignment with NGSS Standards

Clearly the QuarkNet program predated the release of the Next Generation Science Standards (1999 versus 2013). That said inquiry, specifically guided inquiry, and a claims-evidence-reasoning approach (McNeill & Krajcik, 2008) were evident as foundational to the program reflected in both its implementation and instructional materials before the emergence of these standards. To reflect both current thinking about best practices in the instruction of science and the implementation model embedded in the program, the Science and Engineering Practices of the NGSS (April 2013) were explicitly stated as program anchors in the PTM. The eight practices are:

1. Asking questions (for science) and defining problems (for engineering).
2. Developing and using models.
3. Planning and carrying out investigations.
4. Analyzing and interpreting data.
5. Using mathematics and computational thinking.
6. Constructing explanations (for science) and designing solutions (for engineering).
7. Engaging in argument from evidence.
8. Obtaining, evaluating, and communicating information.

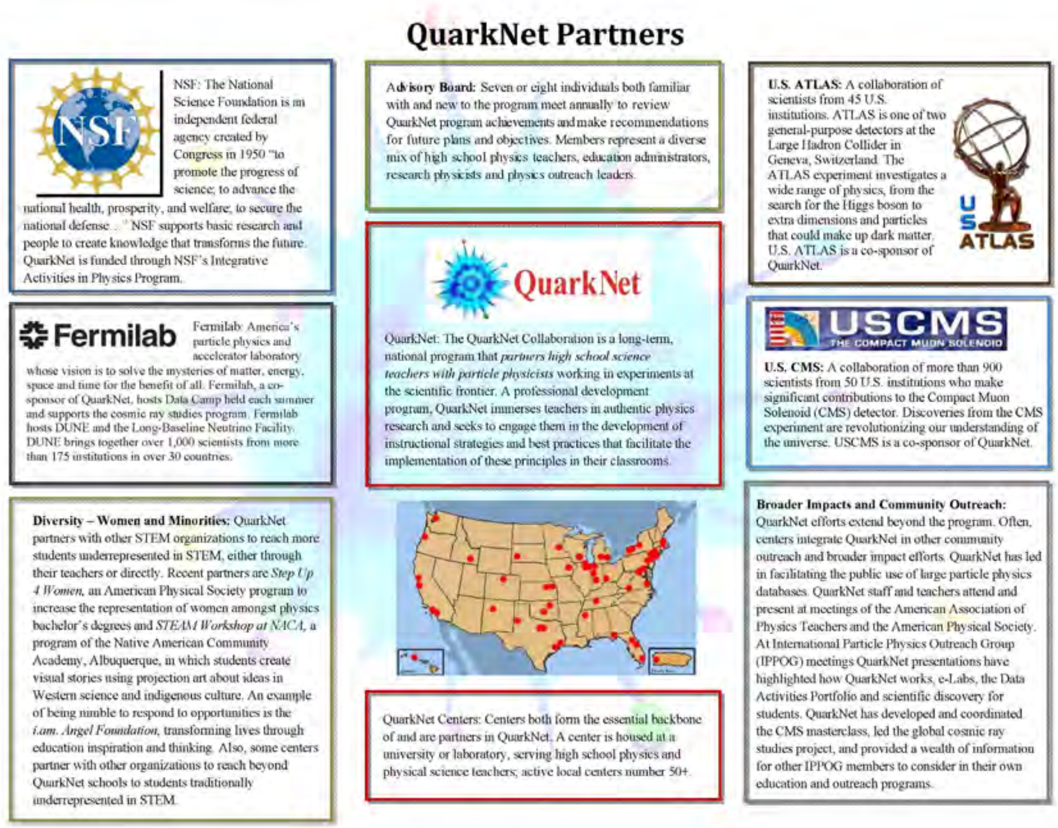
As important, Crosscutting Concepts (NGSS) were included as well. These are:

1. Patterns
2. Cause and Effect
3. Scale, Proportion and Quantity
4. Systems and System Models
5. Energy and Matter in Systems
6. Structure and Function
7. Stability and Change of Systems (see NGSS at https://www.nextgenscience.org)

Program's Use of the Concept of Guided Inquiry

In the PTM and in the *implemented* program, guided inquiry is operationally defined using Herron's model of inquiry (Herron, 1971) as modified by Jan-Marie Kellow (2007). That is, as defined, guided inquiry is seen as to occur in situations where the teacher provides the problem or question; and for structured inquiry in situations where the teacher provides the problem and procedure. Further, as modified, in guided inquiry the solution is not already existing/known in advance and could vary from student to student. Students *either* investigate a teacher-presented question (usually open-ended) using student designed/selected procedures *or* investigate questions that are student formulated (usually open-ended) through a prescribed procedure (some parts of the procedure may be student/designed/selected).

In QuarkNet's case, it is likely that the teacher may be a mentor or lead/associate/staff teacher; and the student(s) -- may be participating teacher(s) engaged in active learning as students--; or, actual students engaged in activities from the Data Activity Portfolio.



QuarkNet Partners

NSF: The National Science Foundation is an independent federal agency created by Congress in 1950 "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense…" NSF supports basic research and people to create knowledge that transforms the future. QuarkNet is funded through NSF's Integrative Activities in Physics Program.

Fermilab: America's particle physics and accelerator laboratory whose vision is to solve the mysteries of matter, energy, space and time for the benefit of all. Fermilab, a co-sponsor of QuarkNet, hosts Data Camp held each summer and supports the cosmic ray studies program. Fermilab hosts DUNE and the Long-Baseline Neutrino Facility. DUNE brings together over 1,000 scientists from more than 175 institutions in over 30 countries.

Diversity – Women and Minorities: QuarkNet partners with other STEM organizations to reach more students underrepresented in STEM, either through their teachers or directly. Recent partners are *Step Up 4 Women*, an American Physical Society program to increase the representation of women amongst physics bachelor's degrees and *STEAM Workshop at NACA*, a program of the Native American Community Academy, Albuquerque, in which students create visual stories using projection art about ideas in Western science and indigenous culture. An example of being nimble to respond to opportunities is the *i.am. Angel Foundation*, transforming lives through education inspiration and thinking. Also, some centers partner with other organizations to reach beyond QuarkNet schools to students traditionally underrepresented in STEM.

Advisory Board: Seven or eight individuals both familiar with and new to the program meet annually to review QuarkNet program achievements and make recommendations for future plans and objectives. Members represent a diverse mix of high school physics teachers, education administrators, research physicists and physics outreach leaders.

QuarkNet: The QuarkNet Collaboration is a long-term, national program that *partners high school science teachers with particle physicists* working in experiments at the scientific frontier. A professional development program, QuarkNet 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.

QuarkNet Centers: Centers both form the essential backbone of and are partners in QuarkNet. A center is housed at a university or laboratory, serving high school physics and physical science teachers; active local centers number 50+.

U.S. ATLAS: A collaboration of scientists from 45 U.S. institutions. ATLAS is one of two general-purpose detectors at the Large Hadron Collider in Geneva, Switzerland. The ATLAS experiment investigates a wide range of physics, from the search for the Higgs boson to extra dimensions and particles that could make up dark matter. U.S. ATLAS is a co-sponsor of QuarkNet.

U.S. CMS: A collaboration of more than 900 scientists from 50 U.S. institutions who make significant contributions to the Compact Muon Solenoid (CMS) detector. Discoveries from the CMS experiment are revolutionizing our understanding of the universe. USCMS is a co-sponsor of QuarkNet.

Broader Impacts and Community Outreach: QuarkNet efforts extend beyond the program. Often, centers integrate QuarkNet in other community outreach and broader impact efforts. QuarkNet has led in facilitating the public use of large particle physics databases. QuarkNet staff and teachers attend and present at meetings of the American Association of Physics Teachers and the American Physical Society. At International Particle Physics Outreach Group (IPPOG) meetings QuarkNet presentations have highlighted how QuarkNet works, e-Labs, the Data Activities Portfolio and scientific discovery for students. QuarkNet has developed and coordinated the CMS masterclass, led the global cosmic ray studies project, and provided a wealth of information for other IPPOG members to consider in their own education and outreach programs.

Exhibit A. The first page of the PTM highlighting key partners and outreach efforts.

In summary, information from these sources were culled into drafts of the PTM; and, shared and revised during iterative meetings with the PIs and key stakeholders until agreement was reached on the content of its component parts. Once the narrative of the PTM was agreed upon, a detailed, graphic presentation was created. (As already stated, this process is summarized in more detail in Appendix B.)

QuarkNet Program Theory Model

In its fully articulated form, the PTM describes the QuarkNet program *as designed* (as already stated). The model identifies program strategies framed within the specific program structure and components and seeks to describe how outcomes logically link to the program. In the model, a program statement, program centers, program goals, assumptions/core values, participant selection and key program components including anchors, the program's structure, core strategies and program outcomes are stated or described. In addition, enduring understandings and a sustainability framework are included.

<u>The PTM</u>

The first two pages of the PTM are presented here (Exhibit A above; and Exhibit B, next page); the full model is shown in Appendix C. These first two pages serve as an

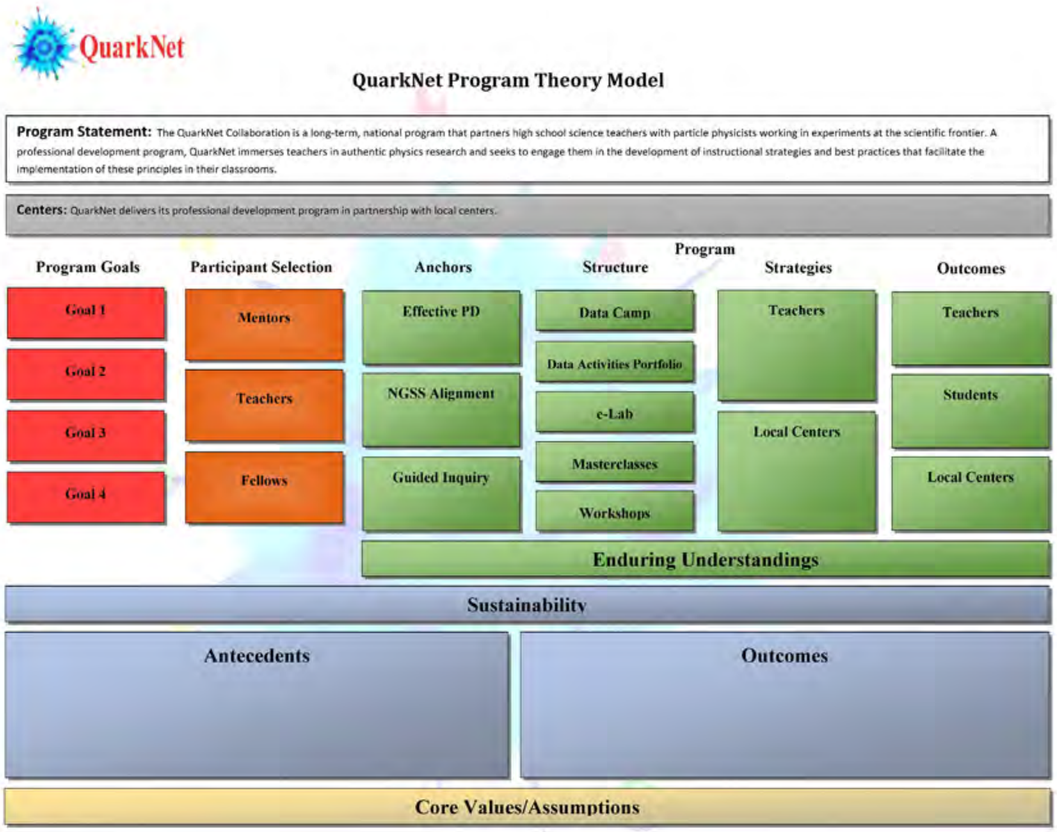


Exhibit B. The second page of the PTM which over views its component parts.

abbreviated version of the model and may be very useful depending upon the audience. The first page of the model presents the context in which the program operates identifying active partners and acknowledges the oversight responsibility of the program's Advisory Board. It also highlights additional outreach efforts associated with the program that extend beyond the program's core. The second page of the PTM provides a schematic overview of the program "a map" of the elements of the model suggesting how each may relate to the other. (Graphics created by L. Hudson.)

The details reflected in the PTM are at the strategic level and are deliberatively not activity specific. The intent is to capture ideas core to the program or "its big ideas" as well as the supportive structure of the program in which these strategies are embedded. The component, *Enduring Understandings,* previously developed and recently revised by Young, Bardeen, Roudebush, Smith and Wayne (2019), was included in the PTM because it succinctly describes expectations about understandings -- that are core to the program and reflective of particle-physics science practices and good science practices in general. Ultimately, the PTM can be viewed as a "blueprint" as to how change is expected to happen through the program's underlying components and strategies (DuBow & Litzler, 2019).

At the program level, the information presented in the PTM is not intended to be prescriptive; an in-depth look at the program would likely be supported (and is) with other information; for example, details about the sequencing of Data Activities Portfolio activities and highlighting how these instructional materials align with other science standards such as AP or IB Physics Science Standards.

Who is the Audience*?* The audience for the PTM is someone who is or is not familiar with QuarkNet and who has an interest in or a stake in the program. The abbreviated model is likely to have the widest audience; an audience who may include individual teachers, mentors, participating centers, future funders, among others.

Details in the PTM regarding program strategies and its structure are offered as a guide for the stakeholders responsible for these program components and to help in program operations and revisions; and, to help guide reflections or assessments as to whether or not the program *as implemented* is aligned with the program *as designed* (i.e., its theory). For the external evaluator, the PTM has directed the outcomes-based evaluation.

Program Structure of QuarkNet

The structure of the QuarkNet program includes specific and varied program events that are part of the national and center-level program. The key program structure includes:

Data Camp

Data Camp is a 1-week program offered annually in the summer at Fermilab. It is an introductory workshop for teachers of physics and physical science who either have had little-to-no experience with particle physics and/or who have had little experience with quantitative analysis of LHC (Large Hadron Collider) data. The camp emphasizes an authentic data analysis experience, in which the teachers are expected to engage as students as active learners of a challenging topic they may initially have known very little about. In the beginning of the week, teachers receive an authentic CMS (Cosmic Muon Soleniod) dataset and work in small groups to analyze the dataset. Groups use these data to determine the mass of particles produced during LHC proton-proton collisions. Successful completion of this phase of the workshop culminates in each group presenting and explaining their data. Then, teachers explore various instructional materials in the Data Activities Portfolio (to be explained shortly) that offer them help in incorporating particle physics concepts into their everyday lessons and propose an implementation plan for their classrooms. Throughout the week, teachers take tours (e.g., LINAC tunnel, MINOS experiment) and participate in seminars held by theoretical and experimental physics.

It should be noted that because of the hands-on, in-person necessity of Data Camp during the 2020 and again in the 2021 program years, Data Camp was replaced with Coding Camp. This will be described in more detail shortly.

e-Lab

e-Lab is a browser-based online platform in which students can access and analyze data in a guided-inquiry scientific investigation. An e-Lab provides a framework and pathway as well as resources for students to conduct their own investigations. e-Lab users share results through online plots and posters. In the CMS e-Lab, data are available from the CMS experiment at CERN2's LHC. In the Cosmic Ray e-Lab, users upload data from QuarkNet cosmic ray detectors located at high schools, and once uploaded, the data are available to any and all users [CERN, Conseil Européen pour la Recherche Nucléaire].

Masterclass: U.S. Model

In the U.S. Model, Masterclass is a one-day event in which students become "particle physicists for a day." Teachers and mentors participate in an orientation by QuarkNet staff or fellows. Teachers implement about three hours of classroom activities prior to a masterclass. Then, during the masterclass that usually takes place at a center, mentors introduce students to particle physics and explain the measurements they will make using authentic particle physics data. Working in pairs, students are expected to analyze the data in visual event displays; to characterize the events; pool their data with peers; and draw conclusions, helped by one or more particle physicists and their teacher. At the end of the day, students may gather by videoconference with students at other sites to discuss results with moderators at Fermilab or CERN. Some masterclasses take place at schools with teachers providing the particle physics and measurement information. U.S. Master-classes are part of a larger program, International Masterclasses.

Workshops

The primary vehicle through which participating QuarkNet teachers receive professional development are workshops conducted through the national program or at the center level.

Center-run Workshops**.** A center's second year involves new associate teachers in a multi-week experience that focuses on a research scenario prepared by their mentor(s) with support from lead teacher(s). The mentor models research, similar to Data Camp, -- teachers, as students and active learners, have an opportunity to engage in an experiment, receive and analyze data, and present results. Then teachers have time to create a plan to share their experiences with their students and often use instructional materials from the Data Activities Portfolio in this planning.

During a center's third year and after, lead teacher(s) and mentor(s) have flexibility to organize 4-to-5-day workshops to meet local needs and interests. These workshops vary in content and structure. Centers may meet only during the summer, only during the school year or both during the summer and school year. Some centers meet even more frequently depending upon interest and availability of teachers. These workshops may include a national workshop and offer a learning-community environment with opportunities for teachers to interact with scientists and learn and share ideas related to content and pedagogy.

National Workshops. On request, QuarkNet staff and/or fellows conduct workshops held at local centers. These workshops typically occur during the summer and can vary in length from several days to a week period. Content includes, for example, cosmic ray studies, LHC or neutrino data, and related instructional materials from the Data Activities Portfolio. National workshops also support opportunities for teachers to work in a learning-community environment, learn and share ideas related to content and pedagogy, and develop classroom implementation plans (PTM, 2019).

COVID Program Modifications. Most implemented 2020 QuarkNet programs (and to some extent 2021 programs) were modified in structure and/or content and held in virtual environments because of COVID. Only a very few workshops were held face-to-face during this program year. These occurred very early in the calendar year or later in the year when socially-distant teachers could meet outdoors in a very limited capacity.

Regarding modifications, for example, Data Camp which is typically a very hands-on program experience at Fermilab with on-site tours was revised as a "Coding Camp." In 2020, this consisted of two, 1-week sessions on Zoom where two groups of 12 teachers concentrated on coding CMS data using Jupyter and Python platforms. This effort led to pilot testing a Coding Workshop implemented in 2021; and additional workshops were held in 2022.

An adaptation of the current CMS masterclass was created in 2020 (that is, BAMC Big Analysis of Muons in CMS) such that students could engage in a masterclass experience while working remotely. Measurement was simplified measuring only muons and online support was ramped up by user screen casts and intensified communication with teachers. Workshops held in 2020, and some in 2021, occurred over Zoom were often modified as half-day events spread over 1 to 2 days (or more) to help reduce online instruction fatigue and to give teachers time to engage in off-line exercises either alone or in working groups online at designated times. Often, the scope of the instructional content was reduced as well to better support learning/sharing in a virtual environment.

Data Activities Portfolio

The Data Activities Portfolio (DAP) is an online compendium of particle physics classroom instructional materials organized by Data Strand, Level of student engagement, Curriculum Topics and NGSS standards (https://quarknet.org/data-portfolio). This compendium is an important component of the program connected to the national program's Data Camp as well as to other national and center-run workshops and programs where teachers have opportunities to explore these sequenced lessons and to develop classroom implementation plans. These instructional materials are based on authentic experimental data used by teachers to give students an opportunity to learn how scientists make discoveries. Strands include LHC, CMS, Cosmic Ray Studies, and neutrino data. Curriculum topics include, for example, activities related to conservation laws; and, electricity and magnetism. Activities increase in complexity, sophistication and expected student engagement from Levels 0 to 4 (a new level 4 activity has been added to the mix). Draft instructional materials are reviewed by QuarkNet staff based on specified instructional design guidelines and are aligned with NGSS, IB, and AP science standards (Physics 1 and Physics 2) as relevant.

Table 2
Data Activities Portfolio: Level Definitions

Level	Description of Expected Student Engagement
0	Students build background skills and knowledge needed to do a Level 1 activity. Students analyze one variable or they determine patterns, organize data into a table or graphical representation and draw qualitative conclusions based on the representation of these data.
1	Students use background sills developed in Level 0. They calculate descriptive statistics, seek patterns, identify outliers, confounding variables, and perform calculations to reach findings; they may also create graphical representations of the data. Datasets are small in size. The data models come from particle physics experimentation.
2	Students use skills from Level 1 but must apply a greater level of interpretation. The analysis tasks are directed toward specific investigations. Datasets are large enough that hand calculation is not practical, and the use of statistics becomes central to understanding the physics. They perform many of the same analysis tasks but must apply a greater level of interpretation.
3	Students use the skills from Level 2. They develop and implement a research plan utilizing large datasets. They have choices about which analyses they do and which data they use; they plan their own investigations.
4	Students use the skills from Level 3. They identity datasets and develop code for computational analysis tools for the investigation of their own research plan.

Note: A new Level 4 activity has been added into the mix. (D. Roudebush, 2023)

Through guidance from teachers, students are provided the opportunities shown in Table 2, which shows five instructional levels of these instructional materials; (level 0 and level 4 are new to this award period). Masterclasses and e-Labs offer additional options at levels 3 and 4 with project maps offered as guidance for Masterclass implementations. By selecting activities from across available levels, teachers can develop a sequence of lessons or activities appropriate for their students and to help build student skills-sets by moving from simple to more complex. Teachers can also search for activities by a specific NGSS Practice or across all applicable practices.

Linking Program Strategies to Outcomes

The principal intent of the PTM is to logically link core strategies to program outcomes. Tables 3 and 4 reflect this alignment, first by showing the alignment of program anchors, -- that is, effective professional development, NGSS standards and guided inquiry, -- with core strategies (Table 3). This table (and this section of the PTM) presents the grounding of these program strategies as suggested by the educational research literature.

The overarching strategy of the program is the recognition that QuarkNet is not static but evolves to reflect changes in particle physics and the education context in which it operates. Two big-picture strategies relate to opportunities for teachers to be exposed to instructional strategies that model active, that is, guided-inquiry learning, and big ideas in science and enduring understandings. Strategies directed toward teachers include: *Engage as active learners, as students;* and, *Discuss the concept of uncertainty in particle physics.* There are two strategies relate to local centers, these are: *Interact with other*

Table 3. QuarkNet: Aligning Program Anchors and Core Strategies

<table>
<tr><th>Program Anchors: Effective Professional Development and Best Practices</th><th>Core Strategies: What Happens in QuarkNet?</th></tr>
<tr><td>
Characteristics of Effective Professional Development[1]

Is content focused
Incorporates active learning utilizing, adult learning theory
Supports collaboration, typically in job-embedded contexts
Uses models and modeling of effective practice
Provides coaching and expert support
Offers opportunities for feedback and reflection
Is of sustained duration.

[1]Darling-Hammond, L., Hyler, M.E., & Gardner, M. (2017, June). Effective teacher professional development. Palo Alto, CA: Learning Policy Institute.
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<td rowspan="2">
QuarkNet is not static but evolves to reflect changes in particle physics and the education context in which it operates.

Teachers
Provide opportunities for teachers to be exposed to:

Instructional strategies that model active, guided-inquiry learning (see NGSS science practices).
Big Idea(s) in Science (cutting-edge research) and Enduring Understandings (in particle physics).

Provide opportunities for teachers to:

Engage as active learners, as students.
Do science the way scientists do science.
Engage in authentic particle physics investigations (that may or may not involve phenomenon known by scientists).
Engage in authentic data analysis experience(s) using large data sets.
Develop explanations of particle physics content.
Discuss the concept of uncertainty in particle physics.
Engage in project-based learning that models guided-inquiry strategies.
Share ideas related to content and pedagogy.
Review and select particle physics examples from the Data Activities Portfolio instructional materials.
Use the pathways, suggested in the Data Activities Portfolio, to help design implementation plan(s).
Construct classroom implementation plan(s), incorporating their experience(s) and Data Activities Portfolio instructional materials.
Become aware of resources outside of their classroom.

Local Centers (Each center seeks to foster lasting relationships through collaboration at the local level and through engagement with the national program.)

In addition, through sustained engagement provide opportunities for teachers and mentors to:

Interact with other scientists and collaborate with each other.
Build a local (or regional) learning community.

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Pedagogical and Instructional Best Practices
Aligns with the Science and Engineering Practices of the NGSS APPENDIX F – Science and Engineering Practices in the NGSS (2013, April). As suggested, these practices are intended to better specify what is meant by inquiry in science. https://www.nextgenscience.org

Asking questions (for science) and defining problems (for engineering).
Developing and using models.
Planning and carrying out investigations.
Analyzing and interpreting data.
Using mathematics and computational thinking.
Constructing explanations (for science) and designing solutions (for engineering).
Engaging in argument from evidence.
Obtaining, evaluating, and communicating information.

Content addresses Disciplinary Core Ideas and Crosscutting Concepts (NGSS):

Patterns
Cause and Effect
Scale, Proportion and Quantity
Systems and System Models
Energy and Matter in Systems
Structure and Function
Stability and Change of Systems

Guided Inquiry
Guided inquiry (teacher provides problem or question) and Structured inquiry (where teacher provides problem and procedure) [Herron, M.D. (1971). The nature of scientific enquiry. School Review, 79(2), 171- 212.] Guided Inquiry - The solution is not already existing/ known in advance and could vary from student to student. Students EITHER investigate a teacher-presented question (usually open-ended) using student designed/selected procedures OR investigate questions that are student formulated (usually open-ended) through a prescribed procedure (some parts of the procedure may be student designed/ selected). (2007 Jan-Marie Kellow)]
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Table 4. QuarkNet: Aligning Core Strategies and Program Outcomes

Core Strategies: What Happens in QuarkNet?	Program Outcomes
QuarkNet is not static but evolves to reflect changes in particle physics and the education context in which it operates. ***Teachers:*** *Provide opportunities for teachers to be exposed to:* • Instructional strategies that model active, guided-inquiry learning (see NGSS science practices). • Big Idea(s) in Science (cutting-edge research) and Enduring Understandings (in particle physics). *Provide opportunities for teachers to:* • Engage as active learners, as students. • Do science the way scientists do science. • Engage in authentic particle physics investigations (that may or may not involve phenomenon known by scientists). • Engage in authentic data analysis experience(s) using large data sets. • Develop explanations of particle physics content. • Discuss the concept of uncertainty in particle physics. • Engage in project-based learning that models guided-inquiry strategies. • Share ideas related to content and pedagogy. • Review and select particle physics examples from the Data Activities Portfolio instructional materials. • Use the pathways, suggested in the Data Activities Portfolio, to help design implementation plan(s). • Construct classroom implementation plan(s), incorporating their experience(s) and Data Activities Portfolio instructional materials. • Become aware of resources outside of their classroom. **Local Centers** (Each center seeks to foster lasting relationships through collaboration at the local level and through engagement with the national program.) *In addition, through sustained engagement provide opportunities for teachers and mentors to:* • Interact with other scientists and collaborate with each other. • Build a local (or regional) learning community.	**Teachers** *Translate their experiences into instructional strategies, which reflect guided inquiry and NGSS science and engineering practice and other science standards as applicable. Specifically:* • Discuss and explain concepts in particle physics. • Engage in scientific practices and discourse. • Use particle physics examples, including authentic data, when teaching subjects such as momentum and energy. • Review and use instructional materials from the Data Activities Portfolio, selecting lessons guided by the suggested pathways. • Facilitate student investigations that incorporate scientific practices. • Use active, guided-inquiry instructional practices in their classrooms that align with NGSS and other science standards. • Use instructional practices that model scientific research. • Illustrate how scientists make discoveries. • Use, analyze and interpret authentic data; draw conclusions based on these data. • Become more comfortable teaching inquiry-based science. • Use resources (including QuarkNet resources) to supplement their knowledge and instructional materials and practices. • Increase their science proficiency. • Develop collegial relationships with scientists and other teachers. • Are life-long learners. **(And their) Students will be able to:** • Discuss and explain particle physics content. • Discuss and explain how scientists develop knowledge. • Engage in scientific practices and discourse. • Use, analyze and interpret authentic data; draw conclusions based on these data. • Become more comfortable with inquiry-based science. **Local Centers** • Model active, guided-inquiry instructional practices that align with NGSS and other science standards that model scientific research. *Through engagement in local centers* ***Teachers as Leaders:*** • Act in leadership roles in local centers and in their school (and school districts) and within the science education community. • Attend and/or participate in regional and national professional conferences sharing their ideas and experiences. ***Mentors:*** • Become the nexus of a community that can improve their teaching, enrich their research and provide broader impacts for their university. ***Teachers and Mentors:*** • Form lasting collegial relationships through interactions and collaborations at the local level and through engagement with the national program.

scientists and collaborate with each other; and, *Build a local (or regional) learning community*. More will be said about centers latter in this report.

Table 4 shows the logical links between core strategies and program outcomes. As shown, these outcomes are organized by "target audience," including Teachers, their Students, and Local Centers. Of importance, teacher outcomes are directed toward how teachers translate their experiences into instructional strategies, which reflect guided inquiry and NGSS science and engineering practices and other science standards such as AP; as applicable and to the extent possible in their school setting. These outcomes include: *Discuss and explain concepts in particle physics;* and, *Use instructional practices that model scientific research.* Outcomes directed toward their students include: *Use, analyze and interpret authentic data; draw conclusions based on these data.*

Outcomes directed toward local centers include Teachers as Leaders, such as: *Act in leadership roles in local centers and in their school (and school districts) and within the science education community.* There are outcomes directed toward Mentors, such as: *Become the nexus of a community that can improve their teaching, enrich their research and provide broader impacts for their university*; and Teachers and Mentors such as: *Form lasting collegial relationships through interactions and collaborations at the local level and through engagement in the national program.*

As will be seen in subsequent sections of this report, program outcomes directed toward teachers are measured by a Full Teacher Survey (or subsequently a short update) distributed on an annual basis. And program outcomes related to mentors and interactions between mentors and teachers are captured in a Center Feedback Template (as well as sustainability outcomes). The Center Feedback Template serves a dual-role, to provide the context in which teachers receive the implemented program; and, to serve as a center-level outcome measure in its own right. These principal evaluation measures are supported, for example, by links to program operations data such as implemented workshop agendas and implementation plans developed by participating teachers (when available). In addition, the external evaluator conducts virtual visits of workshop discussions by teachers on proposed implementation plans and how QuarkNet content and materials may be used in their classrooms.

Finally, it is important to note that the designed and ultimately the implemented program are strategy-based in part because of the recognized need for flexibility in conducting workshops and events across 50+ centers (currently 52 centers). Program strategies offer guidelines and guard rails encouraging program versatility within these. There is not a prescriptive "recipe" of specific workshops/events and classroom activities but rather a family of workshop options and classroom-activities engagement (first by teachers and then their students through the Data Activities Portfolio) that can be implemented. Strategies increase the likelihood of providing teachers with professional development that reflects their individual -- as well as center -- needs and at the same time provide a framework that aligns with effective practices reflected in the educational research literature.

Enduring Understandings

Table 5 presents the Enduring Understandings of Particle Physics developed by Young, Bardeen, Roudebush, Smith and Wayne (originally in 2015 and revised in 2019). These were incorporated into the PTM because of their fundamental relevance to expected understandings of big ideas associated with participation in QuarkNet; and, because these are integral to the design and implementation of instructional materials contained in the Data Activities Portfolio.

Accordingly, these Enduring Understandings are in keeping with Wiggins and McTighe's (2005), *Understanding by Design*, who describe backward design as a three-stage process in which the teacher first identifies the desired results; then determines what would count as evidence to determine whether or not the students did or did not reach those results; and then designs the learning experience around these desired results and evidence. In this way, Wiggins and McTighe recommended four criteria, i.e., to what extent does the idea, topic or process:

1. Represent a "big idea" having enduring value beyond the classroom?
2. Reside at the heart of the discipline?
3. Require uncoverage?
4. Offer potential for engaging students?

Sample (2011) noted that uncoverage implies depth over breath; determining how much material to cover; how deep to go and how deeply to dig down into core principles or processes of a given discipline to gain a lasting understanding. Thus, *enduring understanding*s are defined as "statements summarizing important ideas and core processed that are central to a discipline and have lasting value beyond the classroom. They synthesize what students should understand – not just know or do – as a result of studying a particular content area." (Wiggins and McTighe, 2003; http:/Enduring Understandings | iTeachU (uaf.edu)]

Sustainability Framework

Atypical of PTM's, a sustainability framework has been included. Its inclusion seems particularly warranted given the longevity of the program, and the multiple centers that serve as partners and the "essential backbone" of the program. Of importance, this framework is intended to help us think about sustaining a program beyond its funding period – asking how and in what ways this may be possible and to what end. This framework, shown in Table 6, is based on the work of Scheirer and Dearing (2011) and has been modified as recommended by Schierer, Santos, Tagai, Bowie, Slade, Carter and Holt (2017) to better reflect the QuarkNet program. We have adopted Scheirer and Dearing's definition as well, "Sustainability is the continued use of program components and activities for the continued achievement of desirable program and populations outcomes" (2011, p.2060).

Table 5
Enduring Understandings of Particle Physics

1. Scientists make a claim based on data that comprise the evidence for the claim.
2. Scientists use models to make predictions about and explain natural phenomena.
3. Scientists can use data to develop models based on patterns in the data.
4. Particle physicists use data to determine conservation rules.
5. Indirect evidence provides data to study phenomena that cannot be directly observed.
6. Scientists can analyze data more effectively when they are properly organized; charts and histograms provide methods of finding patterns in large datasets.
7. Scientists form and refine research questions, experiments and models using patterns in large data sets.
8. The Standard Model[1] provides a framework for our understanding of matter at its most fundamental level.
9. The fundamental particles are organized according to their characteristics in the Standard Model[1].
10. Particle physicists use conservation of energy and momentum to measure the mass of fundamental particles.
11. Fundamental particles display both wave and particle properties, and both must be taken into account to fully understand them.
12. Particle physicists continuously check the performance of their instruments by performing calibration runs using particles with well-known characteristics.
13. Well-understood particle properties such as charge, mass, momentum and energy provide data to calibrate detectors.
14. Particles that decay do so in a predictable way, but the time for any single particle to decay, and the identity of its decay products, are both probabilistic in nature.
15. Particle physicists must identify and subtract background events in order to identify the signal of interest.
16. Scientists must account for uncertainty in measurement when reporting results.

Note. Developed by Young, Bardeen, Roudebush, Smith & Wayne, 2019
[1]The Standard Model of Particle Physics: the current theoretical framework that describes elementary particles and their forces (six leptons, six quarks and four force carriers). Physicists (and other scientists) can understand every phenomenon observed in nature by the interplay of the elementary particles and forces of the Standard Model. The search beyond the Standard Model of Particle Physics may lead to a larger, more elegant “theory of everything.”
(http://www.fnal.gov/pub/science/inquiring/matter/ww_discoveries/index.html)

Table 6
PTM: QuarkNet Sustainability Framework[a]

Antecedents	Outcomes
Characteristics of the Specific Program 1. Fidelity to PTM core strategies as implemented (national or center-level).[b] 2. Evidence of flexibility/adaptability at the center level (if/as needed). 3. Evidence of effectiveness. **Organizational Setting at the Center-level Program**[c] 1. (Good) fit of program with host's organization and operations. 2. Presence of an internal champion(s) to advocate for the program. 3. Existing capacity and leadership of the organization to support program. 4. Program's key staff or clients believe in the program (believe it to be beneficial). **Specific Factors Related to the Center-level Program** 1. Existing supportive partnerships of local organizations (beyond internal staff). 2. Potentially available/existing funders or funding. 3. Manageable costs (resources and personal; supported by volunteers).[d]	1. Program components or strategies are continued (sustained fidelity in full or in part).[e] 2. Benefits or outcomes for target audience(s) are continued.[e] 3. Local/center-level partnerships are maintained.[f] 4. Organizational practices, procedures and policies in support of program are maintained. 5. Commitment/attention to the center-level program and its purpose is sustained.[f] 6. Program diffusion, replication (in other sites) and/or classroom adaptation occur.[f]

[a]This framework is based on the work of Scheirer and Dearing (2011); adopting their definition of sustainability, as well: "Sustainability is the continued use of program components and activities for the continued achievement of desirable program and population outcomes" (p. 2060). The QuarkNet Sustainability Framework has been modified to better reflective the QuarkNet program (as recommended by Scheirer, et al., 2017). (See notes below.)
[b]Program fidelity, as *implemented*, has been added as a program characteristic.
[c]The language used to describe these organizational characteristics has been modified slightly to better fit the QuarkNet program.
[d]This cost component was moved to environmental or contextual concerns of the specific program.
[e]The order of these two outcomes are reversed from the original.
[f]The language of this characteristic was modified to better fit the QuarkNet program.

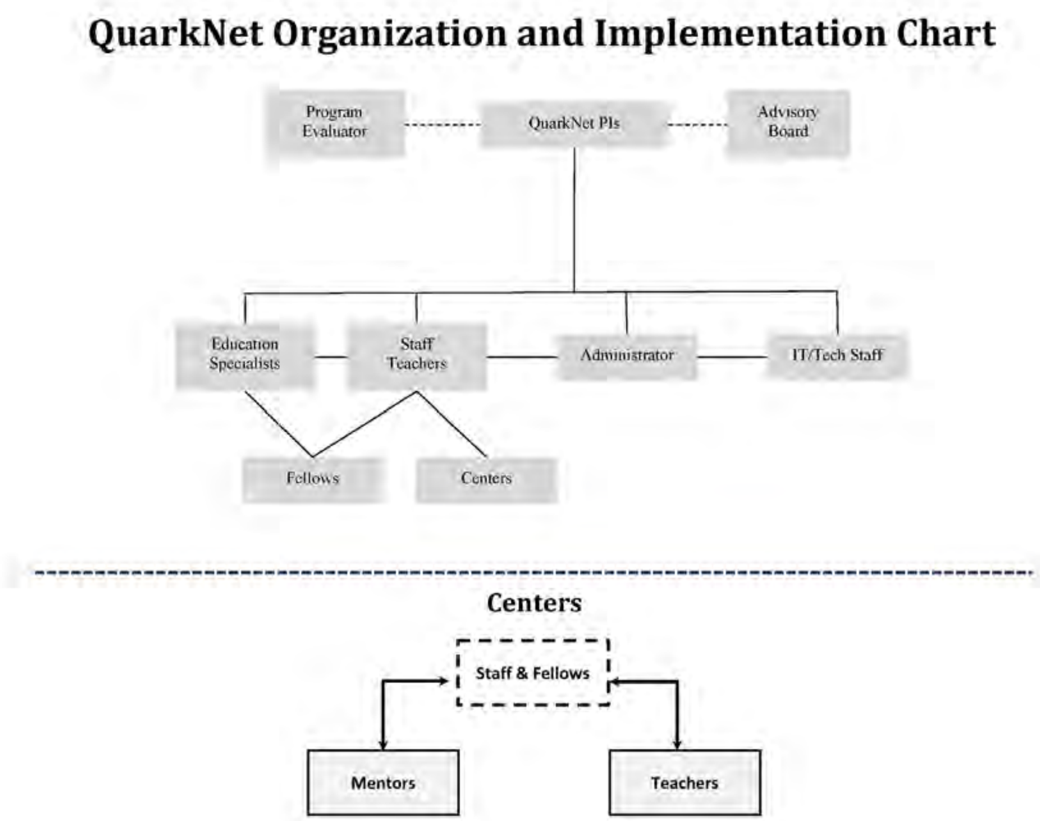


Figure 1. An overview of the organization and implementation of the QuarkNet Program.

Stated in a different way, the sustainability framework identifies long-term outcomes, often articulated in a PTM. At the same time, it attempts to distill the program components that might have the greatest influences on sustainability (referred to as antecedents).

As will be seen in subsequent sections of this report, the sustainability framework is used to guide the assessment of the engagement of centers in the QuarkNet program and how factors related to this activity may help in the longevity of the center's broader impacts. It may also serve to better illuminate the context in which teachers engage in the QuarkNet program.

Before embarking on a discussion of measured teacher-level and center-level outcomes and preliminary results, it is important to briefly highlight a picture of the *implemented* program.

Implementation of QuarkNet Program

An overview of the roles and responsibilities of key QuarkNet stakeholders is shown in Figure 1. Also shown is a depiction of a typical center that is comprised of a mentor(s) and teachers with support from QuarkNet staff and fellows. As already stated, these centers are housed at a university or laboratory; serving primarily teachers who live within reasonable commuting distances. Initially, mentors interested in QuarkNet submitted a proposed research project, identified a mentor team, and described previous outreach experience.

As part of the implementation of the QuarkNet program, staff members hold weekly meetings, that is, a staff-wide meeting focused on program-wide issues and discussions; meetings with IT QuarkNet developers focused on IT needs and updates; and a curriculum development team focused on workshop content and activity development of the Data Activities Portfolio (personal communication, email M. Bardeen, April 17, 2019). Although a long-standing component of the program's operational structure, these weekly meetings were especially helpful in discussing and planning program content and delivery modifications because of COVID. This was particularly noteworthy during the early spring of 2020 when it became evident that the United States and the world at large were dealing with a novel virus that grew into a pandemic with full national and international impact.

Centers

Typically, at centers, as already noted, program leaders include one or two physicists who serve as mentor(s) who team up with one or two lead teacher(s). Teachers, whether a lead teacher or participant, are high school physics or physical science teachers who express interest in QuarkNet and who may be invited to participate through staff, fellows, or mentor/center teachers. Mentors often know high school teachers who are good additions to their research teams and/or who may become lead teachers at the center. Fellows are teachers who are invited by staff to become fellows based on participants' experiences working with a local center or on national program such as Data Camp (PTM, 2019). Fellows may interact with any of the centers. As already stated, the primary vehicle through which participating QuarkNet teachers receive professional development is a workshop conducted through the national program or that is center run.

In an email distributed by the co-PIs (Wayne, Bardeen and Swartz, December 2018) and already noted, a center is operationally defined as active "if they provide at least one day of teacher development (not in a student workshop) and 'semi-active' if they and their teachers participate only in International Masterclasses, International Muon Week, World Wide Data Day, International Cosmic Day, or an equivalent activity which they indicate." (See Table 7.)

Data Activities Portfolio: Instructional Design and Review of Activities

Figure 2 shows the process used to develop and review activities for inclusion in the Data Activities Portfolio; this process follows the design recommendations by Wiggins and McTighe (2005) as already noted. This process has evolved since the start of QuarkNet; outlined in 2015, by Young, Roudebush and Bardeen; and later updated in 2019. Its intent is to help ensure the quality of developed activities; to align these with the science practices of NGSS; and to provide a standardized template and format. The complete document is shown in Appendix D along with the review protocol. Over the course of the QuarkNet program, the development (and review) of activities in the Data Activities Portfolio has been a dynamic process. This has included making sure that all activities, in particular older activities, were

Table 7
QuarkNet Centers through Program Years 2019-2023: 52 Total

Single or combined[a]	Center	Single or combined[a]	Center
1	Black Hills State University		~~University of California – Riverside~~
2	Boston/Brown University/ Northeastern University	1	University of California at Santa Cruz
2	Brookhaven National Laboratory/Stony Brook University	1	University of Cincinnati
1	The Catholic University of America	1	University of Florida
1	Colorado State University	1	University of Hawai'i
2	Fermilab/University of Chicago/College of DuPage	2	University of Illinois at Chicago/ Chicago State University
	~~Florida Institute of Technology~~	2	University of Iowa/Iowa State University
1	Florida International University	1	University of Kansas
1	Florida State University	1	University of Minnesota
1	Idaho State University	1	University of Mississippi
1	Johns Hopkins University	1	University of New Mexico
1	Kansas State University	1	University of Notre Dame
1	Lawrence Berkeley National Laboratory	1	University of Oklahoma
1	Northern Illinois University	1	University of Oregon
1	Oklahoma State University		~~University of Pennsylvania~~
1	Purdue University	1	University of Puerto Rico at Mayaguez
1	Purdue University Northwest		~~University of Rochester~~
1	Queensborough Community College	1	University of South Dakota
			~~University of Tennessee~~
2	Rice University/University of Houston	1	University of Washington
1	Rutgers University	1	University of Wisconsin –Madison
1	Southern Methodist University	1	Vanderbilt University
1	Syracuse University	1	Virginia Center (Hampton, George Mason, William & Mary Universities)
1	Texas Tech University	1	Virginia Tech
1	University of Alabama		
1	University at Buffalo – SUNY	1	Virtual Center
1	University of California -- Irvine		~~Wayne State University~~

[a]A center is noted as a combined center if two (or more) centers work together to hold a QuarkNet workshop or event. Combined centers receive additional funds to support more teachers and/or more days to hold these events. ~~Center~~ denotes a center that is no longer active (as of April 2023).

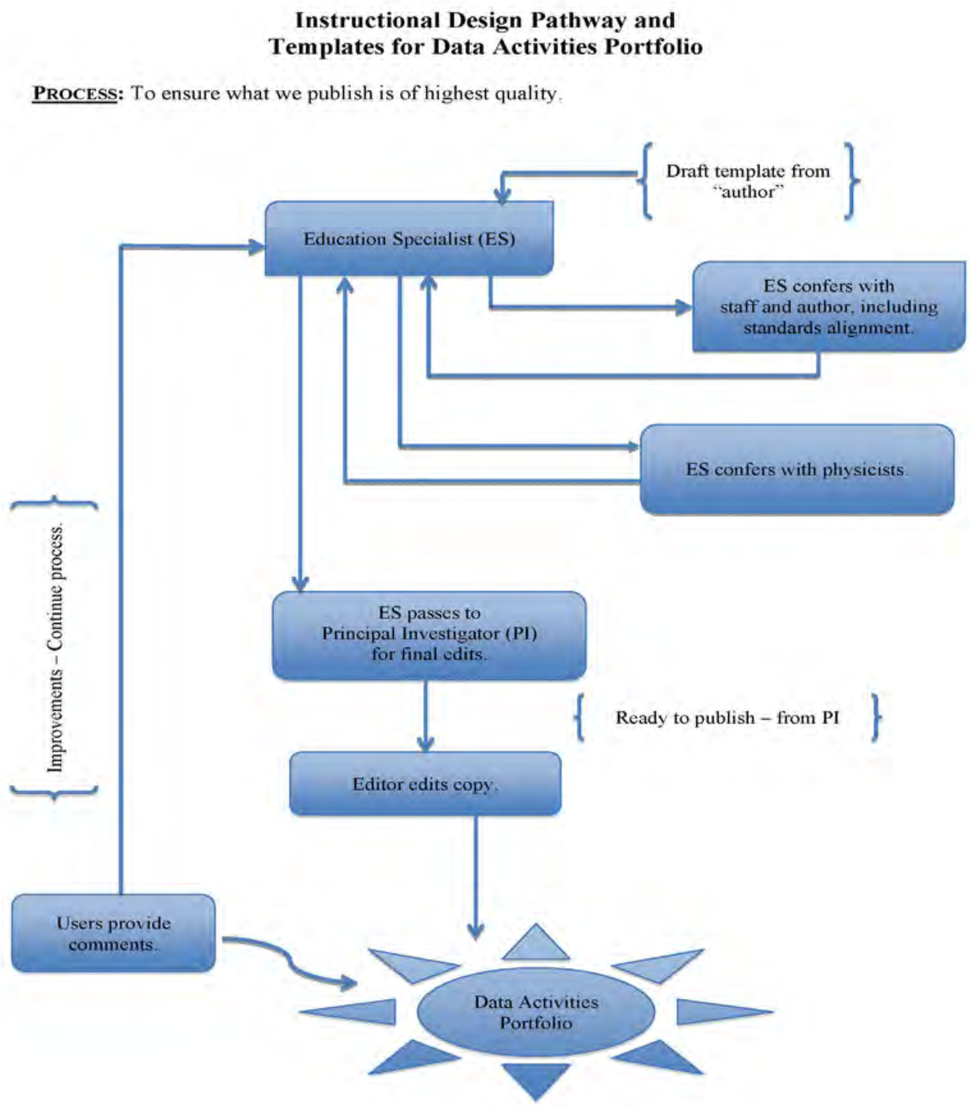


Figure 2. Instructional Design Pathway for Data Activities Portfolio (created by Young, Roudebush & Bardeen, 2019).

reviewed or re-reviewed before posting on the website; and that these aligned with the review guidelines just discussed. Other activities, for example, were split to accommodate either the required student-skills level (introducing level 0) or split because the content suggested the need for this (e.g., masterclasses split by data strand such as ATLAS Z-path or CMS-WZH-path). As the science (or availability of data) evolved, physicists helped to add activities (e.g., 3-D puzzle activity and creating a simulation) and to advise on existing ones. In addition, over the past two years, curriculum topics were created to help teachers envision and plan for sequencing lessons (and helping to ensure that their students develop the required skills-set). This effort revealed possible gaps in student skills-sets; thus, additional activities were created to help fill these gaps.

Current on-going efforts included the re-review of previously posted activities; filling in gaps for improved sequencing; developing neutrino materials; and creating activities at level 4. A brief history of the Data Activities Portfolio is highlighted in Appendix E.

Data Activities Portfolio: Activities, Masterclasses and e-Labs

The criteria used to determine the alignment of DAP activities with the Next Generation Science Standards: Science Practices (Appendix F, NGSS April 2013) are shown in Table 8.

Table 9 provides a list of the current activities in the Data Activities Portfolio (DAP); there are a total of 35 activities. This represents: 9 activities at Level 0; 13 activities at Level 1; 10 activities at Level 2; 2 activities at Level 3; and 1 activity at Level 4.

As noted, there are three activities that are not included in Table 9. These activities were developed through a partnership with STEP UP focused on Diversity and Inclusion. These activities are: QuarkNet: Changing the Culture (Level 0); QuarkNet STEP UP: Careers in Physics (Level 1); and QuarkNet STEP UP Women in Physics (Level 2). And, these three activities align with the NGSS All Standards, All Students" commitment to making NGSS accessible to all students (Appendix D, NGSS, April 2013).

This has brought the total of DAP activities to 38.

In comparison during the 2012-2017 program grant years, there were 14 activities at the conclusion of that time period. (See Exhibit C created by D. Roudebush, May 2023 and used with permission). Also shown in Exhibit D is a listing of DAP activities developed for online use, an effort that occurred during COVID to support these efforts during this turbulent period. Currently, five DAP activities have been translated into Spanish.

Table 8
Criteria Used to Align Data Activity Portfolio Activities with the
Science and Engineering Practices in the Next Generation Science Standards (NGSS)

NGSS Practice	Alignment Criteria (Provide opportunity for required/ recommended engagement by students)
1. Asking questions (for science) and defining problems (for engineering)	• Students must determine the problem for which questions and answers lead to solutions.
2. Developing and using models	• Students must use data to develop a qualitative or quantitative model that explains the data and predicts subsequent data.
3. Planning and carrying out investigations	• Students may receive a research question for which they must develop and carry out a plan for their own investigation. Or the students may receive preliminary data from which they develop and carry out a plan for their investigation.
4. Analyzing and interpreting data	• Students must either collect data or receive data which they analyze qualitatively or quantitatively.
5. Using mathematics and computational thinking	• Students must use mathematical techniques for interpreting graphs and histograms including linearization and correct histogram uncertainties.
6. Constructing explanations and designing solutions	• Students must gather and analyze data and report out either to their group, the teacher or the class.
7. Engaging in argument from evidence	• Students must justify their claims with evidence and reasoning that is derived from the data.
8. Obtaining, evaluating, and communicating Information	• Students must gather and analyze data and report out either to their group, the teacher or the class.

Criteria articulated by D. Roudebush and M. Bardeen August 18, 2020.

Table 9
Instructional Materials in the Data Activities Portfolio

Level	Activity	Data Strand	NGSS Practices
0	Mass of U. S. Pennies	Cosmic Ray, LHC	1,2,3,4,6,7,8
0	Quark Workbench 2D/3D	Cosmic Ray, LHC	1,2,4,6,7
0	Dice, Histogram and Probability	Cosmic Ray, LHC	1,2,3,4,5,6,7,8
0	Shuffling the Particle Deck	LHC	1,2,4,5,6,7
0	Mapping the Poles	LHC	2,4,6,7
0	Signal and Noise: The Basics	Cosmic Ray, LHC	4,5,6,7,8
0	Histograms: The Basics	Cosmic Ray, LHC, Neutrino	4,5,7
0	Making Tracks I	Cosmic Ray, LHC, Neutrino	1,2,4,6,7
0	Introduction to Coding Using Jupyter	Cosmic Ray, LHC, Neutrino	1,2,4
1	What Heisenberg Knew	Neutrino	2,4,5,6,7,8
1	The Case of the Hidden Neutrino	LHC, Neutrino	2,4,5,6,7
1	Making it ‘Round the Bend – Qualitative	LHC	1,2,3,4,6,7
1	Rolling with Rutherford	Cosmic Ray, LHC	1,3,4,5,7
1	Calculate the Z Mass	LHC	1,2,4,5,7,8
1	Calculate the Top Quark Mass	Cosmic Ray, LHC	1,4,5,7
1	Signal and Noise: Cosmic Muons	Cosmic Ray	4,5,6,7,8
1	Mean Lifetime Part 1: Dice	Cosmic Ray, LHC	2,4,5,7
1	Histograms: Uncertainty	Cosmic Ray, LHC, Neutrino	4,5
1	Energy, Momentum, and Mass	Cosmic Ray, LHC, Neutrino	2,4,5,7,8
1	Making Tracks II	Cosmic Ray, LHC, Neutrino	1,2,4,6,7
1	Particle Transformations	Cosmic Ray, LHC, Neutrino	1,2,4,6,7
1	TOTEM 1	LHC	4,5,8
2	Making it ‘Round the Bend – Quantitative	LHC	1,2,3,4,5,6,7,8
2	CMS Data Express	LHC	2,4,5,7,8
2	TOTEM 2	LHC	2,4,5,6,7,8
2	ATLAS Z-path Masterclass	LHC	1,3,4,5,6,7,8
2	CMS Masterclass WZH-path	LHC	1,3,4,5,6,7,8
2	Mean Lifetime Part 2: Cosmic Muons	Cosmic Ray	2,3,4,5,7,8
2	Mean Lifetime Part 3: MINVERvA	Cosmic Ray, Neutrino	2,3,4,6,7,8
2	ATLAS Data Express	LHC	2,4,5,7,8
2	ATLAS W-path Masterclass	LHC	1,3,4,5,6,7,8
2	CMS Masterclass J/Psi	LHC	1,2,4,5,6,7,8
3	Cosmic Ray e-Lab	Cosmic Ray	1,2,3,4,6,7,8
3	CMS e-Lab	LHC	1,3,4,6,7
4	Research Using Coding	Cosmic Ray, LHC, Neutrino	1,2,3,4,5,6,7,8

Note: List of activities taken from QuarkNet website https://quarknet.org/data-portfolio. (As of 3/17/2022). Does not include three STEP UP activities: QuarkNet: Changing the Culture (0): QuarkNet STEP UP; Careers in Physics (1); and, QuarkNet STEP UP Women in Physics (2). (As of April 2023.)

NGSS Practices: 1. Asking questions and defining problems. 2. Developing and using models. 3. Planning and carrying out investigations. 4. Analyzing and interpreting data. 5. Using mathematics and computational thinking. 6. Constructing explanations and designing solutions. 7. Engaging in argument from evident. 8. Obtaining, evaluating, and communicating information. (https://www.nextgenscience.org/)

2012-2017 Grant Period	As of May 2023
14 Activities	38 Activities
Variety of structures	Specific structure
No Protocol	Protocol Aligned with PD Criteria
Level 1-3	Level 0 - 4
No Teacher Answer Key	Teacher Answer Key Provided
No Coding Activities	2 Coding Activities
No Spanish Language Versions	Spanish Language Posted for 5 Activities

Exhibit C. Comparison of the Data Activities Portfolio from past to current grant. (Created by D. Roudebush, May 2023 and used with permission.) Online activities, developed during COVID, are shown below in Exhibit D (for use for remote, online teaching or as homework assignments).

Activity	Level	Activity	Level	Activity	Level
Quark Workbench	0	Calculate the Z Mass	1	Mean Lifetime Part 2: Cosmic Muons	2
Shuffling the Particle Deck	0	Mean Lifetime Part 1: Dice	1	Atlas Data Express	2
Dice, Histograms, and Probability	0	What Heisenberg Knew	1	Making it ‘Round the Bend -Quantitative	2
Histograms: the Basics	0	Histograms: Uncertainty	1	Mean Lifetime Part 3: MINERvA	2
Making it ‘Round the Bend - Qualitative	0	Energy, Momentum, and Mass	1	Cosmic Racy e-Lab	3
Rolling with Rutherford	1	CMS Data Express	2	CMS e-Lab	3

Note. Adapted from: https://quarknet.org/content/comments-adapting-data-activities-teaching-online.

Exhibit D. DAP activities developed for online use (as well as in-person).

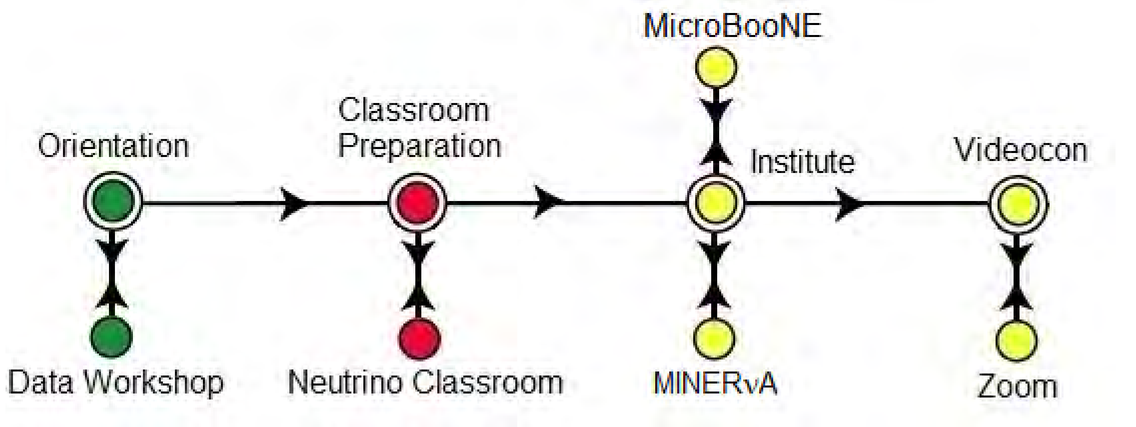


Figure 3. Neutrino Masterclass Project Map 2019 (developed by Cecire, Bilow and Wood; https://quarknet.org/content/neutrino-masterclass-project-map-2020).

Each of the current 38 activities in the DAP is available through the QuarkNet website, https://quarknet.org/data-portfolio. These activities can be searched whether logged into the website or not; and, instructions are provided as to how to search for desired activities. Activities can be searched by scrolling through the web pages (progressing from simple to complex); or, to facilitate searches these are organized by Data Strand (Cosmic Ray, LHC, and Neutrino); Level (0-4), Curriculum Topics, (e.g., Conservation Laws; Electricity; Quantum Mechanics; Half-Life/Mean Lifetime.); and NGSS Science Practices. An individual can search by one or all of these organizational categories. In support of these activities are Teacher Notes; Student Guide files (and at times other support materials); and, information on technology requirements. Estimated class time to implement is also provided.

The word "activity/activities" is frequently used by QuarkNet staff and staff teachers as well as participating QuarkNet teachers. We have adapted this language as well but note that when used we are referring to the full set of teacher and student resources and active learning opportunities that are associated with each.

Level 3 activities, which are contained in the Data Activities Portfolio, are supported by masterclasses and e-Labs. Masterclass instructional materials are organized by three project maps (LHC Project Map, Neutrino Project Map, and World Wide Data Day), which offer a sequence of planning, orientation, and classroom preparation to help teachers get their students ready for this engagement. And, e-Labs include resources to support a series of investigations into high-energy Cosmic Rays; and, to support a student research project using CMS authentic data and analytical tools.

An example of a Project Map is shown in Figure 3. As noted on the website, The Project Map "is arranged in the typical chronological order in which a masterclass is prepared and then carried out. The order is more descriptive than prescriptive. This Project Map has 4 'metro stops' plus associated branches. The main metro stops are: **Orientation** explains orienting of teachers and physicists to run a masterclass and provides schedule information. **Classroom Preparation** details how teachers get their students ready for the masterclass. **Institute** and **Videocon** with their branches cover the main elements of the masterclass day. These make up the heart of the Project Map."

Links to MINERvA resources (MINERvA is the name of an experiment at Fermilab that is collecting data on how neutrinos interact with matter) including classroom information, data sets and the MINERvA web event display are also provided.

In addition, information about e-Labs is available in its own pull-down menu (https://quarknet.org/ content/about-e-labs) and offers overview and resource information links (http://www.i2u2.org/elab/) as well. As stated on the website, "e-Labs provide opportunities for students to: Organize and conduct authentic **research**; Experience the environment of scientific **collaborations**; and, Analyze **authentic data** from large experiments." Students are able to explore data with other students and experts "to share results and publish **original work** to a world wide audience; discover and extend the research of other students, model the processes of modern, large-scale research projects; and access distributed computing techniques employed by **professional researchers**. Students may contribute to and access shared data which can come from professional research databases; and, use common **analysis tools**, store their work and use metadata to discover, replicate and confirm the research of others." Through this collaboration students "correspond with other research groups, post comments and questions, prepare summary reports and participate in the part of scientific research that is often left out of classroom experiments" (https://quarknet.org/content/about-e-labs).

DAP Activities: Alignment with the Enduring Understandings of Particle Physics

Table 10 shows the alignment of the Data Activities Portfolio with the Enduring Understandings of Particle Physics that are an integral part of the PTM and the implemented program. As shown, typically one activity focuses on one Enduring Understanding as suggested by Wiggins and McTighe (2005) covering content in depth over breath. Masterclasses and e-Labs, along with a few other activities, are notable exceptions because these require prior preparation to fully engage in these. Also, it should be noted that when a given activity is embedded in a national-led or center-led program it is used to support the particle physics content contained within a workshop; thus, an Enduring Understanding(s) is sequenced into a workshop as well. Of importance, DAP activities provide a means to suggest how this content may be incorporated into the classrooms of participating teachers.

DAP Activities: Alignment with the Next Generation Science Standard Practices

Two points seem evident from the distribution shown in Figure 4 that shows the alignment of the activities from the Data Activities Portfolio (DAP) with the Next Generation Science Standards, Science and Engineering Practices. First, at the program level a strength of these activities is how well these collectively align with these Practices.

Table 10
Enduring Understandings: Alignment of Activities in the Data Activities Portfolio

Enduring Understandings	QuarkNet Activity	Level
1. Scientists make a claim based on data that comprise the evidence for the claim.	• ATLAS Z-path Masterclass • CMS Masterclass WZH-path	2 2
2. Scientists use models to make predictions about and explain natural phenomena.	• Cosmic Ray e-Lab • CMS e-Lab	3 3
3. Scientists can use data to develop models based on patterns in the data.	• Mapping the Poles • Making it 'Round the Bend – Qualitative • Making it 'Round the Bend – Quantitative • Mean Lifetime Part 1: Dice • Mean Lifetime Part 3: MINERvA • Introduction to Coding Using Jupyter	0 0 2 1 2 0
4. Particle physicists use data to determine conservation rules.	• Making Tracks I • Making Tracks II • Rolling with Rutherford • The Case of the Hidden Neutrino • ATLAS Z-path Masterclass • TOTEM 1	0 1 1 1 2 1
5. Indirect evidence provides data to study phenomena that cannot be directly observed.	• Making Tracks I • Making Traces II • Rolling with Rutherford • The Case of the Hidden Neutrino • ATLAS Z-path Masterclass	0 1 1 1 2
6. Scientists can analyze data more effectively when they are properly organized; charts and histograms provide methods of finding patterns in large datasets.	• Mass of U.S. Pennies • Dice, Histograms & Probability • Histograms: The Basics	0 0 0
7. Scientists form and refine research questions, experiments and models using observed patterns in large data sets.	• Cosmic e-Lab • CMS e-Lab • Research Using Coding	3 3 4
8. The Standard Model provides a framework for our understanding of matter at its most fundamental level.	• Quark Workbench 2D/3D • Particle Transformations • Cosmic e-Lab • CMS e-Lab	0 1 3 3
9. The fundamental particles are organized according to their characteristics in the Standard Model.	• Shuffling the Particle Deck	0
10. Particle physicists use conservation of energy and momentum to measure the mass of fundamental particles.	• Calculate the Z Mass • Calculate the Top Quark Mass • Energy, Momentum, and Mass • CMS Masterclass WZH-path • CMS Masterclass J/Psi	1 1 1 2 2
11. Fundamental particles display both wave and particle properties and both must be taken into account to fully understand them.	• TOTEM 2	2
12. Particle physicists continuously check the performance of their instruments by performing calibration runs using particles with well-known characteristics.	• CMS Data Express	2
13. Well-understood particle properties such as charge, mass, momentum and energy provide data to calibrate detectors.	• Calculate the Z Mass	1
14. Particles that decay do so in a predictable way, but the time for any single particle to decay, and the identity of its decay products, are both probabilistic in nature.	• Mean Lifetime Part 1: Dice • Mean Lifetime Part 3: MINERvA	1 2
15. Particle physicists must identify and subtract background events in order to identify the signal of interest.	• Signal and Noise: The Basics • Signal and Noise: Cosmic Muons • CMS Masterclass J/Psi	0 1 2
16. Scientists must account for uncertainty in measurements when reporting results.	• What Heisenberg Knew • Histograms: Uncertainty	1 1

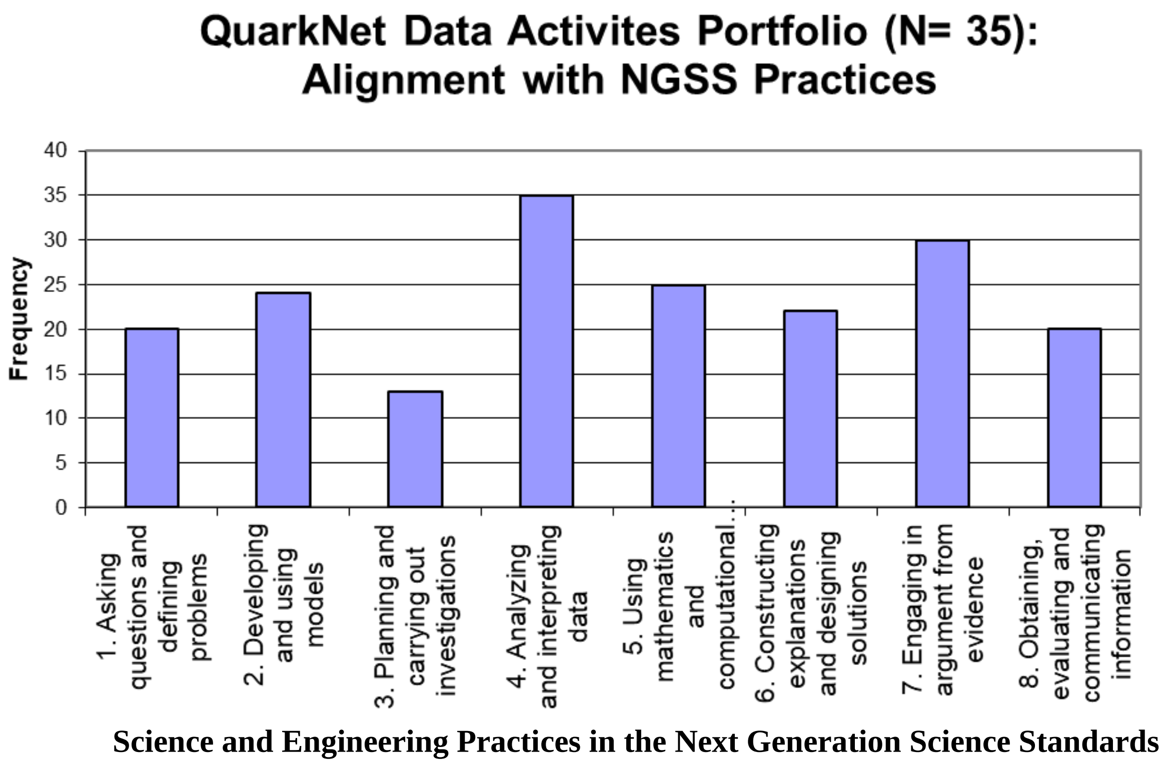


Figure 4. Alignment of Data Activities Portfolio activities with NGSS Science Practices. (Please note that the three Step-Up activities are not included in this graph.)

This is especially the case for Practices 4, 5, 6 and 7 (that is, 4. Analyzing and Interpreting Data; 5. Using Mathematics and Computational Thinking.; 6. Constructing Explanations and Designing Solutions; and 7. Engaging in Argument from Evidence). For example, all activities require analyzing and interpreting data (Practice #4). And, of importance this engagement is based on authentic data, often using large data sets involving cutting-edge physics, especially for higher level activities (e.g., Level 2 and 3 activities).

Second, the less frequently noted first three practices (1. Asking questions and defining problems. 2. Developing and Using Models. 3. Planning and Carrying Out Investigations.) suggest that these activities are largely guided-inquiry engagement (where the teacher provides the question) reflective of the complexity of the concepts covered in these activities.

The Program's Website

As already suggested, with or without a user account (a guest user account is available) a visitor to the QuarkNet website (https://quarknet.org/) can access all of the activities just described (Data Activities Portfolio, Masterclasses, and e-Labs) along with supportive documents and resources. There are also listings and links to QuarkNet centers.

Groups have been created, where on the website center-wide information is shared by a specific center (such as agendas, annual reports) or, where information about a specific need or activity is provided (e.g., Planning the Masterclass 2019). Expectations for mentors are provided; as well as a summary of award support (e.g., stipends for teachers); and how mentors and teachers can become involved in the program. National workshops opportunities for QuarkNet centers and mentor "must-do lists" are posted. Teachers and students can upload data and conduct analyses. There is contact information for key program stakeholders; a place to post questions or problems with the website; and testimonials from teachers, students and international partners reflecting their engagement in the program.

Thus, the website offers teachers, students, and research groups a rich resource of information, whether or not the individual and/or the group are directly engaged in the QuarkNet program.

Implementation of QuarkNet: 2019 through 2022 Program Years

Program Years during this Award Period: Background

Throughout this current award period, each center has been encouraged to apply annually for a budgeted 30 teacher-days; for a merged or combined center (two or more) this budgeted amount is set at 45 teachers-days. This is done through an RFP (Request for Proposal) process which will be described shortly (personal communication, email). There are various ways in which this budgeted 30 teacher-days commitment can be broken down. As explained in an annual email (January 18, 2019; February 3, 2020; March 1, 2021; January 24, 2022; and January 19, 2023), this could mean, for example, 6 teachers for 5 days or 15 teacher-days for 2 days. To help centers plan for a given program year (with most activities starting in the summer), centers are offered a list of national workshop opportunities along with a sample agenda to aid in planning and implementation https://quarknet.org/page/ summer-workshop-opportunities-quarknet-centers) as well as a staff-member representative list (see for example https://quarknet.org/content/ quarknet-center-staff-assignments-january-2020).

As usual in the planning of a given program year, centers are asked to complete a short RFP, requesting contact information (individual's name, email address, and center name); plans for workshops in the program year; expected number of days; anticipated dates; expected number of teachers; which nationally-led workshop if desired; and additional information as needed (see for example, https://quarknet.org/content/summer-2023-rfp). Staff teachers then have followed up with centers via emails and/or phone calls as a reminder and/or to help clarify any questions. As reported by QuarkNet staff teachers, typically these center-level workshop requests are initially confirmed; and finalized with an official follow-up funding letter that stipulates the maximum dollar amounts allocated for that center. Staff teachers also tracked requests for national workshop engagement and accommodate these requests to the extent to which their schedule permits (personal communication, email March 15, 2019).

This process was implemented in the 2018 program year and has been repeated for the 2019 through 2023 program years starting with an annual email blast distributed with a link to support information (as already described).

A series of tables are presented in Appendix F that summarizes QuarkNet Workshops held during past program years. For 2018, there are two tables where Table F-1 shows the national workshops run by QuarkNet staff; and Table F-2 lists the meetings and workshops held at QuarkNet Centers and led by the individual centers. (Data Camp was implemented at Fermilab on July 16-20, 2018.) In subsequent program years, there is one table per program year where nationally-led workshops are highlighted in a bold-face font. (Workshops cancelled in 2020 and 2021 because of COVID are crossed out in these tables -- not deleted -- to help reflect the impact that COVID had on programs.)

Program Years 2019-2021

Starting with the rollout of the 2019-2020 program year, QuarkNet staff provided mentors and workshop facilitators with examples of agendas for nationally-led workshops (as already described), which can and have been modified for workshops led by individual centers, if desired. During nationally-led workshops, these agendas often are modified in real time providing a straightforward way of documenting content and schedule changes. Once a workshop is completed, the updated agenda serves to memorialize the scheduled events, including main topics of presentation and discussion, activities from the Data Activities Portfolio, and implementation plan development. Another benefit of this approach is that it may help centers complete their annual reports; with details regarding the workshop or meeting captured in one or both of these documents.

Nationally-led workshops are implemented within a standard template and reflect the program strategies articulated in the Program Theory Model. That said, each center has and does take advantage of locally-available resources. This is reflected in presentations by scientists related to, for example, computing in particle physics, understanding neutrinos, measuring Muon g-2; tutorials on using cosmic ray detectors; masterclass walkthroughs and access to large data sets; as well as presentations by students related to their research, for example, using cosmic ray detectors, or machine learning. A tour of local laboratories and research centers has often been an integral part of the workshop (pre-COVID and post-COVID); or involve unique-opportunity research (e.g., building a cosmic ray detector and using it to collect data on the National Basilica of the Shrine of the Immaculate Conception in Washington, DC; or a presentation on cosmic ray detection and the 2017 Solar Eclipse).

The Neutrino Workshop, pilot tested during the 2018-2019 program year, was incorporated fully into the 2019-2020 QuarkNet program year. And STEP-UP was incorporated into designated workshops as well (STEP UP is a national movement to provide high school physics teachers with resources to reduce barriers and inspire young women and minorities to major in physics.)

Of importance, QuarkNet staff responded in many ways to address the implications of the coronavirus starting in March 2020. An overview of these early efforts was submitted to NSF on May 1, 2020 and is shared in Appendix G along with a summary table of these efforts. As shown, a variety of program modifications were made to help adapt QuarkNet to online teaching venues. The long-term implications of these modifications are discussed later in this report.

Additional teacher support for online resources were added including for example, remote online simulations and online lessons; how to use Cosmic Ray detectors remotely for data collection and analyses; shifting the content of the *Friday Flyer* (weekly) to remind teachers of available support and new online options; and from May 6 through June 10, 2020, holding QuarkNet Wednesday Webinars on particle physics-related topics. Additional Zoom channels were opened (through the University of Notre Dame) as well as IT infrastructure support, which was already working remotely.

Program Year 2021-2022

The implemented workshops during the 2021-2022 QuarkNet program year are shown in Table 11. Coding Camp, added in the 2019-2020 program year, was pilot tested as a workshop in the 2020-2021 program year and expanded during the 2021-2022 program year.

Table 11 focuses on Data Activities Portfolio (DAP) activities included in the workshops; it is not intended to give a full summary of the engagements and events that occurred during these programs (such as, select talks on cutting edge topics in particle physics; or, tours or experiments/ laboratory associated with the center). But it is important that DAP activities included in the workshops are documented. Especially for nationally-led workshops, DAP activities are a frequent and integral part of a workshop. This focus – and its documentation – coincides with the improved rigor and robust increase in the number of activities included in the DAP (since 2017). By design, the embedded DAP activities align with the workshop content, often at multiple student-skills levels (Levels 0-4). Teachers engaged in these activities as active learners – as students -- and, at times, can select from optional examples of activities during the workshop to enhance this engagement. Experiencing these activities as active learners may give teachers insight as to how and in what ways their students may engage in these activities and subsequent comprehension. This is in line with effective teacher professional development practices outlined by Darling-Hammond, et al., (2017). Of importance, teachers are given time to reflect on how they might use these activities in their class-room – a primary purpose of the DAP -- and incorporate these in implementation plans.

During the 2020-2021 program year, among the most frequently DAP activities embedded within held workshops were: *Shuffling the Particle Deck* (Level 0); *Quark Workbench 2D/3D* (Level 0); *Making Tracks I* (Level 0); *Rolling with Rutherford* (Level 1); and, *Making Tracks II* (Level 1); other activities were frequently used as well. During the 2021-2022 workshops, *Shuffling the Particle Deck* (Level 0); *Calculate the Z Mass* (Level 1); and *The Case of the Hidden Neutrino* (Level 1) were most frequent; others were noted too, including *Where's the Higgs or the Higgs at 10*.

Table 11

2022 QuarkNet Workshops and Meetings: National- and Center-led (December 2021-October 2022)

Center	**2022 Dates (All dates except where noted)**	**Workshop/Meeting**	**Brief Summary of Activities and Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
Black Hills State University	July 6-9	**Coding Workshop**	Coding Sessions 1-4 Implementation plans and discussion
Boston Area/Brown University	January 27	Winter Meeting	Teachers presented favorite lessons in physics Demonstration of DAP Calculate Z-Mass (1) Calculate the Top Quark Mass (1)
	May 19, 2022	Spring Meeting	Presentation by teachers of favorite class presentations, demonstrations, and lab projects
	August 10-11	Nuclear Fusion Workshop	Discussion of energy units; tackling specific calculations that students could use in hydrogen fusion
Brookhaven National Laboratory – Stony Brook University	June 27-29 June 30	**Cosmic Ray Workshop** Talks and Tours	Cosmic ray detector testing, reconditioning and adjustments Shuffling the Particle Deck (0) Implementation plans and discussion
The Catholic University of America	July 19-22	Summer Workshop	Shuffling the Particle Deck (0) Cosmic Ray e-Lab (3) Where's Higgs? Calculate the Z-Mass (1) Time of Flight measurement of muons Presentations on classroom implementation and inquiry-focused curriculum planning; aligning NGSS standards with interactive projects (e.g., e-Labs)
Colorado State University	September 24-26	Workshop	Share-a-Thon Teachers from this center participated in Data Camp (one) and Coding Camp I (one).

Note. National-led QuarkNet workshops are in a bold-face font. Compiled from agenda and final reports posted on QuarkNet website by individual center.

Table 11 (con't.)

2022 QuarkNet Workshops and Meetings: National- and Center-led (December 2021-October 2022)

Center	2022 Dates (All dates except where noted)	Workshop/Meeting	Brief Summary of Activities and Data Activities Portfolio (Level) [and/or classroom use/implementation plans]
Fermilab/University of Chicago/College of DuPage	August 2-4	**CMS Masterclass Workshop: Teaching with Data**	CMS Masterclass measurement Resources (DAP activities): Rolling with Rutherford (1) Calculate the Z Mass (1) Quark Workbench (0) Mass of U.S. Pennies (0) STEP UP Lessons 1 -3 Cosmic Ray Muon Detectors Shuffling the Particle Deck (0) Implementation Plans
~~Florida Institute of Technology~~[a]			
Florida International University	July 18-19	**Neutrino Data Workshop**	Shuffling the Particle Deck (0) Mean Lifetime Part 1: Dice (1) Mean Lifetime Part 3: MINERvA (2) The Case of the Missing Neutrino (1) Implementation Plans and Discussion
Florida State University/University of Florida	July 19-20 July 21 July 22	Summer Workshop **Neutrino Data (NOvA)** **Higgs@10**	The Case of the Missing Neutrino (1) Shuffling the Particle Deck (0) Higgs Search in CMS data Implementation Plans and Discussion
Idaho State University	July 11-14	**Coding Workshop**	Cosmic Ray e-Lab; classroom implementation
Johns Hopkins University	July 25-29	Summer Workshop	Constant motion testing experiment Drawing spacetime diagrams and student-friendly examples What does Goddard (space flight center) have for high school teachers
Kansas State University/University of Kansas	March 5	Masterclass Orientation	In preparation for CRMD research project.
	April 1	Masterclass	CMS
	May31 June 1-3	**Cosmic, Neutrino Data, & Higgs@10 Workshop**	Shuffling the Particle Deck (0) Mean Lifetime Part 3 MINERvA (2) MINERvA Masterclass measurement The Case of the Missing Neutrino (1) Implementation Plans

Note. National-led QuarkNet workshops are in a bold-face font. Compiled from agenda and final reports posted on QuarkNet website by individual center.

[a]QuarkNet staff members are hoping to merge this center with the University of Florida and University of Central Florida (Cecire via email October 15, 2022).

Table 11 (con't.)

2022 QuarkNet Workshops and Meetings: National- and Center-led (December 2021-September 2022)

Center	**2022 Dates (All dates except where noted)**	**Workshop/Meeting**	**Brief Summary of Activities and Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
Lawrence Berkeley National Laboratory	June 24 June 27 June 28	**Particle Physics Data Activities** (1 hour session each day)	Particle Cards (virtual) Quark Workbench Search for Higgs in CMS data
	June 21-July1	Physics in and through the Cosmology Two Week Virtual Workshop (3 hours per day)	A total of 6 teachers and 46 students participated. Discussion on cosmic rays and how a cosmic ray detector works. Presentation by Nobel Prize winner Saul Perlmutter
Northern Illinois University	No activity		
Oklahoma State University/University of Oklahoma	July 18-19 July 20-21	**Coding Workshop** **Higgs Boson, ATLAS, CMS**	Coding Project/Implementation Plan Shuffling the Particle Deck (0) Quark Workbench (0) Where's Higgs Calculate the Z Mass (1) Implementation plan and discussion Brainstorming how center can help in teachers' classrooms
Purdue University	September 8	Modern Physics Remote Teacher Workshop (1/2 day)	Introduction to the Data Activities Portfolio Making Tracks I Prep for In-person full-day workshop in October 22 Shuffling the Particle Deck (0) Quark Workbench (0)
Purdue University Northwest	No date(s)	Summer Workshop	Produced a week-long curriculum Students designed a long-term water shielding study for CRMD's Create a new logo for the PNW Center for High Energy Physics Create a poster for the QuarkNet Center Particle simulation Calculate the Top Quark (1)

Note. National-led QuarkNet workshops are in a bold-face font. Compiled from agenda and final reports posted on QuarkNet website by individual center.

Table 11 (con't.)

2022 QuarkNet Workshops and Meetings: National- and Center-led (December 2021-October 2022)

Center	**2022 Dates (All dates except where noted)**	**Workshop/Meeting**	**Brief Summary of Activities and Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
Queensborough Community College	April 29	Research Symposium	Measuring cable attenuation Cosmic ray Arduino data
Rice University/University of Houston	June 6-7 June 6-9 June 10	**Coding** **Neutrino Data** **Higgs@10**	The Case of the Hidden Neutrino (1) Shuffling the Particle Deck (0) Histograms: The Basics (0) Where's Higgs? Neutrino masterclass measurement MINERvA/NOvA measurement Implementation plans and discussion
Rutgers University	March	MINERvA Masterclass	4 teachers and 25 students
	2 weeks (no dates)	Summer Program on Fundamental Physics	Analyzing data from MINERvA experiment Measurements on Cosmic Ray muons using Cosmic Ray Detectors; student presentations
Southern Methodist University	June 20-21 June 22-23 June 24	**Neutrino Data** **CMS Data** **Higgs@10**	Shuffling the Particle Deck (0) The Case of the Hidden Neutrino (1) Mean Lifetime Part 1: Dice (1) Mean Lifetime Part 2: Cosmic Ray Muons (2) Mean Lifetime Part 3: MINERvA (2) Making Tracks I (Cloud Chamber) (0) Making Tracks II (Bubble Chamber) (1) Calculate the Mass of Z (1) CMS Masterclass measurement Totem (1); Totem (2) Implementation plans and discussion
Syracuse University	August 8-10 August 9	Summer Workshop **Higgs@10**	Rolling with Rutherford (1) Mass of U.S. Pennies (0) Shuffling the Particle Deck (0) Making it 'Round the Bend: Qualitative (1) or Quantitative (2) Mapping the Poles (0) Higgs@10

Note. National-led QuarkNet workshops are in a bold-face font. Compiled from agenda and final reports posted on QuarkNet website by individual center.

Table 11 (con't.)

2022 QuarkNet Workshops and Meetings: National- and Center-led (December 2021-September 2022)

Center	**2022 Dates (All dates except where noted)**	**Workshop/Meeting**	**Brief Summary of Activities and Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
Texas Tech University	July 11-13 (each full day) July 14-15 (each 1/2 day)	Summer Workshop	Cosmic Ray detector reassembly Teachers worked on various DAP activities (not specified) and several e-Lab sites
University at Buffalo –SUNY	April 2	CMS Masterclass (2 teachers/4 students)	Students shared findings with other participating QuarkNet centers via videoconference facilitated by Fermilab moderator
	August 22 August 23-24	**Summer Workshop: Higgs Coding**	Shuffling the Particle Deck (0) Where's the Higgs? Dice, Histograms & Probability (0) Introduction to Coding Using Jupyter Implementation plans and presentations
University of California Irvine	July 7-8	**Summer Workshop**	Shuffling the Particle Deck Mean Lifetime Part 1: Dice (1) Mean Lifetime Part 2: Cosmic Muons (2) Mean Lifetime Part 3: MINERvA (2) The Case of the Missing Neutrino (1) Implementation discussion
~~University of California at Riverside~~[b]			
University of California Santa Cruz	March 5	Masterclass Remote (2 students) and in-person (5 students)	Video conference held with masterclass students from LBNL and facilitated by Fermilab ATLAS and BAMA activity held at local high school (Scotts Valley)
University of Cincinnati	June 14-16	Artificial Intelligence, Machine Learning and STEP UP	Introduction to machine learning STEP UP: Careers in Physics (Lesson 2) (1) STEP UP: Women in Physics (Lesson 3) (2) Calculate the Z mass (1) QuarkNet World Wide Data Day CMS masterclass LHCb masterclass

Note. National-led QuarkNet workshops are in a bold-face font. Compiled from agenda and final reports posted on QuarkNet website by individual center.
bMentors have been unable to gather teachers for masterclasses (Cecire via email October 15, 2022).

Table 11 (con't.)

2022 QuarkNet Workshops and Meetings: National- and Center-led (December 2021-September 2022)

Center	**2022 Dates (All dates except where noted)**	**Workshop/Meeting**	**Brief Summary of Activities and Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
University of Florida	No activity		
University of Hawai`i	March 12	Masterclass	3 teachers and 20 students
	October 6-7	**Workshop and APS FWS Meeting**	Shuffling the Particle Deck (0) Calculate the Z Mass (1) Introduction to: CMS Ray e-Lab; W2D2 measurement; Introduction to Coding Implementation Discussion
University of Illinois at Chicago/Chicago State University	August 10-11	**Cosmic Ray** **Higgs@10**	
University of Iowa/Iowa State University	No activity		
University of Kansas	No activity		
University of Minnesota	April 23	**NOvA Masterclass Pilot**	NOvA measurement Part 1 & 2
	June 13-14 June 15 Jun 16	**Summer Workshop Cosmic Ray** **Neutrino Data Update** **Higgs@10**	Cosmic Ray studies and discussion NOvA Part 1 NOvA Part 2 Shuffling the Particle Deck (0) Where's the Higgs? Implementation plans and discussion
University of Mississippi	May 27-28	**QN@FPCP**	Shuffling the Particle Deck (0) MINVERvA Neutrino Masterclass Introduction Mean Lifetime Part 1: Dice (1) Mean Lifetime Part 3: MINERvA (2)
	July 9	Particle Detection	Building a simple detector

Note. National-led QuarkNet workshops are in a bold-face font. Compiled from agenda and final reports posted on QuarkNet website by individual center.

Table 11 (con't.)

2022 QuarkNet Workshops and Meetings: National- and Center-led (December 2021-September 2022)

Center	**2022 Dates (All dates except where noted)**	**Workshop/Meeting**	**Brief Summary of Activities and Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
University of New Mexico	July 26-29	**Cosmic Ray & ATLAS Data Workshop**	Shuffling the Particle Deck (0) Making Tracks: 1 (0) Rolling with Rutherford (1) Cosmic Ray Sessions 1, 2 & 3 Mass of U. S. Pennies (0) Calculate the Z Mass (1) ATLAS analysis (BAMA) Implementation discussion
University of Notre Dame	March 31	MINERvA Masterclass	Introduction and masterclass measurement Video conference with Sanford, South Dakota
	August 1-5	**Workshop** (Virtual Center)	Shuffling the Particle Deck (0) Calculate the Z Mass (1) Implementation and Discussion Plans
University of Oregon	June 22	Series of Talks	Talks on scientific research in high-energy physics and astrophysics (e.g., recent updates and progress),
~~University of Pennsylvania~~[c]			
University of Puerto Rico - Mayaguez	March	Masterclass Orientation	
	March 26	MINERvA Masterclass	
~~University of Rochester~~[c]			
~~University of Tennessee Knoxville~~[e]			
University of Washington	No activity		
University of Wisconsin - Madison	No activity		
Vanderbilt University	June 21-24 July 27	Summer Workshop then Additional Short Workshop	Shuffling the Particle Deck (0) Where's Higgs? Using CRMDs and discussion on how to use in classroom
Virginia Center (Hampton University, the William and Mary, and the George Mason University)	August 1 August 2 August 3	**What's New** **Neutrino Data** **Higgs@10**	Shuffling the Particle Deck (0) Where's Higgs? Totem activities STEP UP: Careers in Physics (Lesson 3) (2) Calculate the Z Mass (1) Implementation Plans & Reflections

Note. National led QuarkNet workshops are in a bold face font. Compiled from agenda and final reports posted on QuarkNet website by individual center.
[c]No longer an active QuarkNet center.

Table 11 (con't.)
2022 QuarkNet Workshops and Meetings: National- and Center-led (December 2021-September 2022)

Center	**2022 Dates (All dates except where noted)**	**Workshop/Meeting**	**Brief Summary of Activities and Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
Virginia Tech	no date	Spring Meeting	Lead teacher gave presentation on online adaptation of DAP activities
	June 27	Zoom 1-day link with BNL	CMS e-Lab introduction and exploration
	June 28-29	**Neutrino Data Workshop**	Shuffling the Particle Deck (0) Mean Lifetime Part 1: Dice (1) Mean Lifetime Part 2: Cosmic Muons (2) Mean Lifetime Part 3: MINERvA (2) The Case of the Missing Neutrino (1)
Virtual Center	August 3-5	**Summer Virtual Workshop** (with Notre Dame)	Shuffling the Particle Deck (0) Calculate the Z Mass (1) Implementation Discussion and Plans
~~Wayne State University~~[c]			
Coding Camp	June 13-17	**Coding Camp 1** (Held virtually)	Introduction to how to: Code in Python Analyze particle physics data Integrate into classroom
	July 24-29	**Coding Camp 2**[d]	In-depth experience with fundamental computer programming skills and applications with particle physics used as the context
Data Camp	July 10-15	**Week-long Workshop** held at Fermilab	How We Roll CMS calibration Quark Workbench (0) Rolling with Rutherford (1) Calculate the Top Quark Mass (1) Mass of U.S. Pennies (0) Overview of masterclasses & QuarkNet events

Note. National led QuarkNet workshops are in a bold face font. Compiled from agenda and final reports posted on QuarkNet website by individual center.
[c]No longer an active QuarkNet center.
[d]Funded through a grant from IRIS-HEP.

Development of Evaluation Measures and Evaluation Plan

The first goal of the evaluation has been completed, that is, (1) Develop (and use) a Program Theory Model (PTM). Although the PTM will be reviewed and revised as needed, the lion share of this model is completed.

To fulfill the remaining two evaluation goals: (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, three evaluation measures were designed. That is, a Teacher Survey (in two versions full and in an abbreviated update) and a Center Feedback Template. As a reminder, the new evaluation efforts began in September 2018 to coincide with the 2018-2019 program year. Most QuarkNet workshops and meetings at participating centers occur over the summer (as already noted in previous tables). The Teacher Survey (full version) was rolled out to coincide with summer 2019 activities. (This aligns with Goal 2: assess teacher-level outcomes). A pilot test of the Center Feedback Template began in November 2019 and has been rolled-out during the 2019-2020, 2020-2021 and 2021-2022 program years. This coincides with assess center-level outcomes (Goal 3) and will serve to provide a context for teacher-level responses.

Program operations data, gathered from the Center Feedback Template, and other sources have been linked to teacher-level evaluation data, when possible, to assess outcomes relative to program engagement at the individual level (by teacher) and at the center level (teachers embedded or nested by center).

Serving both program and evaluation needs, QuarkNet staff teachers (Wood, Cecire) and the education specialist (Roudebush) posted on the QuarkNet website a *Guide to Teacher Implementation Plan Development* to help teachers think through classroom implementation. Rolled out during the 2019-2020 program year, this involved a more structured approach to implementation where a specific time slot was allocated as a required activity for nationally-led workshops. This activity was strongly recommended for center-run workshops. Often these classroom implementation plans are posted on the QuarkNet's website (in the comments section where a given the workshop agenda is posted). And, to coincide with the 2020-2021 program year, a template was created to help teachers think through the components of these plans. Teachers were encouraged to post their plans in the comments section of the online workshop agenda.

To complement this effort, an Update: Teacher Survey was integrated into the process starting in spring of the 2019-2020 program year to help capture classroom implementation plans proposed by teachers. Finally, workshop observations (most done remotely) have been incorporated into this process.

We first describe the evaluation measures; then, present preliminary results based on the implementation of these methods and measures.

Table 12
Teacher Survey: Teacher Perceptions of Exposure to Program Core Strategies and Assessment of Program Outcomes

<table>
<tr><th>Core Strategies</th><th>Outcomes</th><th>Evaluation Measure</th></tr>
<tr><td>Provide opportunities for teachers to be exposed to:
• Instructional strategies that model active, guided-inquiry learning (see NGSS science practices).
• Big Idea(s) in Science (cutting-edge research) and Enduring Understandings (in particle physics).</td>
<td rowspan="3">Teachers:
Translate their experiences into instructional strategies, which reflect guided inquiry and NGSS science and engineering practice and other science standards as applicable. Specifically:
• Discuss and explain concepts in particle physics.
• Engage in scientific practices and discourse.
• Use particle physics examples, including authentic data, when teaching subjects such as momentum and energy.
• Review and use instructional materials from the Data Activities Portfolio, selecting lessons guided by the suggested pathways.
• Facilitate student investigations that incorporate scientific practices.
• Use active, guided-inquiry instructional practices in their classrooms that align with NGSS and other science standards.
• Use instructional practices that model scientific research.
• Illustrate how scientists make discoveries.
• Use, analyze and interpret authentic data; draw conclusions based on these data.
• Become more comfortable teaching inquiry-based science.
• Use resources (including QuarkNet resources) to supplement their knowledge and instructional materials and practices.
• Increase their science proficiency.
• Develop collegial relationships with scientists and other teachers.
• Are life-long learners.

(And their) Students will be able to:
• Discuss and explain particle physics content.
• Discuss and explain how scientists develop knowledge.
• Engage in scientific practices and discourse.
• Use, analyze and interpret authentic data; draw conclusions based on these data.
• Become more comfortable with inquiry-based science.</td>
<td rowspan="3">The Teacher Survey is intended to assess teachers' perceptions related to their exposure to core strategies (as implemented); and, their perceptions regarding teacher and student outcomes. (See Appendix H for a copy of the survey.)

The unit of measure for this survey is the individual teacher. The intent is to complete the survey during their on-site program engagement. The survey is conducted via SurveyMonkey.

An annual event. Teachers are asked to complete a much shorter survey (Update) the following year they complete the full survey; focused on use of activities in the use of QuarkNet content and DAP activities in their classroom; teacher-level and student-level outcomes. (See Appendix I.)</td></tr>
<tr><td>Provide opportunities for teachers to:
• Engage as active learners, as students.
• Do science the way scientists do science.
• Engage in authentic particle physics investigations (that may or may not involve phenomenon known by scientists).
• Engage in authentic data analysis experience(s) using large data sets.
• Develop explanations of particle physics content.
• Discuss the concept of uncertainty in particle physics.
• Engage in project-based learning that models guided-inquiry strategies.
• Share ideas related to content and pedagogy.
• Review and select particle physics examples from the Data Activities Portfolio instructional materials.
• Use the pathways, suggested in the Data Activities Portfolio, to help design implementation plan(s).
• Construct classroom implementation plan(s), incorporating their experience(s) and Data Activities Portfolio instructional materials.
• Become aware of resources outside of their classroom.</td></tr>
<tr><td>Local Centers (Each center seeks to foster lasting relationship through collaboration at the local level and through engagement with the national program.)

In addition, through sustained engagement provide opportunities for teachers and mentors to:
• Interact with other scientists and collaborate with each other.
• Build a local (or regional) learning community.</td></tr>
</table>

Assessment of Program Outcomes at the National and Center Levels: Full Teacher Survey

The Full Teacher Survey was developed to assess teacher-level program outcomes at the national and center levels as perceived by participating teachers. As implied, the unit of measure is the individual teacher (see Table 12, previous page). The full survey is shown in Appendix H (in a PDF format). Teachers participated in the survey electronically through a SurveyMonkey link. Teachers are encouraged to complete the survey using their own electronic device, although the use of their personal cell phone is not recommended.

There are six segments to the survey, questions about: 1) who is completing it; 2) level of QuarkNet participation; 3) classroom use of activities from the Data Activities Portfolio; 4) opportunities to be exposed to QuarkNet program strategies, including big-picture and community-building strategies; 5) teacher-level outcomes and the degree to which QuarkNet may have influenced these; and 6) (their) student-level outcomes and the degree to which QuarkNet may have influenced this engagement.

To begin, teachers are asked to provide information about themselves (e.g., *How many years have you been teaching?*) brief information about their school (e.g., *What best describes the location of your school?)* (Segment 1)*;* as well as the nature and extent of their participation in QuarkNet (e.g., Which *QuarkNet Workshops or Programs have you participated in*?) (Segment 2). The central thesis of the survey incorporates questions related to the use of DAP activities in their classrooms (Segment 3); exposure to core program strategies (segment 4); teacher-level program outcomes (Segment 5); and student-level outcomes articulated in the PTM (Segment 6).

A detailed description of strategies and program outcomes covered in this survey is shown in Table 12 (segments 4-6). Specifically, teachers are asked their perspectives on the degree to which they were exposed to or engaged in the program strategies listed in the table (and reflected in the PTM) (e.g., *QuarkNet provides opportunities for me to: a. Engage as an active learner, as a student.*). Then, teachers are asked their perceptions as to how (or if) they have applied what they have experienced or learned through their QuarkNet participation in their classrooms (e.g., *Demonstrate how to use, analyze and interpret authentic data*). Also, they are asked to reflect on the degree to which they think QuarkNet has influenced these behaviors. Finally, teachers are asked to reflect on student-level outcomes based on perceived student classroom engagement and the degree to which QuarkNet has influences these behaviors as well (e.g., *Discuss and explain concepts in particle physics*).

Throughout the survey there is a full array of response options, with many opportunities for open-ended responses. A 5-point, Likert-like scale is used to gather teacher perspectives on questions related to exposure to core program strategies (Poor, Fair, Average, Good or Excellent); teacher program outcomes that are event-based in the classroom (Almost Always, Very Often, Sometimes, Not Very Often, or Rarely); and student classroom engagement (Very High, High, Moderate, Low or Very Low). When used, a "Not Applicable" option carried a value of zero. These responses were coded such that the higher the value, the more positive the response.

In support of the Teacher Survey, an email blast was sent in early spring (2019) to active centers to underscore the importance of evaluation efforts prior to the planned summer (2019) workshops (and then repeated in subsequent program years). Evaluation requests were also included on their "must do" list (which included information for teachers to receive their stipend). Mentors, fellows and facilitators were asked to include time to complete the survey in the agenda of the event as well (including the SurveyMonkey link). Teachers were encouraged to self-identify on the survey to facilitate the linking of this survey information to program participation levels. Thus, evaluation requests and requirements were embedded along with other program announcements and actions.

The first administration of the Full Teacher Survey occurred during QuarkNet workshops and programs implemented during the 2019-2020 program year. Teachers were asked to complete the survey during their at-site QuarkNet event. Time to complete the survey was incorporated into most workshop agendas and many workshop facilitators announced and emphasized the importance of survey participation. According to Survey Monkey, it took (and will take) an estimated 16-18 minutes to complete.

The survey is a planned annual event; however, a given teacher was asked to complete the full survey only once during this grant period. Starting in spring 2020, if a teacher had completed the Full Teacher Survey, he or she was asked to complete the short Update: Teacher Survey (see Appendix I). The update focused on the use (or planned use) of activities in the Data Activities Portfolio in the classroom; teacher-level outcomes and their perceptions about (their) student outcomes. The update was rolled out to coincide with the 2019-2020 program year and continued during each subsequent program year. (There is also a Spanish language version.) Teachers access it through a SurveyMonkey link with an estimated 6-minute completion time. Time to complete this update is also incorporated into the agenda.

Assessment of the Sustainability of Program Centers: Based on Center-level and Sustainability Outcomes – Center Feedback Template

Given that most teachers experience the QuarkNet program through their engagement of the program at a specific center, the center provides an important context in which the teachers experience the program and at the same time, centers are a source of outcomes in their own right. To this end, the Center Feedback Template was designed to assess this program context, assess center-level outcomes (see Table 13); and gather information on success factors as a means to assess sustainability outcomes (see Table 14).

The Center Feedback Template is a 4-page form divided into four sections (see Appendix J). Information about the Center (who is participating in this effort and who is completing this form) is requested in Section I. Section II asks about program events over the past two years. Section III gathers information about center-level outcomes (described in

Table 13
Center Feedback Template: Linking Core Strategies and Center-level Outcomes

<table>
<tr><th>Core Strategies</th><th>Outcomes</th><th>Evaluation Measure</th></tr>
<tr><td>Provide opportunities for teachers to be exposed to: Instructional strategies that model active, guided-inquiry learning (see NGSS science practices).
1. Asking questions and defining problems
2. Developing and using models
3. Planning and carrying out investigations.
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information.</td>
<td rowspan="3">Local Centers
• Model active, guided-inquiry instructional practices that align with NGSS and other science standards that model scientific research.

Through engagement in local centers
Teachers as Leaders:
• Act in leadership roles in local centers and in their school (and school districts) and within the science education community.
• Attend and/or participate in regional and national professional conferences sharing their ideas and experiences.
Mentors:
Become the nexus of a community that can improve their teaching, enrich their research and provide broader impacts for their university.
Teachers and Mentors:
Form lasting collegial relationships through interactions and collaborations at the local level and through engagement with the national program.</td>
<td rowspan="3">The Center Feedback Template is intended to serve as a guide or protocol to capture center-level information related to implemented program strategies and well as key center-level outcomes. (See Appendix J for a copy of this protocol.)

The unit of measure for this evaluation effort is the center. The narrative of this report explains the plan for how this template is and will be distributed and in what ways centers are offered assistance in completing it based on staff teacher aid and/or assistance from the evaluator.

This template also addresses sustainability outcomes, which are presented in Table 14.</td></tr>
<tr><td>Program provides opportunities for a strong mentor.
(Mentor provides leadership skills mainly of content and/or technical expertise; understands education and professional development -- working with teacher leaders as needed; models research.)</td></tr>
<tr><td>Local Centers: In addition, through sustained engagement provide opportunities for teachers and mentors to:
• Interact with other scientists and collaborate with each other.
• Build a local (or regional) learning community</td></tr>
</table>

Table 13); and Section IV is focused on the Success Factors listed in Table 14. Finally, there is an optional fifth page for Centers to add any additional comments, if desired.

Given that this template is more complicated than a survey per se, we adopted the following protocol. First, relying on help from QuarkNet's staff teachers, centers were selected on a rolling basis. More on this rolling process will be presented in a subsequent section of this report.

Table 14
Center Feedback Template: Sustainability Outcomes and Success Factors[a]

Sustainability Outcomes[b]	Success Factors[a]
1. Program components or strategies are continued (sustained fidelity in full or in part). 2. Benefits or outcomes for target audience(s) are continued. 3. Local/Center-level partnerships are maintained.[c] 4. Organizational practices, procedures and policies in support of program are maintained. 5. Commitment/attention to the center-level program and its purpose is sustained.[c] 6. Program diffusion, replication (in other sites) and/or classroom adaptation occur.[c]	1. *Program provides opportunities for a **strong teacher leader**.* (Teacher provides leadership in areas of content and/or is a technical expert; models exemplary pedagogical skills; able to provide organizational skills. These characteristics may be present in one or a team of teacher leaders.) 2. *Program provides opportunities for a **strong mentor***. (Mentor provides leadership skills mainly of content and/or technical expertise; understands education and professional development -- working with teacher leaders as needed; models research.) 3. *Participants meet regularly*. (QuarkNet model is for a summer session with follow-up during the academic year or sessions during the academic year. Follow up includes working with the national staff and collaboration within and across centers. Mentors and teachers have flexibility to set the annual program locally.) 4. *Meaningful activities* (The standard for meaningful activities is focusing topics in modern physics, discussing how to implement this content in classrooms, conducting research and discussing scientific inquiry methods; using Data Activities Portfolio instructional materials.) 5. *Directly addresses classroom implementation of instructional materials for all teachers.* (Time for teachers to discuss Data Activities Portfolio instructional materials and pathways; to consider NGSS, AP, IB or other science standards; presentation(s) from veteran teachers on classroom implementation experiences or similar engagement.) *6. Program is able to provide regular contact and support with teachers*. (Specific support and or follow up from staff; staff teachers are available and/or volunteers who support teachers, especially related to classroom implementation.) *7. Money for additional activities or additional grants.* (Seeking additional funding to fulfill the mission/ objectives of the center; providing supplemental or complementary support for QuarkNet e.g., providing transportation, lodging, buying equipment; providing food.) *8. Stable participant base*.(A stable participant base can provide an expert group that can help other teachers, support outreach, and provide organizational leadership.) *9. Addresses teacher professionalism.* (The standard is to provide opportunities for at least a few teachers to attend professional meetings; support teachers taking leadership roles in their school, school districts, outreach, and highlight PD opportunities for continuing development.) *10. Establish a learning community*. (The standard is forming a cohesive group where teachers learn from one another; engage with mentors and other scientists; provide outreach to other teachers.)

[a] M.J. Young & Associates (2017, September). *QuarkNet: Matrix of Effective Practices*

[b]This framework is based on the work of Scheirer and Dearing (2011); adopting their definition of sustainability, as well: “Sustainability is the continued use of program components and activities for the continued achievement of desirable program and population outcomes” (p. 2060). The language has been modified slightly to better fit the QuarkNet program.

[c]The language of this characteristic was modified to better fit the QuarkNet program.

II. **QuarkNet Program Activities**: *Please indicate which of the following QuarkNet programs have been implemented at your Center in the past two years, based on your Center's typical engagement in this program. (Check all that apply).*

Check, if yes ✔	*QuarkNet Program Component*	*2019 Program Year*	*2018 Program Year*
	National Workshop (facilitated by national program staff or fellows) Workshop list at https://quarknet.org/page/summer-workshop-opportunities-quarknet-centers		
	Center-run Workshop (facilitated by center with center-focused topics/interests)		
	Data Camp:		
	1. Center-level teacher(s) participates at Fermilab		
	2. Teacher(s) introduces activity/methods at Center (based on Data Camp experience)		
	Data Activities Portfolio: Activities at https://quarknet.org/data-portfolio		
	1. Work through and reflect on activity/ities (in the portfolio) at the center.		
	2. Present/discuss examples of classroom implementations based on these activities		
	Masterclass(es): Held one or more at center		
	Cosmic Ray Detector *(e.g., assemble, calibrate)*		
	Other *(please specify any other center-led or center-wide event)*		

QuarkNet Websites: https://quarknet.org/; https://quarknet.org/page/summer-workshop-opportunities-quarknet-centers; https://quarknet.org/data-portfolio

Figure 5. Section II of the Center Feedback Template

To help ease the task, a draft of Section II was completed by the evaluator using information gathered from existing annual reports and agenda(s) for a given center over the past two years, for example, 2021 and 2020 program years. Each of these draft summaries were reviewed by a QuarkNet staff teacher who had worked with that center and who has direct knowledge about it. Each summary was revised as needed. (Figure 5 shows a blank Section II.) Then, the mentor was sent an email suggesting that an initial conference call was likely necessary to help the center fulfill this request. In practice, this conference call ran about an hour and typically had included a QuarkNet staff teacher, the mentor and lead teachers from the center and the evaluator. During discussion, Section II was reviewed but the focus of the call was on helping the center complete Sections III and IV after the call (see Figures 6 and 7). (Not all centers elected to participate in this conference call, completing the form on their own.) An agreed upon completion deadline was set. Once the center completed the form a short summary of teacher survey responses (from their center) was emailed to them as a thank you and to help guide future program plans.

III. **Center-level Outcomes:** *Please indicate which of the following QuarkNet program outcomes have been evident, by whom and the degree of QuarkNet's influence at your Center in the past two years. (Check all that apply.)*

Center-level Outcomes	Who?						QuarkNet's Influence?					
	Almost All	Most	Some	A Few	Rarely	Don't Know	Very High	High	Moderate	Low	Very Low	Does Not Apply
Engage Teachers as Active Learners, as Students (across workshops/events)												
During National/Center-run Workshops or Programs, Teachers Experience Active, Guided-inquiry Instruction through:												
1. Asking questions and defining problems.												
2. Developing and using models.												
3. Planning and carrying out investigations.												
4. Analyzing and interpreting data.												
5. Using mathematics and computational Thinking.												
6. Construct explanations and designing solutions.												
7. Engaging in argument from evidence.												
8. Obtaining, evaluating, and communicating information.												
Networking/Community Building:												
1. Teachers engage/interact with mentors and other scientists.												
2. Teachers engage/interact with other teachers.												
Teachers as Leaders:												
1. Provide leadership at local centers.												
2. Attend and/or participate in regional and national professional conferences sharing their ideas and experiences.												
***Teachers and Mentors**:* Form lasting collegial relationships through interactions and collaborations at the local level and through engagement with the national program.												
Mentors: Become the nexus of a community that can improve their teaching, enrich their research and provide broader impacts for their university.												

Figure 6. Section III of the Center Feedback Template.

At the start of this process, a center was selected because a QuarkNet staff teacher has been/is very familiar with the center and has good rapport with its mentor(s) and lead teachers. These early selections tended to represent centers that have successfully implemented QuarkNet over the years; in part because these selected centers tend to reflect the national program (and likely align well with the Program Theory Model) through active participation in programs such as workshops (either national or center-led), e-Labs, and/or Masterclasses.

As we moved through this process, it was likely that selected centers reflected QuarkNet engagement that is both strong in some areas and in need of reflection in other areas (which may be the case for centers that were selected early as well). In addition to serving the evaluation needs that have been described, we hoped that this information was of value to the centers – as a means to reflect on program engagement (past or present) – as well as helpful to QuarkNet staff as they think about current or future needs of the center. Also, we hoped that this process offered a summary of broader impacts of the program for centers to use for other purposes.

IV. **Center-level Success Factors:** *Please view the center's QuarkNet engagement through the lens of the Success Factors related to effective practices as described below.*

Effective Practices/Success Factors[a]	Meets Criteria?				Comments: Please use this space (and additional space if needed) to explain your ratings or to indicate action that may need to occur.
	Yes	Yes, but[1]	No	Unsure	
1. *Program provides opportunities for a* ***strong teacher leader***. (Teacher provides leadership in areas of content and/or is a technical expert; models exemplary pedagogical skills; able to provide organizational skills. These characteristics may be present in one or a team of teacher leaders.)					
2. *Program provides opportunities for a* ***strong mentor***. (Mentor provides leadership skills mainly of content and/or technical expertise; understands education and professional development -- working with teacher leaders as needed; models research.)					
3. *Participants meet regularly*. (QuarkNet model is for a summer session with follow-up during the academic year or sessions during the academic year. Follow up includes working with the national staff and collaboration within and across centers. Mentors and teachers have flexibility to set the annual program locally.)					
4. *Meaningful activities* (The standard for meaningful activities is focusing topics in modern physics, discussing how to implement this content in classrooms, conducting research and discussing scientific inquiry methods, using Data Activities Portfolio instructional materials.)					
5. *Directly addresses classroom implementation of instructional materials for all teachers.* (Time for teachers to discuss Data Activities Portfolio instructional materials and pathways; to consider NGSS, AP, IB or other science standards; presentation(s) from veteran teachers on classroom implementation experiences or similar engagement.)					
6. *Program is able to provide regular contact and support with teachers.* (Specific support and or follow up from staff, staff teachers are available and/or volunteers who support teachers, especially related to classroom implementation.)					
7. *Money for additional activities or additional grants.* (Seeking additional funding to fulfill the mission/objectives of the center, providing supplemental or complementary support for QuarkNet e.g., providing transportation, lodging, buying equipment; providing food.)					
8. *Stable participant base.* (A stable participant base can provide an expert group that can help other teachers, support outreach, and provide organizational leadership.)					
9. *Addresses teacher professionalism.* (The standard is to provide opportunities for at least a few teachers to attend professional meetings, support teachers taking leadership roles in their school, school districts, outreach, and highlight PD opportunities for continuing development.)					
10. *Establish a learning community.* (The standard is forming a cohesive group where teachers learn from one another, engage with mentors and other scientists, provide outreach to other teachers.)					

[a]This section of the protocol has been adapted from M.J. Young & Associates (2017, September). *QuarkNet Matrix of Effective Practices*

[1]Needs work or fine tuning; or, there are notable caveats

Figure 7. Section IV of the Center Feedback Template.

As mentioned, we linked teacher responses from the survey to program participation data captured through the Center Feedback Template, as well as other program operations data so that teacher and center responses can be understood in the context of the degree and type of program engagement.

QuarkNet Participant: Teacher Survey (2019-2022)

Based on enrollment numbers (as recorded for each year), 311 teachers participated in QuarkNet during 2019; 251 teachers participated during 2020; 242 teachers during 2021; and 281 teachers participated during 2022.

The response rate for the 2019 Full Teacher Survey was 78% (based on a total of 242 surveys from teachers who participated in the 2019-2020 program year -- 242 out of 311). An additional 78 teachers (who participated in QuarkNet in 2018-2019 *but not* in 2019-2020) were contacted via email and asked to participate in the survey. A total of 22 of these teachers completed the survey for a response rate of 28%. Thus, a total of 264 teachers responded to the survey. In the program year 2020, a total of 91 teachers completed the full survey and 90 teachers completed the shorter update survey, from a total of 251 participants. This represents a response rate of 72%. In the program year 2021, a total of 68 teachers completed the full survey and 124 teachers completed the shorter update survey for a total of 192 (out of 242 teachers) or a response rate of 79%.

Table 15
Full Teacher Survey: Gender of QuarkNet Teachers

Gender	Program Year: Unique Count				
	2019	(*new in*) 2020	(*new in*) 2021	(*new in*) *2022*	Total
Men	157 (61%)	34 (42.5%)	41 (63%)	42 (55%)	274 (57%)
Women	100 (39%)	46 (57.5%)	24 (37%)	34 (45%)	204 (43%)
Total	257 (100%)	80 (100%)	65 (100%)	76 (100%)	478 (100%)

$\chi^2_{(3,\ 478)} = 9.69$, $p < .03$ (comparing gender across program years) Please note that this represents a unique count of teachers. Numbers in 2020, 2021 and 2022 do not represent the total number of teachers who participated in QuarkNet for each of these program years. *New* means new to the survey process not necessarily new to QuarkNet. Five teachers did not specify gender.

In the program year 2022, a total of 76 teachers completed the full survey and 148 teachers completed the shorter update survey for a total of 224 (out of 281 teachers) or a response rate of 79%.

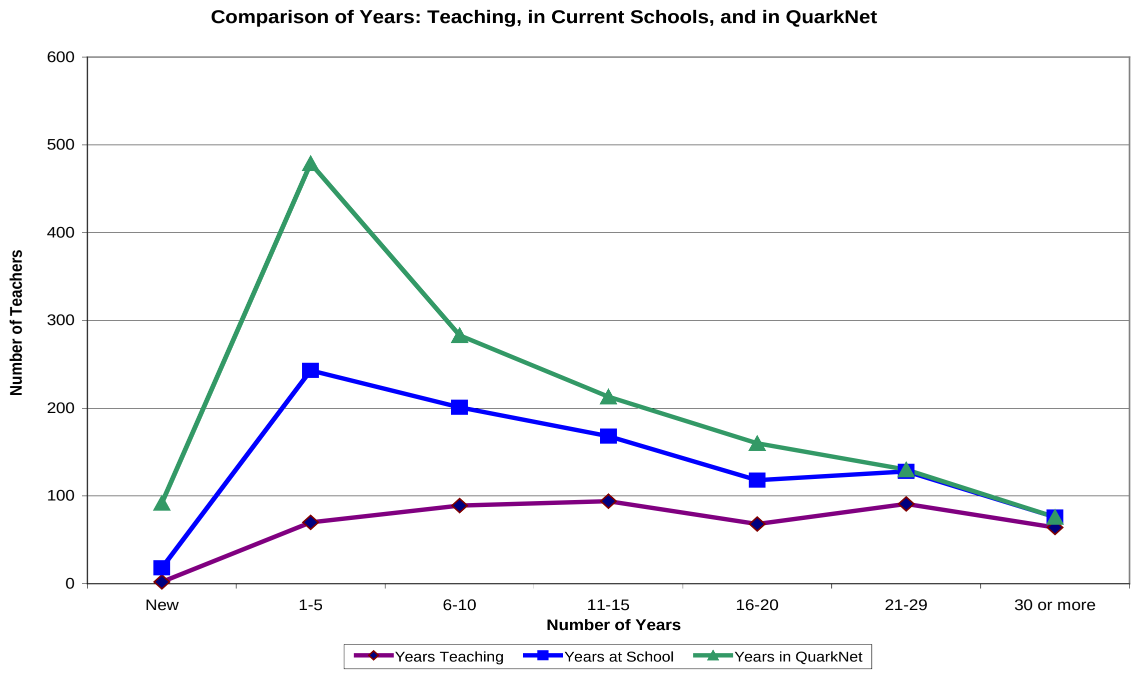
For each year, participating teachers completed the survey at the time of the workshop/ program; or, after one email reminder. We believe the reason behind the high response rate for participating teachers is that the survey was administered face-to-face during 2019 workshops and programs; at the time of the workshop or program mostly in a virtual environment for 2020 and 2021; and, again in 2022 during in-person workshops. Thus, the credit for this high response rate is due to the commitment by the staff and facilitators of QuarkNet and we are thankful for it.

Raw Data

For each program year, raw data were downloaded from Survey Monkey via an Excel spreadsheet and exported to SPSS (Statistical Package for the Social Sciences, Version 28) for subsequent analyses. Although the survey is accessible to teachers by a link, the raw data are only accessible via a specific Survey Monkey account.

Data were reviewed, cleaned, and new variables were created to facilitate data analysis, when necessary. (These data manipulations are described in the analysis sections of this report.) When a teacher self-identified and completed both surveys (full and update) 2019 through 2022 survey responses were linked so that year-to-year comparisons for these teachers could be made.

Survey responses labeled as 2020, 2021and 2022 reflect *new* teachers who did not participate in QuarkNet in 2019 (although not likely new to the QuarkNet program) (See Table 15). Thus, teachers are counted only once to arrive at this unique count -- a total of 483 teachers completed the full survey. 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 so that multiple-year comparisons can be made. This represents a unique count of 208 teachers who completed their update survey at least once during this time period.



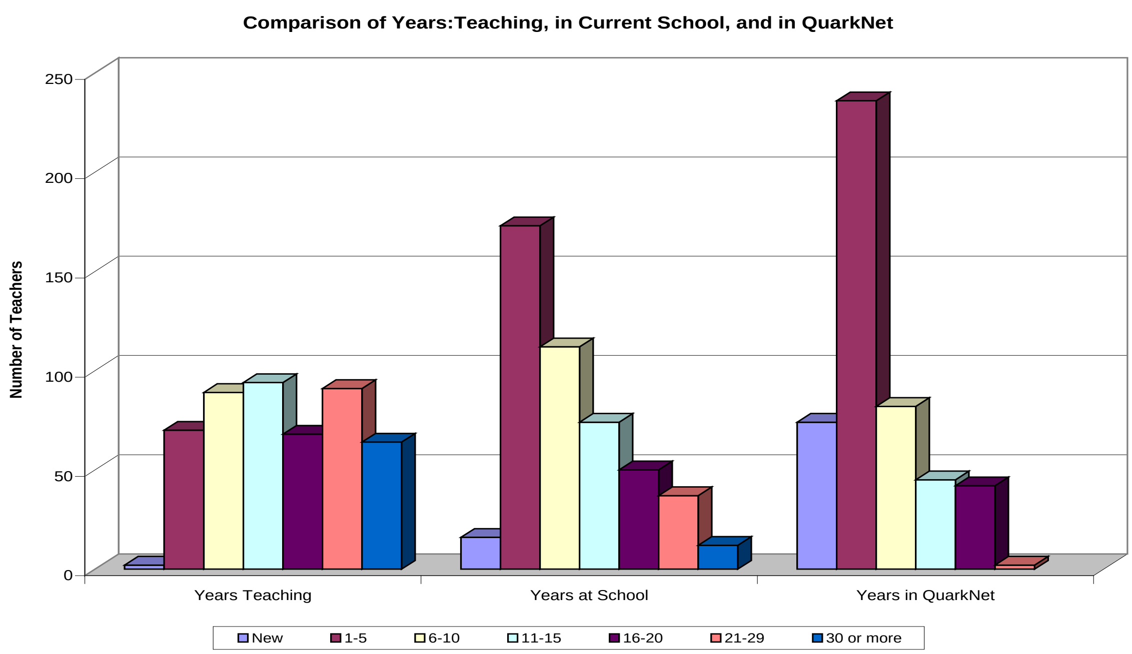


Figure Set 8. Comparison of the number of years: Teaching; at current school; and participating in QuarkNet.

Before teacher-level (and their students) outcomes are explored, a brief look is provided as to who are these teachers.

Demographics

As already noted, a combined 483 teachers participated in the Full Teacher Survey; of these 478 indicated their gender 274 are men (57%), and 204 are women (43%) (see Table 15 page 53). Five teachers did not indicate gender. As shown in Table 15, there were gender differences based on program year where more female teachers participated in QuarkNet in 2020 (than expected) compared to 2019, 2021 and 2022 program years. Of importance, however, there were no statistically significant differences when teacher-level outcomes were analyzed by gender of the teacher; thus, these responses are combined across gender to help simplify analyses.

Shown in Figure Set 8 (on previous page), many participants were new to QuarkNet or had participated in the program for just a few years; however, the number of long-term participants is noteworthy. That is, the mean number of years in QuarkNet was 5.46 years (Standard Deviation, SD = 5.73), with a median of 3 years (50^{th} percentile). Collectively, these teachers had a mean number of years teaching of 16.6 years (SD= 10.36) (median 15 years); and a mean of 9.46 years at his/her school (SD = 7.99) (7.0 median years); with a few participating teachers who are retired.

The number of years a teacher has participated in QuarkNet is statistically related to teacher's gender and the program year in which a survey is captured. In a 2 x 4 Analysis of Variance (ANOVA), male teachers reported a higher mean number of years in QuarkNet (6.06; SD = 5.96) compared to female teachers (Mean = 4.61; SD =53.25) [$F_{(1, 469)} = 5.127$, $p < .03$]. Regarding program year, teachers reporting in 2022 indicated a fewer number of years of QuarkNet participation (Mean = 2.83; SD = 1.57) compared to teachers who completed their surveys in 2019, 2020, or 2021 [$F_{(3, 469)} = 6.86$, $p < .03$].

Relative to the number of years teaching, male teachers reported a mean number of years of 18.01 (SD= 10.63) compared to female teachers (Mean = 14.81; SD = 9.72) a difference that was statistically significant [$F_{(1, 465)} = 6.95$, $p < .01$]. Number of years teaching was not statistically related to the program year in which the teacher's survey was captured. Number of years at a given school was not statistically related to either the teacher's gender or program year.

The correlation between years teaching and years at current school was high (r = .63); slightly lower but still high was the correlation between years teaching and QuarkNet experience (r = .47); and, years at current school and QuarkNet experience (r = .46). The number of years that teachers participated in QuarkNet ranged from 0 (his/her first time) up to 21 years.

<u>School Location</u>

As shown in Table 16, most often participating teachers represented schools in suburban areas (182 or 38%); followed by urban, central city (106 or 22%); urban (96 or 20%); or rural (91 or 19%); (1% not reported). Compared to data from the previous grant period

Table 16
QuarkNet Teachers: School Location and Teaching Physics

Demographic	Program Year: Unique Count				
	2019	2020	2021	2022	Total
School Location					
Rural	48 (19.0%)	15 (19.2%)	16 (23.9%)	12 (15.6%)	91 (19.2%)
Suburban	124 (49.0%)	38 (48.7%)	12 (17.9%)	8 (10.4%)	182 (38.3%)
Urban	49 (19.4%)	15 (19.2%)	7 (10.4%)	25 (32.5%)	96 (20.2%)
Urban, Central City	32 (12.6%)	10 (12.8%)	32 (47.8%)	32 (41.5%)	106 (22.3%)
Total	253 (100%)	78 (100%)	67 (100%)	77 (100%)	475 (100%)
Teach Physics?					
Yes	223 (87.5%)	58 (73.4%)	47 (69.1%)	59 (77.6%)	387 (80.9%)
No	32 (12.5)	21 (26.6%)	21 (30.9%)	17 (22.4%)	91 (19.0%)
Total	255 (100%)	79 (100%)	68 (100%)	76 (100%)	478 (100%)

Please note that this represents a unique count of teachers. Numbers in 2020, 2021 and 2022 do not represent the total number of teachers who participated in QuarkNet for each of these program years. *New* means new to the survey process not necessarily new to QuarkNet. Eight teachers did not indicate the location of their school. And five teachers did not indicate whether or not they are teaching physics.

– based on a unique count from the 2017 program year --, QuarkNet teachers represented schools most often in suburban settings (51.4%); followed by urban settings (20.6%); rural (16.6%); and urban, inner city (10.0%); (1.3% not reported) (data not shown). From the past to current grant period, this suggests a shift in school presentation by QuarkNet participating teachers from the past to current grant period with a percent decrease from participating teachers who represent suburban schools to more participating teachers from schools in urban settings; and slightly more from rural schools [$\chi^2_{(3, 658} = 3.66$, p <.001].

The type of “best descriptor” for location of school was slightly related to the gender of the teacher, where slightly more than expected male teachers taught in rural school locations as compared to female teachers [$\chi^2_{(3, 470)} = 7.88$, p <.05]. Over the program years, there has been a shift in the school location as reported by participating QuarkNet teachers. That is, in program years 2021 and 2022 more teachers indicated that their represent schools from urban, or urban, central city school locations [$\chi^2_{(9, 475)} = 88.98$, p <.001]. (School location was not statistically related to exposure to core program strategies; and not related to teacher-level and student-level outcomes, either.)

To take a deeper dive into the schools represented by QuarkNet participating teachers a large-scale case study was undertaken to explore the student demographics represented by these schools. To this end, we selected teachers registered for the 2022 QuarkNet program year from among the 24 (31 combined) QuarkNet Centers that were included in quantitative analyses. (The number of centers was reduced to 21 because a few centers had too few teachers registered to be included.) This resulted in the inclusion of approximately 250 teachers from about 120 schools. Some teachers do represent the same school but please keep in mind that QuarkNet program engages individual teachers and does not represent a school-wide or science-department level of professional development.

We have organized this information by center. The summary provided the name and city, state location of the school, school-level student demographics including school enrollment size; gender breakdown of students (by percents); ethnicity of students (by percents); and the percent of students who are eligible for free or reduced lunch programs. We based this summary on publicly available information, and we have accepted information at face value.

What have we learned from this review? That the 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. As mentioned, we have organized this information by center in the hope that such organization would help facilitate its usefulness. It is likely most helpful if used by and for the local centers especially in discussions as to how to draw new teachers into QuarkNet to improve representation by teachers who teach at schools with under-represented student populations, as needed.

Teaching Physics

As reflected in Table 16, across the grant period a total of 81% of teachers reported that they teach physics. Over this time period (2019 through 2022), there was a tendency for more teachers to report that they are not teaching physics [$\chi^2_{(3, 478)} = 16.62$, $p < .001$] from a percent high of 88% to a low of 78%. Slightly more female teachers do not teach physics as compared to male teachers [$\chi^2_{(1, 473)} = 13.24$, $p < .001$]; that is, roughly 60% of the teachers who teach physics are male.

It is important to note that these survey results present a snapshot in time as to where and what a given teacher is teaching. Given that teachers often participate in QuarkNet frequently over the course of a grant period, these data and results do not reflect this fluidity (e.g., scheduling changes for a given teacher at the same school over school years; or a change of schools during this time period). Changes, when they occur, are at times reflected in open-ended comments teachers have made during completion of the shorter, update surveys; but even here these changes are likely under-reported.

Table 17
Which Workshop or Program?

Workshop/Program	Num. Teachers	Workshop/Program	Num. Teachers
Data Camp	183	Neutrino Data Workshop	87
ATLAS	49	ATLAS Masterclass	58
CMS Data Workshop	102	CMS Masterclass	116
CMS e-Lab Workshop	87	Neutrino Masterclass	41
Cosmic Ray e-Lab Intro	183	Coding Workshops/Camps	56[a]
Cosmic Ray e-Lab Advanced Topics	35		
Other QuarkNet Events			
International Muon Week	39[b]	International Cosmic Day	34[b]
CERN	53	International Muon Week	40[b]
Greece Trip	13	World Wide Data Day	24[b]

Note. Multiple responses were allowed.
[a]Early exposure to coding was embedded in workshops that also included other physics content such as neutrino data and/or CMS updates.
[b]Since the main vehicle for gathering survey responses from teachers is through workshop participation, it is likely that some of these counts underestimate the actual number of teachers who participate in other programs, such as masterclasses or special events.

QuarkNet Participation

Teachers were asked to select the QuarkNet workshops or programs where they were participants. These responses are summarized in Table 17. Clearly, a workshop (workshops collectively) is the most frequently mentioned QuarkNet program. Given that multiple responses are allowed, summing these numbers would not provide a unique count of teachers. As to specific programs, most often, teachers indicated that they had participated in Data Camp and Cosmic Ray e-Lab introduction (183). The variety of workshops and masterclasses is noteworthy as well.

It is important to note that the value of Table 17 is in our ability to gauge the type and degree of QuarkNet engagement by teachers as this relates to their perceived assessment of exposure to strategies core to the program. Another way to say this is, at the time that they evaluated their exposure to core program strategies what had their past (and immediately present) engagement in QuarkNet looked like. Table 17 *is not* a program operations data table indicating participation totals for a particular program year or across this grant period.

<u>QuarkNet Participation Beyond the Survey: Masterclasses and e-Labs.</u> It is noteworthy that workshops are the principal vehicle in which professional development is provided to participating QuarkNet teachers (supported by other opportunities as well); it is also the principal means by which survey responses are collected. Thus, these data may overrepresent workshop participation and undercount engagement in other types of QuarkNet events.

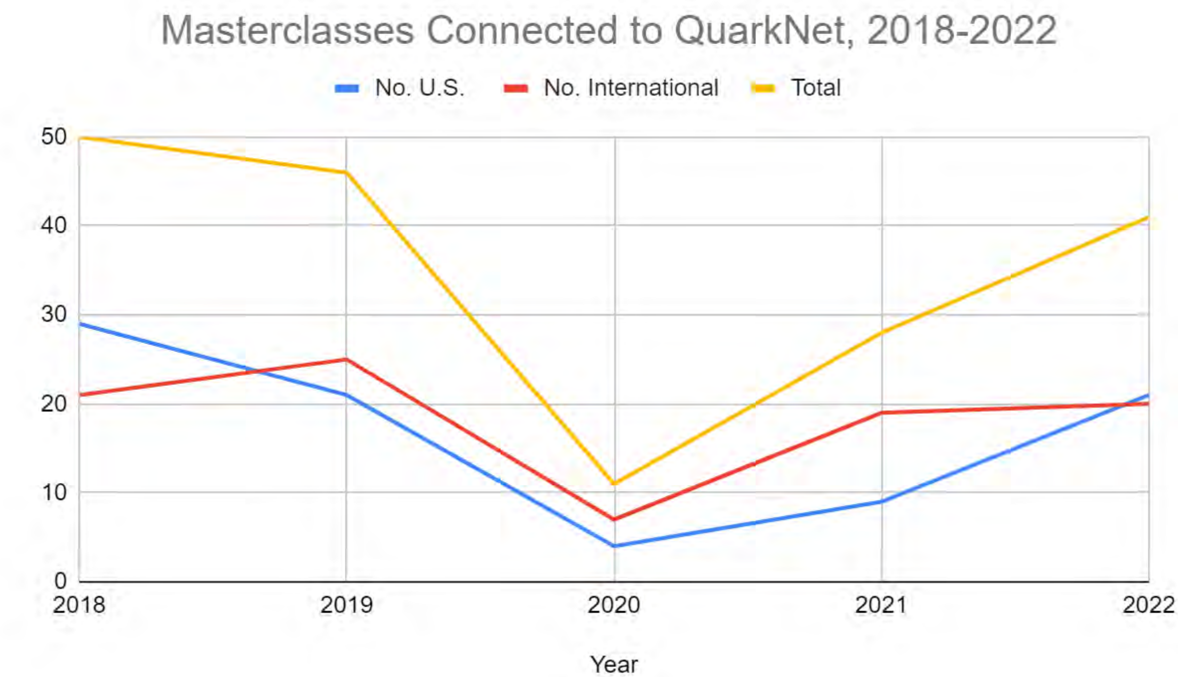


Figure 9. QuarkNet Masterclasses by program year (data from K. Cecire, 2022).

To offer a sense of the wider uses of QuarkNet programs and materials we offer the following. As to likely undercounts, we know from other sources that the number of teachers who engaged in coding programs (e.g., Coding Camp 1 and 2) exceeds that which is reported in Table 17. Based on Race (2022b) and working with Adam LaMee, a QuarkNet staffer, a total of 103 teachers were reported to have engaged in coding programs from 2020 through 2022 (not a unique count). Including workshops that incorporated coding activities across this grant period, LaMee puts this count at 120 teachers (also, not a unique count).

A graph created by Cecire, (see Figure 9 displayed here with permission) shows the number of QuarkNet masterclasses held over the course of the current grant. Although the number of events and not teachers are provided, this graph offers a more accurate picture of the possible opportunities for QuarkNet teachers to engage in QuarkNet masterclasses across the current grant period.

Table 18

High School Long-term Collaboration Using
High Energy Physics Model

Time Period	DAQs (Data Acquisitions) [a]	Uploads	Analyses Run
Apr-Oct 2019	66	2,173	--
Apr-Oct 2020[b]	27	2,733	2,182 (from 26 DAQs)
Apr-Oct 2021	42	2,871	4,300 (from 30 DAQs)
Apr-Oct 2022	55	3,513	5,055 (from 34 DAQs)

Note. Data compiled by M. Adams used with permission (email Adams 1/31/23)
[a]DAQ measurement/experiments using Cosmic Ray Muon Detectors.
[b]During COVID.

As to e-Lab activities, QuarkNet teacher engagement is measured in various ways. For example, information compiled by Adams (and used here with permission) suggests that there are over 2,000 teacher accounts. These teachers support approximately 1,400 student accounts (with a single student account representing one to many students).

Table 18 shows the number of uploads during 2019 through 2022; and the number of analyses run during 2020 through 2022. A total of 382 e-Lab plots were saved in 2022. (Historic totals for plots and file uploads are 26,115 and 119,213, respectively.)

Table 19
QuarkNet Participation by Program Year (Responses from Full Surveys)

QuarkNet Program	Program Year				Total
	2019	2020	2021	2022	
Data Camp[a]					
Yes	112	33	14	53	183
No	146	47	54	24	300
Total	258	80	68	77	483
Variety of Prior Workshops[b]					
None	79	37	35	46	197
One workshop	79	19	20	17	135
Two or more	100	24	13	14	151
Total	258	80	68	77	483
Masterclasses[c]					
None	147	24	52	69	324
One or more	111	56	26	8	159
Total	258	80	68	77	483

[a][$\chi^2_{(3, 483)} = 13.85$, $p < .01$]
[b][$\chi^2_{(6, 483)} = 30.08$, $p < .001$]
[c][$\chi^2_{(3, 483)} = 32.65$, $p < .001$]

QuarkNet Participation and Program Year

Returning to QuarkNet participation as gauged by the Teacher Survey, please keep in mind that teachers were asked about their current and past QuarkNet participation. When doing so, engagement in QuarkNet by type of opportunity was found to be related to the program year in which they responded to the full survey (see Table 19).

Participation by program year differences may likely be linked to the onset of COVID which altered the implementation of QuarkNet especially during the 2020 and 2021 program years. For example, Data Camp (fundamentally an in-person event) was implemented only in 2019 and again in 2022. Those teachers who indicated that they had participated in Data Camp, as reflected in program years 2020 and 2021, were reporting past engagement in QuarkNet and not the program year when their survey responses were gathered. That said, analysis suggests that more than expected teachers reported having participated in Data Camp in 2019 as compared to 2020-2022 program years. This was also the case of the variety of prior workshop engagement during 2019 (more teachers than expected reported engaging in prior workshops) as compared to 2020-2022 program years. And, the number of masterclasses where more teachers than expected engaging in masterclasses in 2019 as compared to 2020-2022 program years.

In subsequent sections of this report, program-year results will be reported if this was found to be statistically related to exposure to core strategies and/or program outcomes.

Overview of Analyses: Teacher (and their Students) Outcomes

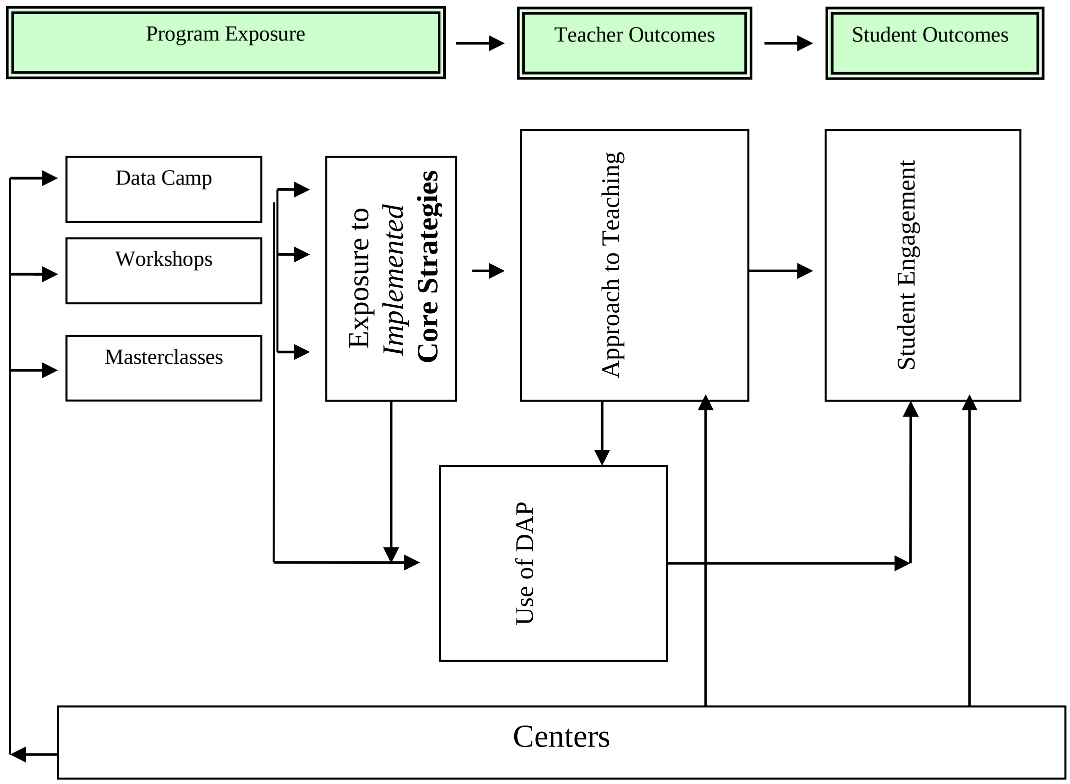


Figure 10. Teacher (and their Students) Outcomes: Overview of Analyses

We began quantitative analyses on outcomes by exploring the relationship between engagement in QuarkNet and exposure to core program strategies; and subsequently the potential impact this involvement may have on teacher outcomes and student engagement outcomes. We have analyzed responses from the 2019 through 2022 Full Teacher Surveys and have conducted a descriptive look at responses from the 2020 through 2022 Update Teacher Surveys (the latter of which will be discussed in subsequent sections).

At times, a given measure serves as the dependent measure in a set of analyses; and in turn, a given measure may be used as a "predictor" variable as we build models toward understanding teachers' approach to teaching (both teacher and student-level outcomes) and use of activities in the Data Activities Portfolio. Because of this complexity, Figure 10 provides an overview of these analyses as a means of offering a road map to their logic. Each analysis is presented and discussed separately in the next several sections. To help simplify these analyses and to use data with measured reliability (internal consistency), several scale scores were created (which will be explained shortly).

Please be mindful that these analyses explore the association of exposure to core strategies through QuarkNet programs and outcomes; and are not intended to imply causality. Multiple models are proffered as a means of helping us understand these relationships. The weight of the evidence suggests a strong association between program participation and exposure to core strategies; and exposure to core strategies and expected outcomes as described below. We reserve judgment as to the best model(s) to use at this time because these analyses are preliminary. The additional data added into this mix over the course of this grant period has permitted us to incorporate center-level data into these models, when statistically feasible. We had used descriptive analyses to help understand the impact of teachers nested within QuarkNet centers may have on these outcomes. We look to center-level engagement to help provide a context to better understand the relationship between teacher-level engagement and subsequent outcomes; and, to analyze center-level engagement in its own right.

Scale Score Development to Measure Exposure to Program and Teacher (and their Students) Outcomes

The following scale scores were developed in support of these analyses: Core Strategies (assess program exposure); Approach to Teaching; QuarkNet's Influence on Teaching; Student Engagement; and, QuarkNet's Influence on Student Engagement. A *new* scale score has been added, that is, Long-term Outcomes: Teachers. All scale scores are based on teacher self-reported responses to the Full Teacher Survey.

To help understand the content of these scales, the individual survey items, included in each of these scale scores, are shown in Table 20. In all cases, the responses to a given item set (scale) are summed with the *higher* the score, the more positive response, based on individual 5-point Likert-like response categories. Descriptive statistics and the reliability coefficient for each scale are shown in Table 21. Results have been stable across survey years. We provide more descriptive details about these scales in Appendix K.

Single-variable Analyses of Core Strategies and Approach to Teaching Scores

To begin, we posed a series of questions as a check to see if **Core Strategies** scores and **Approach to Teaching** scores behaved in a way that made sense. That is, the more engagement in specific types of QuarkNet program options, the more exposure to core strategies, leading to higher scores when measuring program exposure (Core Strategies); and, to test whether greater engagement in QuarkNet program options is related to better teacher outcomes (that is, higher Approach to Teaching scores). To this end, we asked four basic questions, *Is there a difference in perceived exposure to QuarkNet core program strategies (Core Strategies scores) or teacher-level outcomes (Approach to Teaching scores) for participating teachers, who:*(1) Did or did not participate in Data Camp? (2) Engaged in a variety of workshops (e.g., CMS Workshop, ATLAS Workshop, Neutrino Workshop)? (3) Did or did not participate in a Masterclass? and (4) Is perceived exposure to QuarkNet Core Strategies and Approach to Teaching scores related to reported use of activities from the Data Activity Portfolio in the classroom.

Table 20
Items Used to Form Scale Scores

Scale	Survey Instructions	Individual Items
Core Strategies[a]	*Please rate the following strategies based on your current QuarkNet program experience and, if applicable, on your previous involvement in Quark-Net programs to date. If you have participated in QuarkNet for many years, please respond based on what you think the cumulative effect of this participation has been over the past two years.*	**Exposure to QuarkNet Strategies** *QuarkNet provides opportunities for me to:* 21a. Engage as an active learner as a student. b. Do science the way scientists do science. c. Engage in authentic particle physics investigations. d. Engage in authentic data analysis experiments using large data sets. e. Develop explanations of particle physics content. f. Discuss the concept of uncertainty in particle physics. *QuarkNet provides opportunities for me to:* 22a. Engage in project-based learning that models guided-inquiry strategies. b. Share ideas related to content and pedagogy. c. Review and select particle physics examples from the Data Activities Portfolio instructional materials. d. Use the pathways, suggested by the Data Activities Portfolio, to help design classroom instructional plan(s). e. Construct classroom implementation plan(s) incorporating experience(s) and Data Activities Portfolio instructional materials. f. Become aware of resources beyond my classroom.
Approach to Teaching[b]	*In thinking about your approach to teaching, please rate the frequency in which you engage in each of the following in your classroom.*	**Approach to Teaching Outcomes** 27a. Discuss and explain concepts in particle physics. b. Engage in scientific practices and discourse. c. Use physics examples including authentic data when teaching subjects such as momentum and energy. d. Review and use instructional materials from the Data Activities Portfolio. e. Selecting these lessons guided by the suggested pathways. f. Facilitate student investigations that incorporate scientific practices. 29a. Use active guided-inquiry instructional practices that align with science practices standards (NGSS and other standards). b. Use instructional practices that model scientific research. c. Illustrate how scientists make discoveries. d. Demonstrate how to use, analyze and interpret authentic data. e. Demonstrate how to draw conclusions based on these data. f. Become more comfortable teaching inquiry-based science.

a Response categories: 1= Poor, 2 = Fair, 3= Average, 4 = Good, and 5= Excellent.
b Response categories: 5= Almost Always, 4 = Very Often, 3= Sometimes, 2= Not Very Often, and 1= Rarely

Table 20 (con't.)
Items Used to Form Scale Scores

Scale	Survey Instructions	Individual Items
QuarkNet's Influence on Teaching[c]	*Now, indicate the degree to which you think QuarkNet has contributed to your implementation of these instructional strategies in your classroom.*	**QuarkNet's Influence on Teaching** 28a. Discuss and explain concepts in particle physics. b. Engage in scientific practices and discourse. c. Use physics examples including authentic data when teaching subjects such as momentum and energy. d. Review and use instructional materials from the Data Activities Portfolio. e. Selecting these lessons guided by the suggested pathways. f. Facilitate student investigations that incorporate scientific practices. 30a. Use active guided-inquiry instructional practices that align with science practices standards (NGSS and other standards). b. Use instructional practices that model scientific research. c. Illustrate how scientists make discoveries. d. Demonstrate how to use, analyze and interpret authentic data. e. Demonstrate how to draw conclusions based on these data. f. Become more comfortable teaching inquiry-based science.
Student Engagement[d]	*This last set of questions asks about your students' classroom engagement and how QuarkNet may have influenced (through your participation and/or your students) this engagement. In your judgment, please indicate ...*	**Student Engagement (***My students are able to …*) 32a. Discuss and explain concepts in particle physics. b. Discuss and explain how scientists develop knowledge. c. Engage in scientific practices and discourse. d. Use, analyze and interpret authentic data. e. Draw conclusions based on these data.
QuarkNet's Influence on Student Engagement[e]	*Now, indicate the degree to which QuarkNet (either because of your participation of theirs) have contributed to your students' engagement.*	**QuarkNet has helped my students to:** 33a. Discuss and explain concepts in particle physics. b. Discuss and explain how scientists develop knowledge. c. Engage in scientific practices and discourse. d. Use, analyze and interpret authentic data. e. Draw conclusions based on these data.
Long-term Outcomes: Teachers[f]	*Please respond to the following statements.*	**Long-term Outcomes: Teachers** 31a. I use resources (including QuarkNet resources) to supplement my knowledge and instructional materials and practices. b. I have increased my science proficiency. c. I have developed collegial relationships with scientists and other teachers. d. I think my students have become more comfortable with inquiry-based science.

[c]Response categories: 5= Very High, 4 = High, 3= Moderate, 2 = Low, 1= Very Low)
[d]Response categories: 5= Almost Always, 4 = Very Often, 3= Sometimes, 2= Not Very Often, and 1= Rarely.
[e]Response categories: 5= Very High, 4 = High, 3= Moderate, 2= Not Very Often, and 1= Rarely.
[f]Response categories: 5 = Strongly Agree, 4 = Agree, 3 =Neutral, 2 = Disagree, and 1 = Strongly Disagree.

Table 21
Building Scales for Analysis of Program Engagement and Outcomes
(Higher the Score, the more Positive the Assessment)

Scale	What's Measured	# of Items	N	Mean	Standard Deviation	Cronbach's Alpha[a]
Core Strategies	Teachers' perceived exposure to program core strategies articulated in PTM	12	464	54.10	6.97	0.86
Approach to Teaching	Perceived assessment of QN teacher outcomes	12	447	42.85	8.38	0.87
QN's Influence on Teaching	Perceived assessment of how QN has influenced teaching practices and content	12	402	48.04	9.51	0.91
Student Engagement (SE)	Teachers' perceptions of student engagement in their classroom	5	425	18.38	3.66	0.84
QN's Influence on SE	How QN has influenced this student engagement	5	357	19.63	4.06	0.91
Long-term Outcomes: Teachers	Overarching behaviors related to personal knowledge, influence on teaching, development of collegial relationships, and student comfort level with inquiry.	4	450	17.53	2.56	0.82

[a]Measure of reliability (internal consistency). (Factor analyses suggest one factor solutions for each.) This summary is based on 2019-2022 Full Teacher Survey responses.
Note. The smaller mean value for student engagement (SE), QN"s Influence on SE, and Long-term Outcomes: Teachers is due to the smaller number of items that comprise each of these scales.

These single-variable analyses are helpful as these suggest meaningful relationships and help build confidence in more complicated analyses (i.e., multiple regression analyses, and hierarchical linear regression), which are the focus of the narrative of this report.

Briefly, and in general, participating teachers reported higher **Core Strategies** scores based on degree of program engagement. Teachers who participated in Data Camp (as compared to teachers who did not) reported higher scores, on average. Analyses found that teachers who engaged in a variety of prior workshops reported higher scores, on average, the more varied the engagement. The same held for the number of masterclasses where teachers who engaged in at least one masterclass reported higher Core Strategies scores, on average, when compared to teachers who had not yet participated in a masterclass. Finally, those teachers who reported using activities from the Data Activities Portfolio (DAP) tended to report higher Core Strategies scores than those teachers who had not yet used these instructional materials in their classrooms. (Program year was not statistically related in any of these analyses.)

These analyses are not intended to imply causality, nor do we want to pit a type of QuarkNet engagement against each other. These analyses *do* suggest that program engagement and measurement of Core Strategies are related in a meaningful way. This speaks to the fidelity of the *implemented* program as compared to the program as *designed* (as perceived by participating teachers). And this suggests that it is a relevant measure to use in subsequent analyses in particular serving as a surrogate for the type, degree and length of program engagement.

In a similar fashion, we looked at how the type and degree of QuarkNet engagement are related to reported Approach to Teaching scores. Participating teachers reported higher **Approach to Teaching** scores based on type of program engagement. This is evident for teachers who participated in Data Camp (as compared to teachers who did not); for teachers who engaged in a variety of prior workshops (the more varied the workshop experience, the higher the score, on average); and, for those teachers who participated in one or more Masterclasses (compared to teachers who did not). Approach to Teaching scores were also related to use of activities in the Data Activities Portfolio. Again, program year was not statistically related in any of these analyses.

It is important to note that there were no statistically significant differences based on teacher's gender for type of QuarkNet engagement (Data Camp, Variety of Workshop or Masterclass participation); and there were no differences by gender based on Core Strategies, Approach to Teaching, and QuarkNet's Influence on Teaching. (This was also the case for Student Engagement scores, and QuarkNet's Influence on Student Engagement scores.)

In sum, all of the above analyses provide statistical support for our expectation that these measures can be used to evaluate related QuarkNet outcomes. We now turn to an exploration of how QuarkNet is associated with teacher, and student outcomes.

How is QuarkNet Engagement Related to Approach to Teaching?

In an interim combined analysis (that is, a stepwise, multiple regression analysis with Approach to Teaching as the dependent variable), Engagement in Data Camp, Variety of Workshops, Number of Masterclasses were statistically related to perceived exposure to Core Strategies, perceived QuarkNet's Influence on Teaching and reported Use of Activities in the Data Activities Portfolio. A binary logistic regression analysis was conducted as well with Used DAP activities in the classroom as the dependent variable and shown to be statistically related to "predictor variables" that is, program engagement as measured by participation in Data Camp, workshops, and masterclasses.

These results suggest that the stepwise regression model could be simplified to include Core Strategies as a surrogate measure of program engagement. Indeed, a subsequent stepwise regression model supports this idea. A summary of this analysis is shown in Table 22, where QuarkNet's Influence on Teaching (entered first), exposure to Core

Table 22
Approach to Teaching: Summary Statistics and Related Variables
Model Summary[a]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
Final	.582[b]	.339	.334	6.63

Coefficients[b]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	13.275	3.02		4.3777	<.001
QN's Influence on Teaching	.382	.042	.447	9.138	<.001
Core Strategies	.205	.064	.157	3.213	<.001
Used DAP	1.642	.705	.101	2.329	<.02

[a]Predictors: (Constant), QuarkNet Influence on Teaching, Core Strategies, Used DAP
[b]Dependent Variable: Approach to Teaching

Strategies (added second), and Use of DAP activities (added third) are statistically related to **Approach to Teaching** scores [$F_{(3,\ 386)} = 65.99$, $p < .001$, with an $R^2 = .34$]. Although this analysis is informative, it does not take into consideration that teachers participated in QuarkNet nested, as a rule, within their local center.

QuarkNet Centers *Matter*

As just stated and in the main, teachers participate in QuarkNet through their local center. Thus, statistically, it is plausible that center-related variance is systematic and not random (that is, not independent as required in a simple multiple regression analysis). Or said in another way, it is likely that teachers within a given center are more like other teachers within that center than when compared to other QuarkNet teacher who participate in the program at other centers; at least in terms of how we measure their exposure to the program and teacher-level outcomes.

Several statistical steps were necessary before we could explore the influence that centers have on teacher-level and student-level outcomes (the latter is discussed in the next section). First to meet analysis requirements, included centers had at least 10 teachers who engaged in QuarkNet and who responded to the full Teacher Survey. This requirement resulted in the inclusion of 24 centers (31 combined centers) and a total of 390 teachers. Although this represents 80% of participating teachers who completed their surveys, it is important to note that this is indeed a subset of teachers. (With the combined total this represents about 60% of the centers.)

Second as an interim check, analyses showed that QuarkNet centers were statistically related to program exposure (Core Strategies, p <.001), as well as teacher-level outcomes (Approach to Teaching, p <.001; QuarkNet's Influence of Teaching Strategies,

Table 23
Approach to Teaching Scores Nested by Centers:
Summary Statistics and Related Variables
Model Summary[a]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
Final	.620[b]	.384	.378	6.509

Coefficients[b]

Model	Unstandardized Coefficients		Standardized Coefficients	*t*	Sig.
	B	Std. Error	Beta		
(Constant)	-5.862	5.01			ns
QN's Influence on Teaching	.383	.047	.436	8.154	<.001
Core Strategies	.156	.070	.122	2.224	<.03
Center Mean Scores: Approach to Teaching	.526	.122	.208	4.32	<.001

[a]Predictors: (Constant), QuarkNet Influence on Teaching; Core Strategies; Center Mean Scores: Approach to Teaching
[b]Dependent Variable: Approach to Teaching

p <.001); student-level outcomes (Student Engagement, *p* <.04; QuarkNet's Influence on Student Engagement *p* <.001); and, Long-term Outcomes: Teachers, (*p* <.001); This strongly suggests that center-level variance is systematic; therefore it needs to be accounted for in subsequent analyses. To accommodate this, center-level means were created for program exposure (Core Strategies) and all teacher-level and student-level outcomes.

To explore this potential relationship, we took teacher data from the aforementioned 24 (31 combined) QuarkNet Centers and analyzed these data based on a hierarchical multiple regression analysis that included Core Strategies scores, Use of DAP activities, QuarkNet's Influence on Teaching, and Center-level mean scores. These results are summarized in Table 23. That is, perceived QuarkNet's Influence on Teaching, Core Strategies, and Center-level mean scores are statistically related to **Approach to Teaching** scores [$F_{(3,\ 316)} = 65.66$, $p < .001$, with an $R^2 = .38$]. (Use of DAP activities was no longer statistically significant.)

Figure 11 provides a visual of the degree of variability of **Approach to Teaching** mean scores across these 24 (31 combined) Centers.

We caution that these analyses are preliminary (and are correlational in nature and do not suggest causality); however, survey data over multiple program years has provided some clarity. These analyses suggest that as measured by teacher-related outcomes, the Center in which teachers participate in QuarkNet *matters*. Specifically, these analyses suggest that center-related differences are systematically related to teacher's perceived

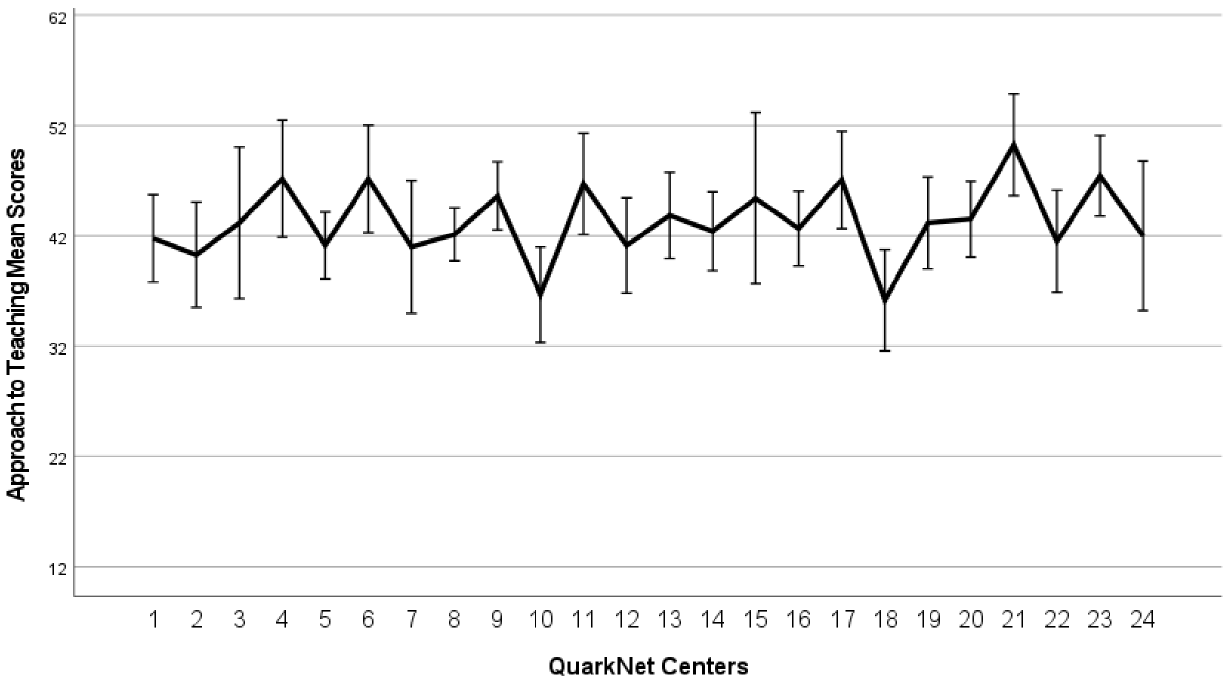


Figure 11. Mean Approach to Teaching Scores for 24 (31 combined) QuarkNet Centers (error bars represent 95% confidence intervals)

influence QuarkNet has had on their teaching practices. Further, the center in which a teacher participates in QuarkNet is related to exposure to core program strategies.

To summarize, the weight of the evidence suggests that there is a positive relationship between the type and degree of program engagement and exposure to core program strategies; and use of DAP activities by teachers in their classrooms. In turn, exposure to core program strategies, which serves as a surrogate to the above, and the perceived influence QuarkNet have on teaching are related to teacher outcomes (Approach to Teaching scores). When viewed through the nesting of teachers by QuarkNet centers, these relationships are *systematically tied* to the Center in which the QuarkNet teacher engages in the program.

Table 24
Student Engagement: Summary Statistics and Related Variables
Model Summary[a]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
Final	.745	.555	.551	2.374

[a]Predictors: (Constant), QuarkNet's Influence on Student Engagement, Approach to Teaching, QuarkNet's Influence and QuarkNet's Influence on Teaching

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	4.265	.801		5.322	<.001
QuarkNet's Influence on Student Engagement	.491	.043	.563	11.527	<.001
Approach to Teaching	.230	.021	.513	10.855	<.001
QuarkNet's Influence on Teaching	-.111	.021	-.284	-5.203	<.001

[a]Dependent Variable: Student Engagement

Student Engagement

How is QuarkNet related to Perceived Student Engagement?

Based on what we have learned from the Approach to Teaching outcome analyses, the following variables were placed in a stepwise, multiple regression analysis: Used DAP Activities and Core Strategies (each used as a surrogate measure for type of QuarkNet engagement related to: Data Camp, Variety of Workshops, and Masterclasses), Approach to Teaching, QuarkNet's Influence on Teaching, and QuarkNet's Influence on Student Engagement to explore these relationships to **Student Engagement** (the dependent measure). The following were statistically related: QuarkNet's Influence on Student Engagement (as perceived by teachers) (entered first); Approach to Teaching; and, QuarkNet's Influence on Teaching [$F_{(3,\ 344)}$ = 141.76 p < .001, with an R^2 = .55]. See Table 24 for the summary statistics for this analysis.

Table 25
Student Engagement Scores Nested by Centers:
Summary Statistics and Related Variables
Model Summary[a]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
Final	.730	.533	.524	2.343

[a]Predictors: (Constant), QuarkNet's Influence on Student Engagement, and Student Engagement Mean by Center

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	B	Std. Error	Beta		
(Constant)	1.412	2.458			*ns*
QuarkNet's Influence on Student Engagement	.421	.049	.480	8.632	<.001
Approach to Teaching	.204	.023	.478	8.747	<.001
QuarkNet's Influence on Teaching	-.063	.025	-.163	-2.539	<.02
Center-level Mean Scores: Student Engagement	.480	.153	.157	3.148	<.01
Center-level Mean Scores: QuarkNet's Influence on Teaching	-.121	.049	-.128	-2.462	<.02

[a]Dependent Variable: Student Engagement

From the analyses of teacher outcomes, we have learned that nested Centers is an important phenomenon that needs to be incorporated into these assessments. Thus, in a similar way, we explored how this relationship is impacted by the center in which the QuarkNet teacher experiences the program relative to student-level outcomes. When analyzed with this nesting in mind, results show that this relationship is *systematically tied* to the Center in which the QuarkNet teacher engages in the program. That is, Student Engagement (as perceived by teachers) is statistically related to QN's Influence on Student Engagement, Approach to Teaching, QuarkNet's Influence on Teaching, and Center-level mean scores: for Student Engagement; and Center-level mean scores for QuarkNet's Influence on Teaching [$F_{(5,\ 275)} = 62.73$, $p < .001$, with an $R^2 = .53$]. See Table 25 for a summary of this analysis and Figure 12 for a visual of these mean scores by individual QuarkNet center.

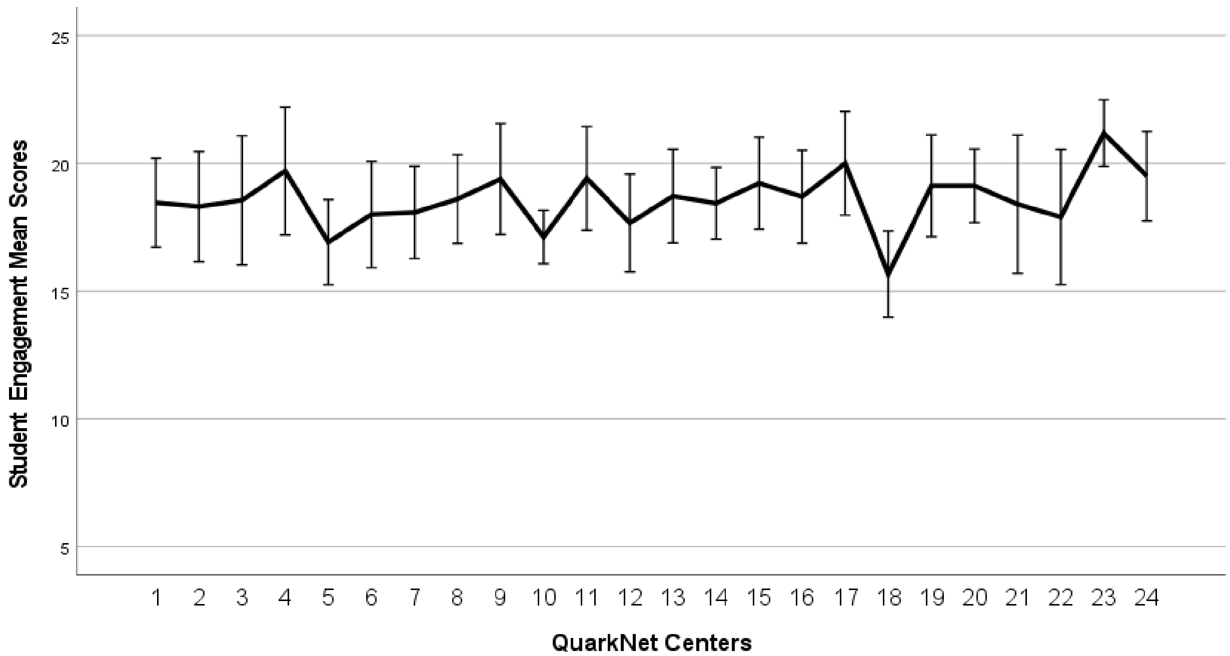


Figure 12. Mean Student Engagement scores for 24 (31 combined) QuarkNet Centers (error bars represent 95% confidence intervals)

In summary, the Center in which teachers participate in QuarkNet *matters* in terms of perceptions of exposure to program core strategies and teacher- and student-level outcomes. Given that these analyses suggest that the differences between centers (i.e., variance associated with centers) is systematic and not random, going forward final regression analyses of these outcomes will incorporate QuarkNet centers into future analyses whenever feasible (i.e., hierarchical multiple regression).

Figure 13 provides a visual of these relationships for teacher- and student-level outcomes (along with perceived exposure to core strategies scores) suggesting the correlational nature of these data. Please note that student engagement is measured on a different scale than core strategies scores and teacher level outcomes. We have kept these original scale score ranges to help provide a clearer picture of these relationships.

Figure 13 suggests that Core Strategies scores as well as Approach to Teaching scores and QuarkNet's Influence on Teaching (as perceived by teachers) are statistically related to the Center in which teachers are engaged in QuarkNet. Indeed, these correlations are notable (Core Strategies and Approach to Teaching Scores, $r = .45$; Approach to Teaching and QuarkNet's Influence on Teaching, $r = .57$; and, Core Strategies and QuarkNet's Influence on Teaching, $r = .56$). QuarkNet's Influence on Student Engagement (as perceived by teachers) is also statistically related to the center in which the teachers engage in QuarkNet (QuarkNet's Influence on Student Engagement and Core Strategies, $r = .26$; QuarkNet's Influence on Student Engagement and Approach

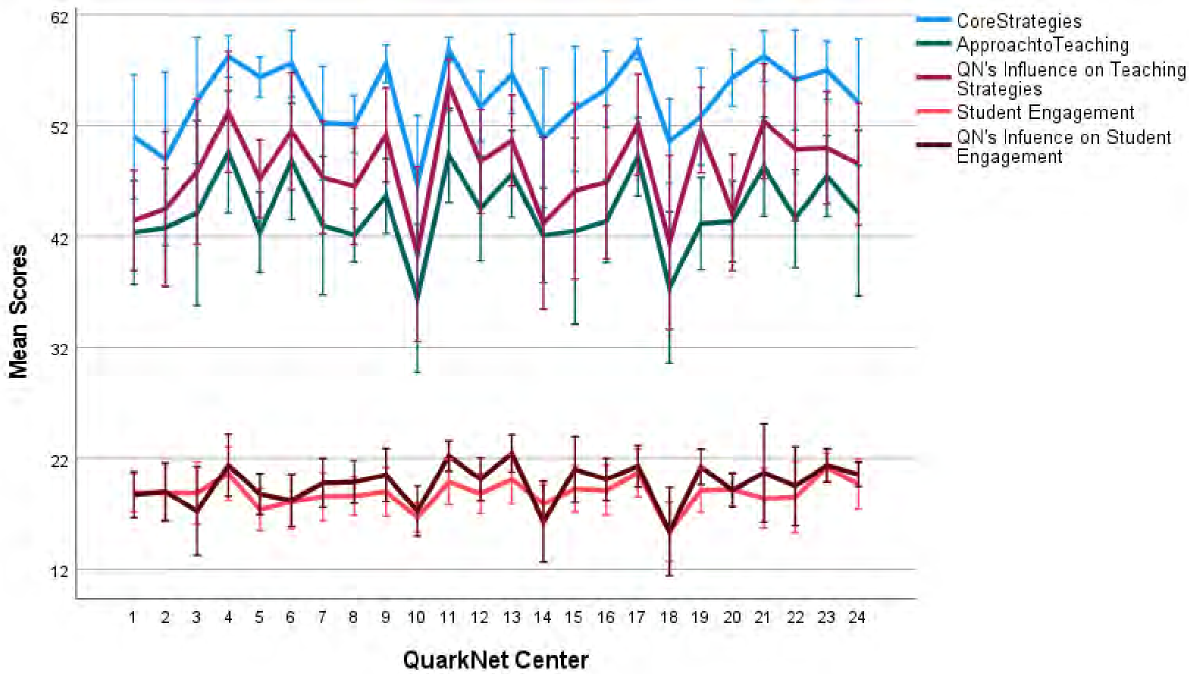


Figure 13. Comparison of mean scores for 24 (31 combined) QuarkNet Centers by core strategies, teacher-level and student-level outcomes (error bars represent 95% confidence intervals). Please note that student engagement is measured on a different scale.

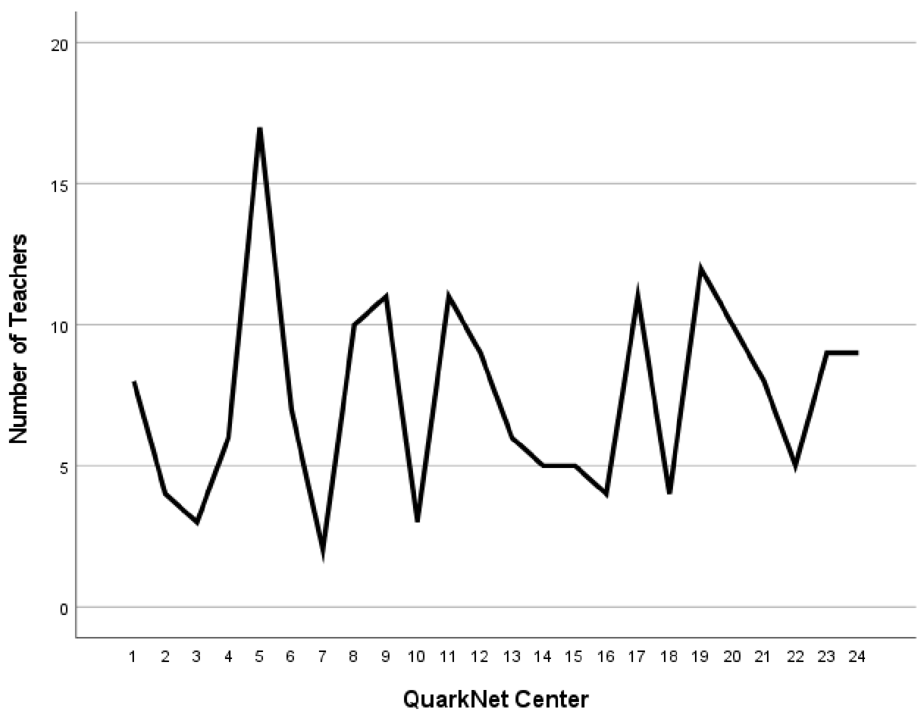


Figure 14. Number of teachers who reported using Data Activities Portfolio (DAP) activities in their classroom for 24 (31 combined) QuarkNet Centers.

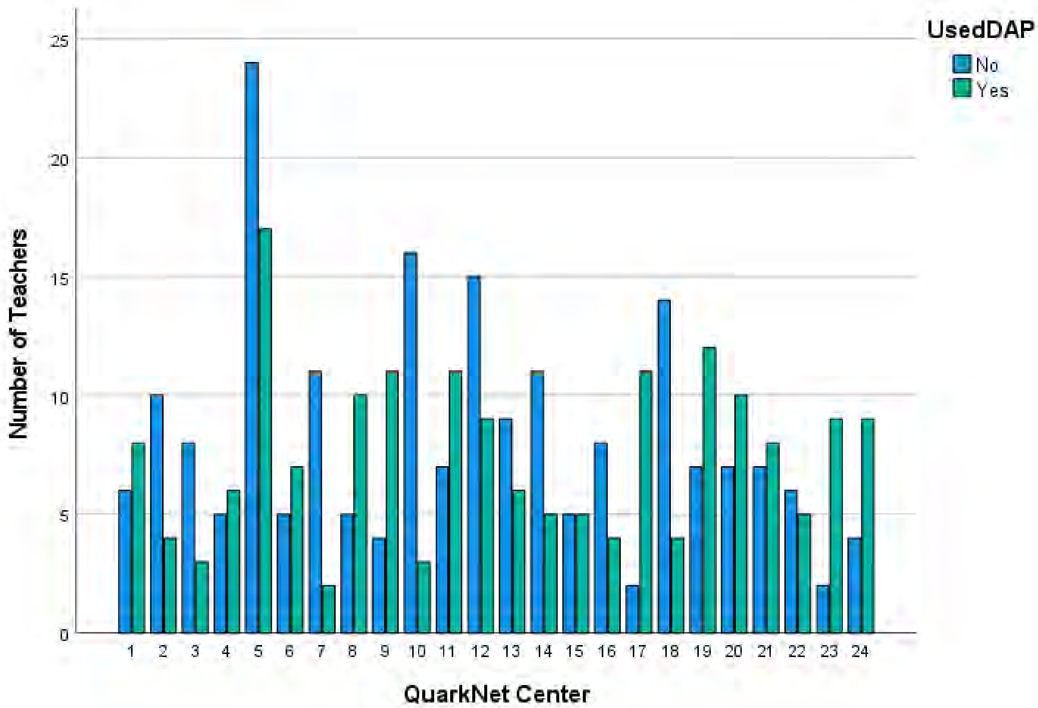


Figure 15. Comparison of use (and not used as yet) of Data Activities (DAP) activities by teachers within 24 (31 combined) QuarkNet Centers.

to Teaching, r =.40; and QuarkNet's Influence on Teaching and QuarkNet's Influence on Student Engagement, r=.65).

Center level differences are evident as shown in Figure 13. What is striking, however, is the similarity and consistence of the pattern reflected in the data across Core Strategies, QuarkNet Influence of Teaching, and Approach to Teaching scores are reviewed. As shown, for each center mean Core Strategies scores are, on average, highest, followed by mean QuarkNet Influence on Teaching scores; followed by mean Approach to Teaching scores. This pattern strongly underscores that exposure to QuarkNet programs (as measured by Core Strategies scores) is consistently and statistically related to measured Approach to Teaching and the perceived influenced QuarkNet has had on this behavior.

Figure 14 (previous page) depicts the number of teachers within each of these QuarkNet centers who reported using activities from the Data Activities Portfolio in their classrooms. (Please keep in mind that the number of teachers per center ranged from a low of 11 to a high of 40 teachers.) This, too, suggests a similar pattern across Centers and may contribute to our understanding of the variability within Centers related to teacher- and student-level outcomes. To provide a fuller picture, the relationship between the use of Data Activities Portfolio (DAP) activities by teachers within 24 (31 combined) QuarkNet Centers is shown in Figure 15 (both the number of teachers who reported using these activities and those teachers who indicated that they have not used DAP activities in their classroom, at the time they completed their survey). Analyses suggest that Use of

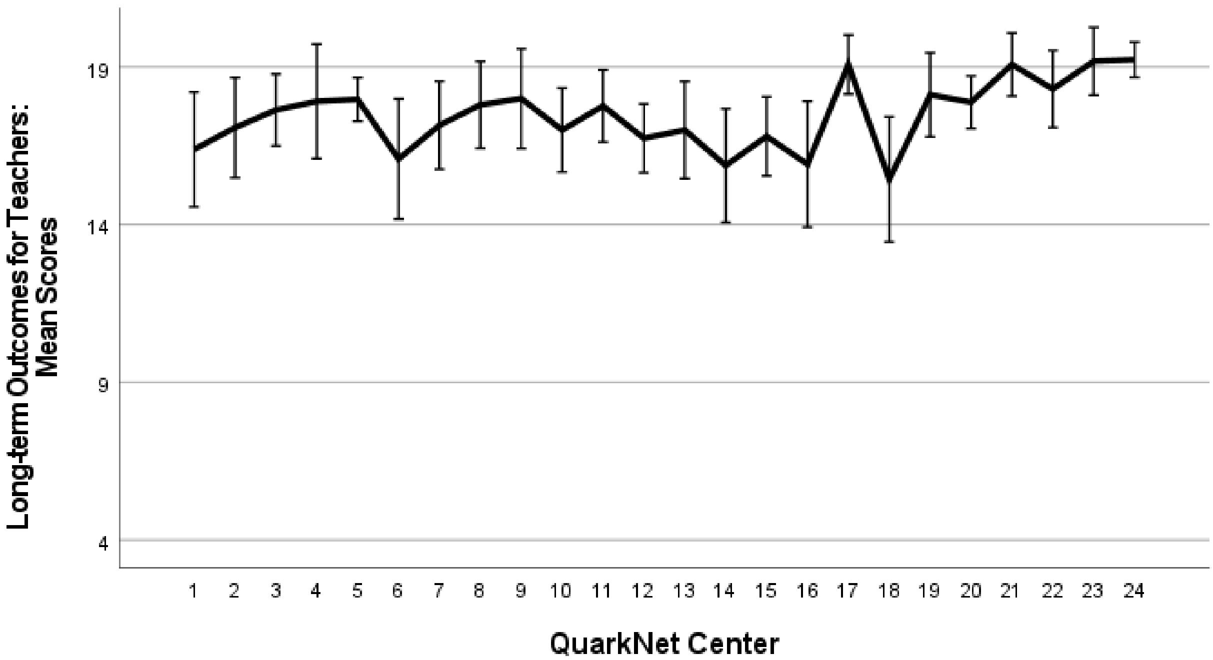


Figure 16. Mean long-term outcome scores (teachers) across 24 (31 combined) QuarkNet Centers.

DAP activities is also statistically related to QuarkNet Centers [$\chi^2_{(23, 377)} = 52.27$, $p < .001$].

Long-term Outcomes

As we have mentioned, we have created a *new* scale based on four items that asked teachers about the use of resources in the classroom (QuarkNet and other sources), perceptions of the individual teacher's increased science proficiency, forming collegial relationships with others, and their students' comfort level with inquiry-based science. At this point in time, we have refrained from adding this scale to regression analyses (either simple or hierarchical). Rather at this stage it may be more helpful to view these data through the descriptive analyses to come in subsequent sections of this report. That said, Figure 16 provides a visual of the degree to which these mean scores vary across 24 (31 combined) QuarkNet centers.

Summary of Outcomes Analysis

To summarize, the weight of the evidence suggests that there is a positive relationship between the type and degree of program engagement and exposure to core program strategies, and use of DAP activities by teachers in their classrooms. In turn, exposure to core program strategies, which serves as a surrogate to type and degree of program engagement, and the perceived influence QuarkNet have on teaching are related to teacher outcomes (Approach to Teaching scores). Student Engagement (as perceived by teachers) is positively related to QN's Influence on Student Engagement, Approach to

Teaching, and QuarkNet's Influence on Teaching. For both analyses, when viewed through the nesting of teachers by QuarkNet centers, these relationships are *systematically tied* to the Center in which the QuarkNet teacher engages in the program.

Thus, the Center in which teachers participate in QuarkNet *matters* in terms of perceptions of exposure to program core strategies and teacher- and student-level outcomes. A consistent pattern across Centers, especially for teacher outcomes, is evident and this pattern similarity suggests the importance of QuarkNet's influence, exposure to program core strategies and the reported approach to teaching in classrooms.

There may be many reasons for this variability across Centers and to some degree such variations should be expected (i.e., invariance across these Centers as measured would indeed be odd). A simple interpretation of these analyses may be that those centers who have integrated classroom implementation into their workshops and opportunities (including engagement in DAP activities, and opportunities for teachers to present and discussion implementation ideas) show higher scores (on average) on measured teacher-level outcomes and student-level outcomes. This is supported by the perceived influence QuarkNet has on teacher and student outcomes, exposure to program core strategies, and more teachers reporting the use of DAP activities in the classroom.

It is helpful to keep in mind that these analyses reflect the cumulative experience of QuarkNet as reported by teachers over time including their engagement in the QuarkNet workshop that coincided with when they completed their full Teacher Survey during the 2019 through 2022 program years. Data from the Update Teacher Survey are more temporally to these implemented program experiences, each providing a snap shot at a given point in time.

In general, during the grant period, workshops moved toward embedding more DAP activities into their agendas and providing more structured time for implementation planning and discussion among teachers. At the same time, the portfolio of activities (i.e., DAP) changed over time growing in overall number as well as the resource materials associated with each activity. Thus, engagement in QuarkNet programs during this grant period has not remained static but reflected the dynamic changes to program structure and content that occurred over this grant period.

In many respects, these data are still preliminary although this may seem frustrating given a 5-year grant period. We have learned that adding centers into the analytical mix (through hierarchical regression) is important, but because of analysis requirements this has been made possible only by the collection of data over multiple years. We also recognize that we are analyzing complex behaviors that are likely influenced by factors and phenomena (e.g., school-wide characteristics, state education requirements and frameworks) well beyond our ability to incorporate through these models. That said, the suggested relationship between QuarkNet and teacher and student outcomes is "not nothing."

We look to descriptive analyses that incorporate these data plus information from the Center Feedback Process, workshop agendas, center annual reports, and implementation plans by individual teachers to help us get a "ground level" picture as to what transpires at these individual center levels and how this links to outcomes.

Implementing the Center Feedback Template: Informing These and Other Analyses

As we have mentioned, the involvement of Center-level engagement in QuarkNet, as measured through the Center Feedback Template, has been added to the mix of the individual-teacher analyses to provide the context in which teachers participate in QuarkNet. This information is used to corroborate (or not) teacher-level responses and is used to gauge center-level outcomes in their own right. Through this center-level analysis, we have hoped to offer a more complete picture of the relationships between program engagement and teacher (and their students) program outcomes. And center-level outcomes may help to explain the center-level variability just noted in the analyses of teacher-level and student-level outcomes. Table 26 shows the timetable of this evaluation effort.

Four QuarkNet centers participated in a pilot test of the process in November 2019. Six additional centers were rolled out in Spring 2020; five centers were added in December 2020/January 2021; four centers were added in Spring 2021; four centers were added in Fall 2021; and three centers were added in Spring 2022. An additional center was added in Spring 2023. All centers have completed this process for a total of 27. (One center was determined to be semi-active and not included in this total.)

A few of these centers are regarded as combined centers reflecting joint participation by two or more centers; these are: Fermilab/University of Chicago; Rice University/ University of Houston; Boston Area/Brown University; University of Iowa/Iowa State University; University of Illinois at Chicago/Chicago State University; University of Oklahoma/ Oklahoma State University; and Brookhaven National Laboratory/Stony Brook University. This brings the total participating in this effort to 34 combined centers.

A total of 21 (28 combined) centers included in the outcomes analyses have completed their Center Feedback Template.

Table 26
QuarkNet Centers with Completed Feedback Templates

Center	Completion Date	Center	Completion Date
Pilot Test		**Added in Spring 2021**	
Catholic University of America	December 7, 2020	Syracuse University	May 25, 2021
Fermilab/University of Chicago[a]	February 17, 2020	Black Hills State University	May 3, 2021
Rice University/ University of Houston[a]	March 31, 2020	University of Puerto Rico-Mayaguez	June 10, 2021
Colorado State University	July 21, 2020	Virtual Center	April 22, 2021
Added in Spring 2020		University of Wisconsin – Madison	Semi-active will revisit
University of Cincinnati	April 6, 2020	**Added in Fall 2021**	
Boston Area/Brown University[a]	May 19, 2020	Texas Tech University	November 16, 2021
University of Kansas	May 21, 2020	University at Buffalo	November 11, 2021
Virginia Center	May 21, 2020	Johns Hopkins University	November 14, 2021
Kansas State University	June 24, 2020	Purdue University NW	November 20, 2021
University of Minnesota	June 29, 2020		
Added in December 2020/January 2021		**Added in Spring 2022**	
Florida State University	January 24, 2021	University of Illinois at Chicago/Chicago State University[a]	February 11, 2022
Southern Methodist University	January 24, 2021	University of Oklahoma/ Oklahoma State[a]	February 18, 2022
Virginia Tech University	February 15, 2021	University of Notre Dame	April 19, 2022
Vanderbilt University	February 23, 2021	**Added in Spring 2023**	
University of Iowa/Iowa State[a]	February 15, 2021	Brookhaven National Laboratory/Stony Brook[a]	March 28, 2023

[a]Combined center.
Note. 21 (28 combined) centers included in the outcomes analyses have completed their Center Feedback Template.

At the start of this process, a center was selected because a QuarkNet staff teacher had been/is very familiar with the center and had good rapport with its mentor(s) and lead teachers. These early selections tended to represent centers that have successfully implemented QuarkNet over the years; in part because these selected centers tend to reflect the national program (and likely align well with the Program Theory Model) through active participation in programs such as workshops (either nationally or center-led), e-Labs, and/or Masterclasses. As we moved through this process, we anticipated that selected centers were reflective of QuarkNet engagement that is both strong in some areas and in need of reflection in other areas (which may have been the case for centers that were selected early as well). Overall, we see this process as helping the evaluation and through this process offering information that we hope is helpful to QuarkNet staff teachers and to the centers themselves.

As already noted, these centers were selected based on conversations with staff teachers and the evaluator. For each of these centers, Section II of the template was completed by the evaluator (and reviewed by the Staff Teachers) before it was distributed. One lesson gleaned from this process is that Section II offers a succinct summary of programs and events at a particular center (an easy reference of two years of agenda and annual reports). Early feedback from centers suggests that pre-filling Section II was helpful and staff teachers have noted that this was of value as well.

Thus, there was a dual purpose in the analysis of center-level information. First, to corroborate (or not) teacher-level responses and provide the context of these responses (at the center level); and second to explain, if possible, the center-level variability noted in analyses of teacher-level and student-level outcomes.

Results: Center-Level Outcomes

To begin, we looked at the engagement of teachers as active learners, as students as part of their participation in QuarkNet; and the alignment of the implemented QuarkNet program with NGSS science practices. For Table 27 (and later Tables 30 and 31) information from 21(28 combined) centers are included; that is, a center that: (1) completed their Center Feedback form; and (2) were included in the outcomes data. [Please note, all of these centers had at least 10 teachers who completed the full survey (a requirement of the outcomes analyses)].

<u>Engagement of teachers as active learners</u>. Engagement by participating teachers as active learners is a core strategy of the program that is assessed at both the teacher- and center-levels. At the center level through the Center Feedback Process, centers were asked about their teachers' engagement as active learners as students (e.g., *Almost all, Most, Some*) and the degree to which QuarkNet has influenced this engagement (e.g., *Very High, High*). Individual teachers were asked a parallel question as part of the Full Survey that they completed (i.e., *QuarkNet provides opportunities for me to: a. Engage as an active learner, as a student).*

A summary of this information is shown in Table 27. As can be seen, there is considerable agreement between how the center has assessed this engagement (e.g., *Almost all; most teachers)* compared to individual teacher's assessment of the level of these opportunities at the same center (e.g., rated as "*Excellent*," "*Good*"). These centers have indicated that they have rated QuarkNet's influence on teachers valuing engagement as active learners as "*High*," or "*Very High*." In particular, 17 centers indicated that "*Almost all"* teachers were engaged in the workshop as active learners as students. In keeping with this, 83.1% of the teachers from these centers rated this opportunity as "*Excellent.*" This was the most frequent response by individual teachers for each of the centers presented in Table 27. Also, 12 centers indicated that they rated QuarkNet's influence on active-learner engagement as "*High*."

Table 27
Summary of Center-level Assessment and Individual Teacher-levels Responses to:
Opportunities for Teachers to Engage as Active Learners, as Students

Center	**Center-level Assessment**			**Individual Teacher-level Responses**					**Center-level Assessment**	
	Engage Teachers as Active Learners, as Students			QN provides opportunities for teacher to engage as an active learner, as a student					QN's Influence on Teachers (on this behavior)	
	Almost All	Most	Some	Excellent	Good	Average	N/A	Total	Very High	High
Boston Area/ Brown University[a]		✔		11	2	0	0	13		✔
Brookhaven National Laboratory/Stony Brook[a]	✔			9	4	0	0	13	✔	
Catholic University of America	✔			7	3	0	0	10	✔	
Colorado State University	✔			10	1	0	0	11	✔	
Fermilab/University of Chicago[a]	✔			31	1	0	1	33		✔
Florida State University/	✔			10	1	0	0	11		✔
Johns Hopkins University	✔			11	2	0	0	13	✔	
Kansas State University	✔			12	2	0	0	14		✔
Oklahoma State/University of Oklahoma[a]	✔			13	3	0	0	16	✔	
Rice University/University of Houston[a]	✔			16	0	0	0	16		✔
Southern Methodist University	✔			18	3	1	0	22		✔
Syracuse University		✔		7	4	0	1	12		✔
University of Cincinnati			✔	11	2	1	0	14		✔
University of Illinois at Chicago[a]	✔			8	2	0	0	10		✔
University of Iowa/Iowa State University[a]	✔			9	4	0	0	13	✔	
University of Minnesota	✔			11	0	0	0	11	✔	
University of Notre Dame	✔			14	2	0	0	16	✔	
University of Puerto Rico – Mayaguez		✔		14	1	0	0	15	✔	
Vanderbilt University	✔			6	2	2	0	10		✔
Virginia Center	✔			7	3	0	0	10		✔
Virtual Center	✔			11	2	0	0	13		✔
Total	17	3	1	246 (83.1%)	44 (14.8%)	4 (1.4%)	2 (0.7%)	296 (100%)	9	12

Note. Percents are used only for the grand total across centers because the responses within an individual center are too small to justify percentages. [a]Combined center (28 total).

Alignment of the implemented QuarkNet program with NGSS Science Practices. We have reviewed the alignment of the *implemented* QuarkNet program with NGSS Science Practices across centers (rather than by individual center). In Figure Set 15, the graph in the upper left-hand corner reflects the potential exposure to NGSS practices based on all DAP activities *as designed* and is repeated here (previously Figure 4) for ease of comparison to QuarkNet DAP activities as *implemented*.

The graph in the upper right-hand corner shows the exposure to NGSS practices based on *implemented* QuarkNet workshops held during the 2019 through 2022 program years (based on review of workshop agendas for each of these program years) where DAP activities embedded in the workshop were counted, and then aligned with NGSS practices.

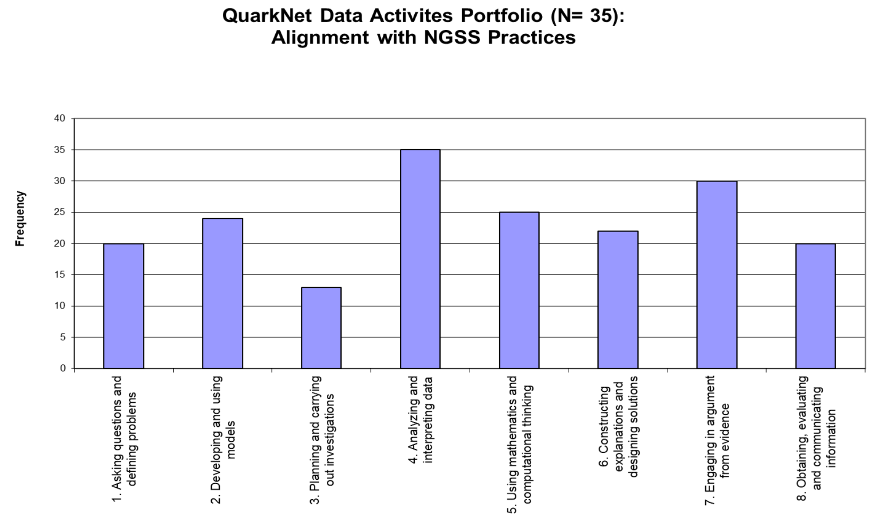
Taken together data in these two graphs suggest the alignment of NGSS science practices evident in DAP activities at the program level as *designed;* and as *implemented* --- via workshops held across the program years during this grant period.

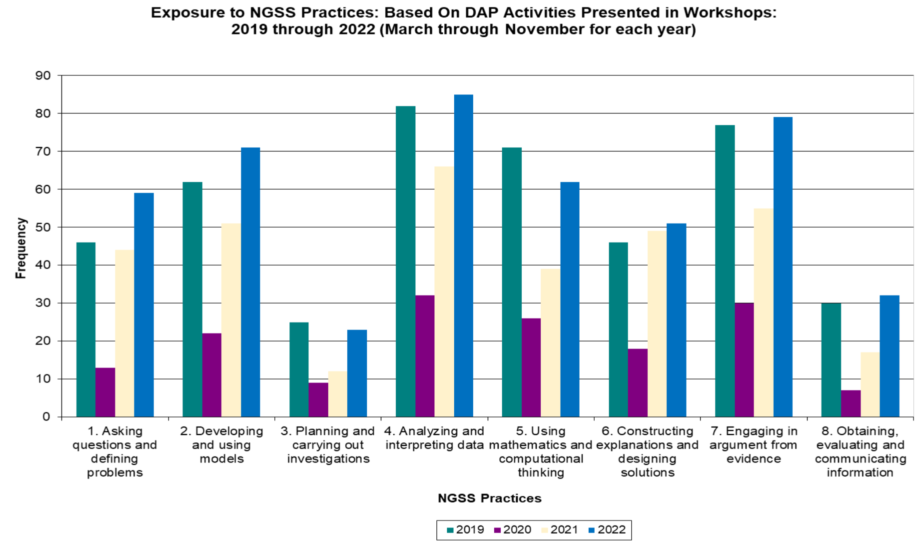
(Also evident, the graph in the upper right-hand corner suggests that the implementation level of embedded DAP activities returned to pre-COVID levels, comparing data from 2019 and 2022 program years.)

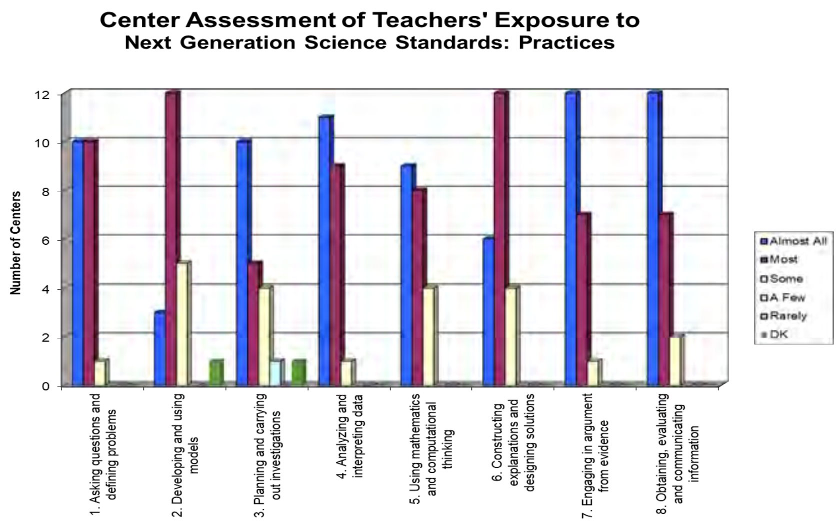
The next graph in the lower left -hand corner presents the perceived engagement in NGSS practices by teachers based on center-level assessment of their *implemented* program. This reflects an assessment of engagement at the individual teacher level. (Based on responses from Center Feedback Templates.) As shown, data in this graph suggest that the individual-teacher engagement at the center aligned with these NGSS practices, as "*Most*" or "*Almost All*" teachers engaged in endeavors that align with each of these science practices during their participation in QuarkNet.

The graph in the lower right-hand corner presents the centers' assessment of QuarkNet perceived influence of this alignment. (Again, based on responses from Center Feedback Templates.) This graph suggests that these centers judged QuarkNet's influence on participating teachers relative to these practices as "*High*" or "*Very High*."

Together these graphs suggest that, at the overall program level, participating QuarkNet teachers are engaged in scientific endeavors during the *implemented* program that align with NGSS science practices; and this engagement mirrors the pattern of alignment with the DAP activities as *designed*. Of importance, this engagement occurred at a high and frequent level as measured by the count of DAP activities embedded in workshops during multiple program years (at the overall program level) and as measured by center-level assessments based on center that participated in the Center Feedback Template process (at the individual teacher level).







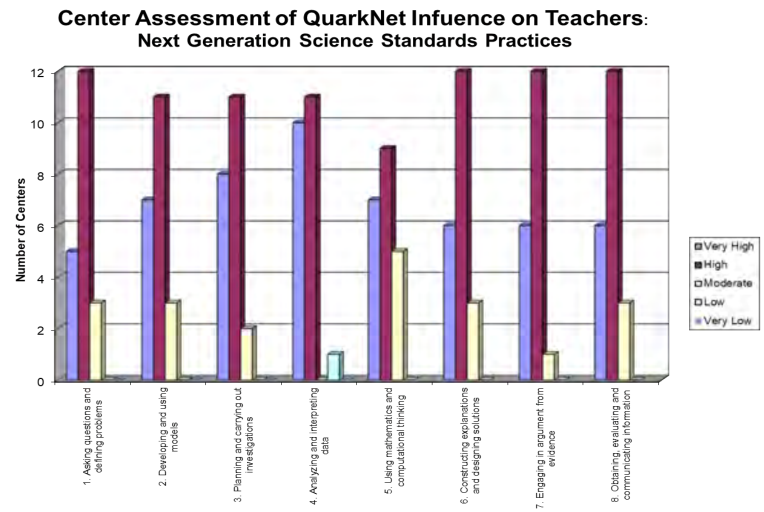


Figure Set 15. Alignment of Next Generation Science Standards (NSS) science practices and activities from the Data Activities Portfolio as designed (upper left-hand corner). Then, the exposure to NGSS practices based on *implemented* QuarkNet workshops held during the 2019 through 2022 program years (upper right-hand corner); and finally based on QuarkNet program content and DAP activities as assessed by center-level assessment of individual teacher engagement (lower left-hand corner) and then the same for perceived influence of QuarkNet on this alignment (lower right-hand corner).

Relevance of the Role of DAP Activities and Time Allocated for Implementation Planning and Discussion

Clearly there is very good agreement between individual teacher-level assessments and assessments at the center level as measured. (This will also be evident when we look at opportunities to form networks and lasting collegial relationships with teachers, scientists, and mentors in a subsequent section of this report.)

Although this is good news, it does not help explain the center-level differences noted in analyses of teacher-level and student-level outcomes. What seems relevant is: (1) the role of DAP activities used during workshops; (2) time allocated during workshops for classroom implementation discussion and plans; and (3) achieving this by centers working closely with QuarkNet staff teachers to help model events that reflect the Program Theory Model.

To explore these relationships descriptively and to perhaps provide insights into center-level differences in teacher-level and student-level outcomes already noted, individual-teacher reports across available program years as to use (or planned use) of DAP activities in their classrooms were reviewed. To this end, we created center-specific tables that extracted individual teacher responses related to DAP use (or planned use) across survey periods for each center included in the outcomes analyses and that completed their Center Feedback Template. These tables are shown in Appendix L for each center included in these analyses; the coded numbers in these tables are the same numbers shown in figures that highlight the quantitative analyses previously described.

In the narrative of this report, however, we focused on an example from two centers (see Tables 28A and 28B) to highlight potential center differences. From the quantitative analyses, mean scores for Center #11 and Center #10 were as follows, respectively: Core Strategies 58.13 (SD = 3.07) vs. 44.65 (SD = 10.52); Approach to Teaching 46.56 (8.78) vs. 35.13 (SD 6.89); QuarkNet's Influence on Teaching [55.36 (SD= 4.19)] vs. 38.83 (SD=10.82)]; Student Engagement [19.06 (SD =3.79) vs. 17.27 (SD = 2.08)]; and QuarkNet's Influence on Student Engagement [22.00 (SD = 2.45) vs. 17.73 (SD = 3.55)]. The descriptive analyses on reported use (or planned use) of DAP activities are shown in Tables 28A and 28B based on responses to an open-ended question about use of QuarkNet content and materials in classrooms. For each table, a given row represents a response from a given individual teacher -- starting with responses from the Full Survey and then data from any subsequent update surveys that a given teacher completed (if he or she provided this update).

Inspection of this table underscores a dramatic difference between teacher responses for these two centers reflective in both the qualitative (and the quantitative analyses highlight above). A total of 19 teachers from Center #11 responded and these responses suggest a progression of DAP activity use (or planned use) by many teachers across four years of survey data collection. In marked contrast, very few of the teachers from Center #10 reported using QuarkNet content and materials in their classrooms.

Table 28A
Self-reported Use of Data Activities Portfolio Activities: Based on Reponses from the Full Survey and then Responses from the Update Survey in Subsequent Years **Center #11**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #11	2019	2020	2021	2022
	I think engaging with the data would be the most helpful to students. They will learn to discover how to interpret data from different perspectives		I plan to use QuarkNet activities at the beginning of the year with careers in physics. I plan to use the particle cards to introduce modern physics to students. We can use the mass of z with the conservation unit. Examples: Mass of pennies, particle cards	
	Mass of the US penny		I plan on getting my cosmic ray detector working and try doing some e-labs and masterclass. Examples: Mass of Pennies Shuffling the particle deck Making tracks 1. I am really excited to use CMS data and the cosmic ray detectors	This year I plan on incorporating histograms and coding into my classes. I plan on using simple coding with matching potion time graphs to have students graph motion. I will be also using the standard model and have a much better background for teaching it. Examples: I have used the shuffling the particle deck and Rolling with Rutherford. I plan on using mean lifetime part 2 this next year for a more original way of doing half life representation.
	Shuffling the Particle Deck - It is a GREAT introduction to the standard model for students who have never seen it or are just learning about it. It also allows them to use pattern recognition and critical thinking to help students gain better understanding. I do like and use several others for similar reasons. I also like the teacher notes and organization of the activities, it makes using them much easier.		District Workshops sharing information, Careers in Physics, Detector Studies, analyzing data, scientific method, Mass of Z, histograms, Current Events. Examples: Mass of Z Particle Cards, W2D2	
	I used the data from CMS e-lab where my students do their own research and provide their outcome in form of research paper as a project.		I am going to create lesson plan where students learn about quark particles while they do research about various colliders while searching latest news. Examples: 1. Rolling with Rutherford. 2. Mass of Z. 3. Particle cards while printing sets for each group.	Data Activities, Content Knowledge using the Standard Model, STEP Up activities, Professional Development for Teachers. Examples: Plan to use: -Intro to coding -Energy, Momentum, and Mass -Step up -Changing the Culture.
	The activities give real world examples of advance physics concepts that can be used to teach physics fundamentals. CMS data can be used to teach conservation of energy, momentum as well as dimensional analysis application, concepts and even where and why it might be discounted.			

Table 28A

Self-reported Use of Data Activities Portfolio Activities: Based on Reponses from the Full Survey and then Responses from the Update Survey in Subsequent Years **Center #11**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #11	2019	2020	2021	2022
	"Mass of US Pennies" makes a great introductory lab exercise. "Calculate Top Quark Mass" is my most frequently used exercise.		I use the Data Activities at various times in the year especially when studying momentum and energy conservation. Examples: Mass of U.S. Pennies, Calculate the Z Mass Calculate the Top Quark Mass.	Case of the Missing Neutrino Energy, Momentum, and Mass Shuffling the Particle Deck. Examples: Mass of U.S. Pennies Shuffling thee Particle Deck Intro to Coding Using Jupyter Calculate the Top Quark Mass The Case of the Hidden Neutrino
	I teach both biology and physics but was primarily a biology teacher when I first learned about the e-lab. Having taught a year of IB physics I see a lot of opportunities to integrate the data activities in the classroom. In particular, the lessons that encourage students to derive relationships using graphical analysis prior to teaching the specific laws. This also provides a great resource for students looking to incorporate accessible and professional databases into their senior research projects in IB physics.			
	So far, I have not had time to do a complete activity, but I have pulled out portions of LIGO e-Lab, Quark Workbench and CMS Data Express.	I teach the conservation laws as part of the required state curriculum. I give my students a Standard Model lecture during the 4th quarter each year and I have them explore the Particle Adventure online. Examples: I used Rolling for Rutherford when I taught Chemistry. I would like to use Mass of Top Quark.	I plan to use the Step Up Careers Activity and Masterclass prep: Standard Model, Conservation Laws, Mass of Z activity. I have also taught about Gravitational Waves. Examples: Mass of Pennies, Particle Cards, Mass of Z Calculation.	Have done Rolling with Rutherford, Masterclass and Standard Model presentation. Plan to do Shuffling the Particle Deck, and Coding Activities. Examples: Use Rolling with Rutherford already, Plan to use Shuffling the Particle Deck and more STEP UP activities like Careers in Physics.
	Rolling with Rutherford and the Penny Lab			Personally I am using the coding skills I have gained to get students into coding with auxiliary lessons and tasks. I am currently being used as a biology teacher, so I have not been able to implement many of the activities in my classroom yet. However, I am able to provide better insight to students into what people in physics fields do.

Table 28A
Self-reported Use of Data Activities Portfolio Activities: Based on Reponses from the Full Survey and then Responses from the Update Survey in Subsequent Years **Center #11**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #11	2019	2020	2021	2022
	I have utilized several of the Data Analysis activities contained in the portfolio within my physics classroom. Rolling with Rutherford is an activity that provides students with the opportunity to use data they have generated for themselves, take measurements, and perform relevant calculations. The activity also provides students with the opportunity to learn firsthand how Rutherford made his influential discovery which resulted in our modern view of the composition of the atom.			
	Mass of the Penny, Quark Workbench, Shuffling the Deck, Rolling with Rutherford, Mass of Top Quark	I intend to use coding in the jupyter notebooks for both my engineering classes as well as my physics classes as a way to deal with large data sets as well as some basic coding skills. Examples: Penny Mass, Quark Workbench, Dice Histograms		I will be using short coding activities throughout my courses. I use data activities as year starters (Shuffling the Particle Deck and Quark Workbench). I also use particle physics and momentum conservation. Examples: Shuffling the Particle Deck, Quark Workbench, Calculating the Z Mass.
	Program Year (Year of Full Survey)	Subsequent Program Year		Subsequent Program Year
	2020	2021		2022
	I used the Rutherford model of finding subatomic particles in an atom and implemented Bohr model too.			Coding activities, neutrino activities etc. implemented python programing to calculate kinetics rate.
	Program Year (Year of Full Survey)	Subsequent Program Year		
	2021	2022		
	Rolling with Rutherford and mass of pennies.	I have incorporated Rolling with Rutherford with my chemistry students, particle deck, mean ½ life. Examples: Rolling with Rutherford, half life, particle deck.		
	Haven't had a class to use it in yet.	Will be using Shuffling the Particle Deck, Particle Transformation, Calculate the Top Quark and Mapping Poles this year. The opportunity to work with other teachers in great.		
	Just introduced to them in this workshop so have not had a chance to implement.			
	Input data into spreadsheet for calculation and graphing.			

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of a total of 19 teachers.)

Table 28B

Self-reported Use of Data Activities Portfolio Activities: Based on Reponses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #10**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #10	2019	2020	2021	2022
	With the advent of Next-Generation Science Standards (NGSS), school curriculum is in flux--and topics of study have not yet been firmly established at this time.	QuarkNet materials were implemented into my General Physics classes in two areas: 1) study of forces, and 2) applications of Conservation of Energy/ Momentum. The LHC was the primary tool. My current school Physics program has a fairly set lab schedule which makes it challenging.	I integrate the fundamental force carriers/The Standard Model when we introduce the forces unit. E-labs will be integrated on a case-by-case basis depending on the topics. Internet connectivity at my school is unreliable--so any access to websites or the 'Cloud' is on a hit-or-miss basis--which limits access to portals like QuarkNet's DAP	
	I have not used these activities yet (this workshop was my first introduction to them) but I will do so!			

Program Year (Year of Full Survey) 2020	Subsequent Program Year 2021	Subsequent Program Year 2022
I have not been introduced to the Data Activities Portfolio.		
This is my first BAMA workshop and I'm planning on using what I'm learning here in my teachings of chemistry		
Mean Lifetime, Part 1: I actually developed a lab that was similar to this and used it for several years in conjunction with our Muon Rest Life Experiment. So I can't comment on the specifics of the version in the Data Portfolio, but the idea of rolling dice to build a histogram of particle lifetimes, and then using this to study mean-life and half-life, and to build conceptual understanding of how distributions of particle lifetimes are very different from lifetimes of people or pets, for example... that's a really valuable exercise for students. Rolling with Rutherford is another good one. Again, I didn't use this exact version, but something similar from an old edition of the Conceptual Physics lab book. Students were guided to develop their own formula to calculate the size of objects they couldn't see using only the statistics from collisions with marbles. Another powerful scientific exercise with direct application to particle physics.		
have not had a chance yet.		

Program Year (Year of Full Survey) 2021	Subsequent Program Year 2022
N/A so far. Maybe in the future as I'm able to explore the activities more.	I'm building a Cloud Chamber for my Astro students to observe subatomic particles. I'm using that to talk cosmic rays and aurorae. I'm using histograms to collate data on labs. I'm hoping to use some of the e-labs but I haven't had a chance to decide on which/how yet. My Astro class is a survey class so I don't get a lot of chances to dive deeply as many of the QuarkNet resources.

Program Year (Year of Full Survey) 2022	
Rutherford, Mass of the Higgs	

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of a total of 19 teachers.)

Table 29
Comparison of Exposure to DAP Activities during Workshops
Held across Four Program Years

Program Year	Center #11	Center #10
2019	*Shuffling the Particle Deck* *Histograms: Uncertainty* *TOTEM Data Express* *Making it Round the Bend* *Qualitative or Quantitative* *Calculate the Z Mass* *Calculate the Top Quark Mass* *CMS measurement*	*The Case of the Hidden Neutrino* *What Heinsberg Knew* *Shuffling the Particle Deck* MINERvA Masterclass Measurement
2020	No workshop	*Rolling with Rutherford*
2021	*Shuffling the Particle Deck* *Rolling with Rutherford* *Calculate the Mass of Z* *Signal and the Noise: The Basics* *Making Tracks I* *STEP UP: Careers in Physics* *STEP UP: Women in Physics* Implementation plans and discussion	No DAP activities included in event
2022	*The Case of the Hidden Neutrino* *Shuffling the Particle Deck* *Histograms: the Basics* Masterclass measurement Implementation plans and discussion	*Particle Cards (virtual)* *Quark Workbench*

Table 29 suggests that exposure to DAP activities and time to engage in these activities during workshops by teachers as active learners (as students) over the course of the grant period were not the same for these two centers. This may contribute to the disparity in reported use of DAP activities by teachers at each of these centers.

Of note, these two centers were selected, in pursuit of explaining center-level differences found in teacher-level and student-level outcomes, to emphasize the point that exposure and engagement in DAP activities and in turn time allocated to develop classroom implementation plans (and discussion) during workshops may be key to encouraging classroom use of QuarkNet content and materials. Picking two centers randomly from among the 21 (28 combined) centers may not have resulted in drawing the dramatic differences among teachers who report frequent use of DAP activities versus those that have not used QuarkNet materials to date. Yet, the present comparison does suggest that exposure to and engagement in DAP activities play an important role.

Please keep in mind, in collecting data from the Full Survey we asked teachers to reflect on their past use of DAP activities in their classrooms. (Although some teachers may respond to this question as to what they might do in the future.) Thus, there is not necessarily a chronological relationship between what a given teacher experienced during a specific workshop (say in 2019) and how (s)he responded to specific questions from the survey (in 2019). It is in subsequent program years (e.g., 2020, 2021, or 2022) when teachers complete their Update Survey that we get closer to tying a given workshop to specific teacher responses at least chronologically.

During this grant period, there has been a concerted effort by QuarkNet staff and many centers to facilitate teachers' use of QuarkNet content and instructional materials in their classrooms. These include, for example, offering centers suggested workshop agenda options (through available templates); offering to hold a nationally-led workshop (in whole or in part of their center-run workshop); increasing the number of DAP activities and standardizing their quality through a rigorous protocol; describing what the DAP is and showing teachers, during workshops, how to find DAP activities on the QuarkNet website and selection options based on curriculum content, data strand, and required student skill sets; how each activity is supported by teacher and student notes; embedding relevant DAP activities within the workshop where teachers can engage in these as active learners (as students) and then offered time to reflect on their use as teachers; and, time allocated for classroom implementation planning and discussion. In addition, the implementation template created to help teachers think through their implementation plans is likely to help make possible the future review of authentic assessment of in-classroom use of QuarkNet content and instructional materials by participating teachers.

Building Networks and Forming Lasting Collegial Relationships Center-level Outcomes

Table 30 provides a summary of center-level responses for two questions (from the Center Feedback Template) related to Network/Community Building: 1. Teachers engage/interact with mentors and other scientists., and, 2. Teachers engage/interact with other teachers. The first two columns in this table relate to the perceived number of teachers (e.g., *Almost All, Most, Some*); and the two columns to the far-right highlight center-level responses to the degree of QuarkNet influence as assessed by each center (e.g., *Very High, High*). In-between, individual teacher responses are shown at a given center to the full survey question, *Provide opportunities for teachers and mentors to: a. Interact with other scientists and collaborate with each other* (e.g., *Excellent, Good*). The bottom of the table provides totals across all participating centers and individual teachers to provide an overall summary.

Although centers and individual teachers were asked slightly different questions, the similarity of responses at the center and teacher level is evident. For example, most centers (14 and 18 respectively) indicated that *Almost All* teachers engage/interact with mentors and other scientists and engage/interact with each other; and most centers rate QuarkNet's influence on these engagements/interactions as *Very High* or *High* (14 and 10 centers, respectively). Similarly, 81.1% of individual teachers rated these opportunities as *Excellent* in a combined question about interactions with mentors, scientists, and other teachers.

Table 31 provides center-level responses to the question from the Center Feedback Template) that is, Teachers and Mentors: Form lasting collegial relationships through

Table 30
Summary of Center-level Assessment and Teacher-levels Responses to:
Opportunities for Teachers to Engage with Mentors and Other Scientists and Other Teachers

Center	Center-level			Center-level			Individual Teacher-level Responses					Center-level Assessment			Center-level Assessment		
	Teachers engage interact with Mentors and other scientists			Teachers engage/interact with other teachers			Opportunities for Teachers to interact with other Scientists and collaborate with each other					QN's influence on Teacher interaction with Mentor/ Scientists			QN's influence on teacher engagement/ interaction with other Teachers		
	Almost All	Most	Some	Almost All	Most	Some	Excellent	Good	Average	N/A Mis.	Total	Very High	High	Mod-erate	Very High	High	Mod-erate
Boston Area/Brown University			✓	✓			9	3	0	2	14		✓		✓		
Brookhaven National Laboratory/Stony Brook University	✓			✓			11	1	1	0	13	✓			✓		
Catholic University of America	✓			✓			9	1	0	0	10	✓			✓		
Colorado State University		✓		✓			10	1	0	1	12	✓			✓		
Fermilab/U of Chicago		✓		✓			29	3	0	4	36		✓			✓	
Florida State University/ University of Florida	✓			✓			10	1	0	1	12						
Idaho State University																	
Johns Hopkins University	✓			✓			10	2	1	0	13	✓			✓		
Kansas State University		✓		✓			11	3	0	0	14		✓			✓	
Lawrence Berkeley National Laboratory																	
Oklahoma State/ University of Oklahoma	✓			✓			14	2	0	0	16	✓			✓		
Rice University/ University of Houston	✓			✓			15	1	0	1	17		✓			✓	
Southern Methodist University	✓			✓			17	6	0	0	23	✓				✓	
Syracuse University[a]							6	2	2	3	13						✓
University of Cincinnati			✓			✓	12	1	1	0	14		✓				✓
University of Illinois at Chicago	✓			✓			9	1	0	0	10	✓				✓	
University of Iowa/Iowa State University	✓			✓			12	1	0	1	14	✓			✓		
University of Minnesota	✓			✓			12	0	0	0	12	✓			✓		
University of Notre Dame	✓			✓			14	2	0	0	16	✓				✓	
University of Puerto Rico – Mayaguez	✓			✓			15	0	0	1	16	✓			✓		
Vanderbilt University		✓				✓	9	0	0	1[b]	10	✓				✓	
Virginia Center	✓			✓			6	4	0	0	10	✓				✓	
Virtual Center	✓			✓			10	3	0	0	13	✓			✓		
Total	14	4	2	18	0	2	250 81.1%	38 12.3%	5 1.6%	15 4.9%	308 100%	14	5	0	10	8	2

[a]Not able to reach consensus on these ratings. [b]Rated as "fair." Note. Percents are used only for the grand total across centers because the responses within an individual center are too small to justify percentages.

Table 31
Summary of Center-level Assessment and Teacher-levels Responses to:
Opportunities for Teachers and Mentors to **Form Lasting Collegial Relationships**

Center	Center-level Assessment				Teacher-level Responses					Center-level Assessment		
	Form lasting collegial relationships locally and nationally				Provide opportunities for teachers and mentors to build a local (or regional) learning community					QN's Influence on forming these relationships		
	Almost All	Most	Some	A Few	Excellent	Good	Average	Fair	Total	Very High	High	Mod-erate
Boston Area/Brown University		✔			8	3	2	0	13		✔	
Brookhaven National Laboratory/Stony Brook University			✔		0	8	3	0	11			✔
Catholic University of America		✔			8	1	1	0	10	✔		
Colorado State University		✔			11	0	0	0	11	✔		
Fermilab/University of Chicago		✔			24	8	0	0	32		✔	
Florida State University/ University of Florida			✔		11	0	0	0	11			✔
Johns Hopkins University	✔				10	1	0	2[a]	13	✔		
Kansas State University	✔				9	4	1	0	14			✔
Oklahoma State/University of Oklahoma		✔			10	4	2	0	16	✔		
Rice University/University of Houston	✔				14	2	0	0	16	✔		
Southern Methodist University			✔		14	8	0	1[a]	23			✔
Syracuse University				✔	5	5	0	0	10			✔
University of Cincinnati			✔		10	3	1	0	14		✔	
University of Illinois at Chicago	✔				9	1	0	0	10			
University of Iowa/Iowa State University	✔				11	1	1	0	13	✔		
University of Minnesota	✔				12	0	0	0	12	✔		
University of Notre Dame	✔				12	3	1	0	16	✔		
University of Puerto Rico – Mayaguez			✔		13	2	0	0	15		✔	
Vanderbilt University	✔				7	2	1	0	10	✔		
Virginia Center	✔				5	5	0	0	10	✔		
Virtual Center	✔				6	3	1	1	11	✔		
Total	10	5	5	1	209 71.8%	64 22.0%	14 4.8%	4 1.4%	291 100%	12	4	5

Note. Percents are used only for the grand total across centers because the responses within an individual center are too small to justify percentages.
21 (combined 28) centers.

interactions and collaborations at the local level and through engagement with the national program (e.g., *Almost All, Most, Some*) (first left-most columns). The far-right columns provide center-level responses as to the degree to which QuarkNet has influenced these relationships (e.g., *Very High, High*). In-between, individual teacher responses are shown in their answer to the full survey question, *Provide opportunities for teachers and mentors to: b. Build a local (or regional) learning community* (e.g., *Excellent, Good*). Overall totals are provided as well.

Most centers reported that (10) *Almost All* teachers were able to form lasting collegial relationships locally and nationally and that 12 centers indicated that QuarkNet's influence on these forming these relationships was *Very High.* Similarly, 71.8% of teachers reported that QuarkNet provided opportunities for teachers and mentors to build a local (or regional) learning community. Again, although centers and teachers were asked slightly different questions together these tables suggest good agreement based on individual-teacher assessment and center-level assessment of teacher participation regarding networking and forming lasting collegial relationships and the perceived influence QuarkNet has had on the development of these relationships, and that these two center-level outcomes have been met.

Effective Practices: QuarkNet Centers

The importance of the partnership between QuarkNet and participating centers have already been noted. To help review these centers through the lens of effective practices, Young and Associates (2017) created a matrix of interrelated factors and in turn, we embedded the assessment of these factors by centers within the Center Feedback Template. A summary of these center-level assessments is shown in Table 32 (for centers included in the analyses of outcomes and that completed their template). Because of the individual characteristics of each center, we would expect some variability across these assessments and indeed variability is evident. The more telling profile, however, is that individually and collectively these centers tend to report that they have met the standards proposed by these factors.

That said, there were two areas where centers most often cited a challenge. We begin with Factor 3. *Participants meet regularly.* (QuarkNet model is for a summer session with follow-up during the academic year or sessions during the academic year. Follow up includes working with the national staff and collaboration within and across centers. Mentors and teachers have flexibility to set the annual program locally.)

These challenges/comments were noted:

- (Yes, but) Strong seasonal involvement; could increase overall frequency and depth.
- (Yes, but) We often fail to follow up during the school year; probably need to try harder to make this happen.
- (Yes, but) We usually only meet as a QuarkNet group during the summer. An in-person meeting during the academic year is not feasible and there are no follow up sessions during the year.
- (Yes, but) No group meetings generally during the academic year – think that would be helpful even if informal. Mentor does visit schools and teachers, often working with small student groups.

Table 32
Summary of Center-Level Success Factors: A Self-assessment by QuarkNet Centers

Effective Practices/Success Factors[a]	QuarkNet Centers										
	A	B	C	D	E	F	G	H	I	J	K
1. *Program provides opportunities for a* ***strong teacher leader***. (Teacher provides leadership in areas of content and/or is a technical expert; models exemplary pedagogical skills; able to provide organizational skills. These characteristics may be present in one or a team of teacher leaders.)	Yes	Yes	Yes	Yes, but[1]	Yes	Yes	Yes	Yes	Yes	Yes, but[1]	Yes, but[1] /No
2. *Program provides opportunities for a* ***strong mentor***. (Mentor provides leadership skills mainly of content and/or technical expertise; understands education and professional development -- working with teacher leaders as needed; models research.)	Yes, but[1]	Yes	Yes, but[1]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes/ Unsure
3. *Participants meet regularly*. (QuarkNet model is for a summer session with follow-up during the academic year or sessions during the academic year. Follow up includes working with the national staff and collaboration within and across centers. Mentors and teachers have flexibility to set the annual program locally.)	Yes	Yes, but[1]	Yes, but[1]	Yes, but[1]	Yes, but[1]	Yes	Yes, but[1] /Yes	Yes, but[1]	Yes, but[1]	No	Yes, but[1]
4. *Meaningful activities* (The standard for meaningful activities is focusing topics in modern physics, discussing how to implement this content in classrooms, conducting research and discussing scientific inquiry methods; using Data Activities Portfolio instructional materials.)	Yes	Yes	Yes	Yes	Yes	Yes	Yes/ Yes, but[1]	Yes	Yes	Yes	Yes
5. *Directly addresses classroom implementation of instructional materials for all teachers.* (Time for teachers to discuss Data Activities Portfolio instructional materials and pathways; to consider NGSS, AP, IB or other science standards; presentation(s) from veteran teachers on classroom implementation experiences or similar engagement.)	Yes	Yes	Yes	Yes, but[1]	Yes	Yes	Yes/ Yes, but[1]	Yes	Yes	Yes	Yes, but[1] /Yes
6. Program is able to provide regular contact and support with teachers. (Specific support and or follow up from staff; staff teachers are available and/or volunteers who support teachers, especially related to classroom implementation.)	Yes	Yes, but[1]	Yes, but[1]	Yes	Yes, but[1]	Yes	Yes	Yes	Yes, but[1]	Unsure	Yes, but[1] /Yes
7. Money for additional activities or additional grants. (Seeking additional funding to fulfill the mission/objectives of the center; providing supplemental or complementary support for QuarkNet e.g., providing transportation, lodging, buying equipment; providing food.)	Yes, but[1]	Yes	Yes	Yes	Yes, but[1]	No	Yes, but[1]	Yes, but[1]	No	No	No
8. Stable participant base.(A stable participant base can provide an expert group that can help other teachers, support outreach, and provide organizational leadership.)	Yes	Yes	Yes	Yes, but[1]	Yes, but[1]	Yes	Yes/ Yes, but[1]	Yes	Yes	Yes	Yes
9. Addresses teacher professionalism. (The standard is to provide opportunities for at least a few teachers to attend professional meetings; support teachers taking leadership roles in their school, school districts, outreach, and highlight PD opportunities for continuing development.)	Yes	Yes	Yes	No	Unsure	Yes	Yes/ Yes, but[1]	Yes	Yes, but[1]	Yes	No/ Yes
10. Establish a learning community. (The standard is forming a cohesive group where teachers learn from one another; engage with mentors and other scientists; provide outreach to other teachers.)	Yes	Yes	Yes	Yes, but[1]	Yes, but[1]	Yes	Yes/ Yes, but[1]	Yes	Yes	Yes, but[1]	Yes, but[1] /No

[a]This section of the protocol has been adapted from M.J. Young & Associates (2017, September). *QuarkNet: Matrix of Effective Practices.* [1]Needs work or fine tuning; or, there are notable caveats.
[1]Needs work or fine tuning; or, there are notable caveats. A= Boston Area/ University of Boston. B= Catholic University of America. C= Colorado State University. D = Fermilab/University of Chicago. E = Florida State University/University of Florida. F = Johns Hopkins University. G = Kansas State University. H = Oklahoma State/University of Oklahoma. I= Rice University/ University of Houston. J=Southern Methodist University. K= Syracuse University. Note. Not all centers reached consensus in their ratings; this is reflected by multiple responses for these centers.

Table 32 (con't.)
Summary of Center-Level Success Factors: A Self-assessment by QuarkNet Centers

Effective Practices/Success Factors[a]	QuarkNet Centers									
	L	M	N	O	P	Q	R	S	T	U
1. *Program provides opportunities for a* ***strong teacher leader***. (Teacher provides leadership in areas of content and/or is a technical expert; models exemplary pedagogical skills; able to provide organizational skills. These characteristics may be present in one or a team of teacher leaders.)	Yes	Yes	Yes, but[1]	Yes	Yes	Yes	Yes	Yes	Yes	Yes
2. *Program provides opportunities for a* ***strong mentor***. (Mentor provides leadership skills mainly of content and/or technical expertise; understands education and professional development -- working with teacher leaders as needed; models research.)	Yes, but[1]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes, but[1]	Yes
3. *Participants meet regularly*. (QuarkNet model is for a summer session with follow-up during the academic year or sessions during the academic year. Follow up includes working with the national staff and collaboration within and across centers. Mentors and teachers have flexibility to set the annual program locally.)	Yes, but[1]	Yes	Yes, but[1]	Yes	Yes	Yes, but[1]	Yes	Yes	Yes	Yes
4. *Meaningful activities* (The standard for meaningful activities is focusing topics in modern physics, discussing how to implement this content in classrooms, conducting research and discussing scientific inquiry methods; using Data Activities Portfolio instructional materials.)	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
5. *Directly addresses classroom implementation of instructional materials for all teachers.* (Time for teachers to discuss Data Activities Portfolio instructional materials and pathways; to consider NGSS, AP, IB or other science standards; presentation(s) from veteran teachers on classroom implementation experiences or similar engagement.)	Yes, but[1]	Yes	Yes	Yes	Yes	Yes	Yes, but[1]	Yes	Yes, but[1]	Yes
6. Program is able to provide regular contact and support with teachers. (Specific support and or follow up from staff; staff teachers are available and/or volunteers who support teachers, especially related to classroom implementation.)	Yes	Yes	Yes, but[1]	Yes	Yes	Yes	Yes	Yes	No	Yes
7. Money for additional activities or additional grants. (Seeking additional funding to fulfill the mission/objectives of the center; providing supplemental or complementary support for QuarkNet e.g., providing transportation, lodging, buying equipment; providing food.)	Yes, but[1]	No	Yes, but[1]	Yes	Yes	No	Yes, but[1]	No	Yes	Yes
8. Stable participant base.(A stable participant base can provide an expert group that can help other teachers, support outreach, and provide organizational leadership.)	Yes, but[1]	Yes, but[1]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
9. Addresses teacher professionalism. (The standard is to provide opportunities for at least a few teachers to attend professional meetings; support teachers taking leadership roles in their school, school districts, outreach, and highlight PD opportunities for continuing development.)	Yes	Yes	Yes, but[1]	Yes	Yes	Yes	Yes	Yes	Yes, but[1]	Yes
10. Establish a learning community. (The standard is forming a cohesive group where teachers learn from one another; engage with mentors and other scientists; provide outreach to other teachers.)	Yes, but[1]	Yes	Yes	Yes	Yes	Yes, but[1]	Yes	Yes	Yes	Yes

[a]This section of the protocol has been adapted from M.J. Young & Associates (2017, September). *QuarkNet: Matrix of Effective Practices.* [1]Needs work or fine tuning; or, there are notable caveats. [1]Needs work or fine tuning; or, there are notable caveats. L = University of Cincinnati. M = University of Iowa/Iowa State University. N = University of Minnesota. O = University of Norte Dame. P = University of Puerto Rico, Mayaguez. Q = Vanderbilt University. R = Virginia Center. S = Virtual Center. T = Brookhaven National Laboratory/Stony Brook University. U= University of Illinois at Chicago Note. Not all centers reached consensus in their ratings; this is reflected by multiple responses for these centers. [1]Yes but defined as *Needs work or fine tuning; or, there are notable caveats.*

- (Yes) We have flexibility to set our program. We enjoy that flexibility. We enjoy meeting in our summer workshop. An extra meeting during the year might be a welcome addition.
- (Yes, but) because of COVID restrictions.
- (Yes, but) Summer sessions are regularly held but meetings during the academic year are difficult. The center would like to see more teachers participate; having Zoom meetings may become more of an option as teachers become more familiar with interacting in a virtual environment (has been a barrier in the past).
- (Yes, but) Currently we meet about twice a year. 3-4 days in the summer, 1 day in Jan/Feb for Masterclass orientation, and 1 day in March/April for Masterclass.
- (Yes, but) We meet every summer and are in email contact with some through the rest of the year. A few usually bring students to a Masterclass.
- (Yes, but) In addition to Summer Workshop, Masterclasses are scheduled each year. There have also been visits to schools (lecture, outreach activities). Work is underway to engage more mentors and restart regular physics lecture series.
- (No) No routine follow up during the academic year.
- (Yes) We have after-school meetings 2 to 3 times per year and usually a 2-to-3-day workshop during the summer.
- (Yes, but) Center communicates with teachers throughout the year and offers support with content and pedagogy; not all teachers choose to participate during the academic year. Possible future plans include a networking event with other QuarkNet centers in the region.
- (Yes, but) We meet every summer and again at Masterclass in the Spring. Many of us also meet at the state Science Conference in the Fall, and the regional AAPT Section Meeting in the Spring.

Perhaps the most frequently mentioned challenge for these centers is reflected in responses to Factor 7. *Money for additional activities or additional grants.* (Seeking additional funding to fulfill the mission/objective of the center; providing supplemental or complementary support for QuarkNet e.g., providing transportation, lodging, buying equipment, providing food.)

These responses include:

- (Yes, but) Money for stipends to attend meetings has been generally available. Also, QuarkNet has provided four teachers with cosmic ray detectors. We have not asked for more.
- (Yes) Preparing a NSF proposal.
- (Yes) QuarkNet helped with paying mileage to teachers who have to travel quite far for our summer workshop and also paid for a shared set of equipment for a specific lab experiment.
- (Yes, but) Lately funding has shrunk, so teacher stipends shrunk or we capped the participant number.
- (No) We can do more with funding. We have had a very successful center but have had budget cut after budget cut.
- (Yes) Extra food and opportunities to discuss in an informal setting are really appreciated.

- (Yes, but) Funding for onsite workshops and activities is adequate, but recent funding restrictions has made it impossible to take field trips to see current physics research.
- (Yes, but) In recent years, we have had to limit the number of teachers and/or length of the summer workshop to stay under budget.
- (No) Buying equipment would be something relevant: updating, existing cosmic ray detectors (even with something as simple as Raspberry PI) or … make them build cheap new one (E.g., MIT's $100 cosmic ray detector).
- (No) The opposite is true. We have to draw funds from other outreach programs to maintain the QuarkNet center-level activities.
- (No) As I understand it, there is really no money for anything beyond just paying teacher stipends; no money has been made available outside of the summer session.
- (Yes, but) Not funding the student research portion of QuarkNet is disappointing. Two post-QuarkNet students (from the most recent cohort) are working in the mentor's research group funded by the University or other grants; this has occurred for other past students as well.
- (Yes, but) University money has been available to provide lunches for teachers during workshops and students during masterclasses. No local money has been accessed for additional stipends, etc.
- (Yes, but) Consider allowing extra support to cover lodging for our far away teachers.
- (Yes) Contributions from schools provides materials for prototypes needed for each project.

Funding is of course fundamental to the sustainability of any program but through the assessment of these factors we had hoped to address the question, *What is sustained via this implemented program?* (relative to program fidelity and measured benefits).

COVID Program Modifications: Long-term Implications and Options

The impact of COVID on QuarkNet implemented during 2020 and 2021 must be underscored. Nearly all of the 2020 workshops and Masterclasses, with few exceptions, 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 pandemic. This was followed by subsequent virus variants that necessitated QuarkNet workshops and Masterclasses in 2021 be implemented in varied venues as well, that is, online, a hybrid of in-person and online, or in-person sessions when feasible. Major modifications to the QuarkNet implemented program during 2020 and 2021 have already been noted. These changes have many implications for long-term benefits or options for the program.

With direct feedback from members of the QuarkNet development team (Cecire, Wood, Roudebush, & Bardeen), the following was proffered:

1. Creating a Virtual Center prior to the onset of COVID gave QuarkNet staff a leg-up on implementing online workshops. Nevertheless, offering numerous online workshops necessitated a rethinking of the content and format of these sessions.

2. After these experiences, teachers may have an increased comfort level in virtual environments; with this, centers may have the option of meeting more frequently during the program year. For example, remote sessions during the school year can support in-person workshops held during the summer or at other times. And, centers might opt to hold their program remotely even when in-person events are possible, bringing in teachers that are more distal to the center's location.

3. Virtual workshops opened possibilities for centers to work collaboratively; for example, teachers could attend virtual workshops and physics talks held at other centers and explore topics that cut across centers.

4. Staff members, when desired, can implement the following remote learning sessions beyond COVID needs (if interest by teachers persists): (a) Coding Camp, which was pilot tested as a Coding Workshop held remotely (in program year 2021 and planned again for 2022); (b) BAMC (Big Analysis of Muons in CMS), which offers a masterclass experience with simplified analyses while working remotely; and. (c) shorter half-day workshops (over a few days) conducted virtually. (And, given their original design, Cosmic and CMS e-labs can be offered in person or remotely.)

5. The QuarkNet STEP UP workshops were modified to support virtual presentation; these can be implemented remotely in future program years.

6. Many DAP activities have been adapted for implementation in remote classrooms or used remotely for in-person classroom instruction (see Exhibit D, p. 28). These modifications enable teachers to use these activities outside the classroom room as homework assignments or in informal settings such as physics club meetings.

Additional online opportunities such as: QuarkNet Weekly Webinars (QW2); Summer Session for Teachers (SST); QuarkNet Educational Discussions (QED); and QuarkNet collected resources for teaching physics (https://quarknet.org/ content/resources-teaching-physics-online) may be implemented or used in the future.

With all this said, the value of in-person workshops, masterclasses and e-labs cannot be overstated. Striking a balance in the future may be key. Although we have noted that more exposure to remote learning as evident during the 2020 and 2021 program years may have increased teachers' comfort level with this option, it is also possible that this lead to considerable burn-out or fatigue to engage in remote environments now that in-person events have returned. Further, an important outcome of QuarkNet is to form and build long-lasting collegial relationships between teachers, mentors and other scientists (as highlighted in Tables 30 and 31); an outcome that fundamentally may require face-to-face engagement. As one member of the development team noted, "For all we gained in opening up new pathways, we also lost valuable personal interaction with and between our teachers and mentors" (Cecire, email May 6, 2021). And, in-person onsite tours at laboratories and research institutions offer teachers the rare opportunity to observe world-renowned physicists conducting research in real time.

Getting the Word Out

Finally, during this current grant period QuarkNet staff and teachers have combined for a total of 71 presentations, posters, or keynote talks at professional conferences such as the American Association of Physics Teachers (AAPT) during this grant period (information compiled by K. Cecire and S. Woods) http/: quarknet.org/content/publications-presentations-and-posters-sept-2018-sept-2013.

Summary and Recommendations

As has been stated, 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).

Each evaluation report prepared annually during this grant period represented a prototype of this final report. Thus, the present report and its review have demonstrated 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.

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 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. We anticipated tweaks made to the PTM if QuarkNet is awarded a renewal grant.

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, developed and implemented to measure the teacher-level and center-level outcomes articulated in the PTM, respectively. The first administration of the Full 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 and 2022) to capture information from participating teachers and to focus on classroom implementation of QuarkNet content and instructional materials.

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 hierarchical 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). (The combined center total this represents about 60% of the centers.)

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 program 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 (31 combined) 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 were shown to be related to Student Engagement (along with Approach to Teaching and QuarkNet's Influence on 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 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.

To date, 27 (34 combined) centers have completed their Center Feedback Template. (This combined total represents about 71% of the centers.) [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.

Impact of COVID

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 pandemic. We have described how COVID (coronavirus) has impacted the implementation of the 2020 QuarkNet program year; and how this 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, this report 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.

Finally, during this current grant period QuarkNet staff and teachers have combined for a total of 71 presentations, posters, or keynote talks at professional conferences.

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.

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Appendices

Brief History of Program

After the cancellation of the Superconducting Super Collider, which occurred in 1993, a concerted effort by a group of physicists was undertaken to help avert what might have resulted in an "impending demise of particle physics research in the U.S." (https://www.nd.edu/stories/causality-principle). This included physicists Randy Ruchti, from Norte Dame; Oliver Baker, from Hampton University; and Michael Barnett, from the Lawrence Berkeley National Laboratory); and, Marge Bardeen an educator (Fermilab educator now emeritus) as well as a commitment from the National Science Foundation and the Department of Energy to support the Large Hadron Collider (LHC) and LHC experiments (QuarkNet proposal, 2018).

In 1999, the National Science Foundation (NSF) affirmed its interest in developing an education and outreach national program across the physics centers in the United States in anticipation of the development of the LHC and to coincide with its support of the LHC and LHC experiments. [The LHC has become the world's largest and most powerful particle collider as part of CERN's (Conseil Européen pour la Recherche Nucléaire) accelerator complex at the European Center for Nuclear Research, with its first started up in September 2008.] In broad terms, the vision for this proposed education and outreach program was to mirror the experience and success of the MarsQuest program (Dusenberry & Lee, 1998), a program started to coincide with an up and coming decade of the exploration of the planet Mars, co-funded by NSF and NASA.

To begin, QuarkNet program stakeholders surveyed as many as 60 research centers to learn what educational and outreach efforts were implemented at these centers, at that time. Results indicated that efforts varied considerably across these centers further underscoring the need for a concerted national effort. From its beginning, QuarkNet focused on bringing teachers into the particle physics research community providing program continuity to participating centers by offering a national network of structured workshops and programs grounded in core program strategies (personal communication, M. Baredeen, September 18, 2018).

Development of the QuarkNet Program Theory Model

In sync with the start of the current award period, the evaluation began with the development of a Program Theory Model (PTM). The complexity of the program and its network of partners as well as its longevity suggested that the development of such a model was warranted. Thus at this stage of the program, the creation of a program theory model largely involved making key program components and strategies -- that have evolved and been implemented over time -- explicit and served to help link these to an outcomes-based evaluation.

Accordingly, we drew on a variety of information sources in its development, including relevant literature on effective professional development; the Next Generation Science Standards (and other relevant standards); and, structured interviews with key program stakeholders. And as discussed in the full narrative of the report, we have included a framework that adds program sustainability strategies and outcomes into the mix.

The narrative of the evaluation report describes in detail the three program anchors:

1. Drawing from the Literature: Effective Professional Development
2. Program Alignment with the Next Generation Science Standards
3. Program's Use of the Concept of Guided Inquiry

of the PTM and will not be repeated in this appendix.

<u>Initial Interviews with Key Program Stakeholders</u>

An important part of the information-gathering step in creating the PTM was the conduct of a structured interview with key program stakeholders, including the Principal Investigators and staff, and the two past evaluators. To guide these interviews, a written protocol was developed; then, reviewed and revised based on suggestions from the Principal Investigators (PIs). The protocol and the list of stakeholders and evaluators who participated in this interview process are shown at the end of this appendix. Each interview was conducted over the phone and most lasted between 1 to 1 ½ hours. As necessary, a second interview was scheduled to complete the information covered in the protocol. All interviews were conducted from September 18, 2018 through October 11, 2018.

There were five general themes discussed during these interviews, to obtain: 1. A general picture of the individual's role and responsibilities in the program; 2. Individual perceptions about program development and implementation; 3. Program strategies that the individual thought essential; 4. Program outcomes for teachers, their students, centers, and others; and, 5. Sustainability issues and concerns for the centers and the national program.

Each interview was digitally recorded, consent of this was verbally obtained, and each individual was given the option of stopping the recording at any time during the interview. These interviews were transcribed, with information extracted with an eye toward informing the PTM and did not necessarily represent a verbatim account of these discussions.

Meeting with Past Evaluators

In addition to these interviews, a face-to-face meeting was conducted with M. Jean Young and Ginny Beal, the two past evaluators, on October 2, 2018 in Tucson, AZ. along with the current evaluator. This was a day-long meeting where past evaluation efforts were discussed as well as plans for future evaluation efforts. Moreover, previous evaluation measures were reviewed and discussed as relevant. Although the purpose of this meeting was not solely focused on the development of the PTM, this discussion did inform the model relevant to QuarkNet's program evolution, its structure and core strategies as well as program outcomes related to teachers, centers, and sustainability efforts.

Information from these sources were culled into drafts of the PTM; and, shared and revised during iterative meetings with the PIs and key stakeholders until agreement was reached on the content of its component parts. Once the narrative of the PTM was agreed upon, a graphic presentation of it was created.

QuarkNet: Initial Interview Protocol

After a brief background question, I would like to discuss five main themes with you. These are: 1) your role in this project; 2) your perceptions about program development and implementation; 3) program strategies that you think essential; 4) program outcomes for teachers, students, centers and others; and, 5) sustainability issues and concerns for the centers and the national program. My purpose in our conversation is to use this information, along with other relevant resources, to build a program theory model of QuarkNet and to focus evaluation efforts around core program strategies and program outcomes including long-term sustainability of the program.

It is expected that our conversation will take about 1 to 1 ½ hours and unless you object I will digitally record our conversation for note taking purposes only. At any time, you may ask that I stop recording and I will comply with your request. I will extract information for this and other interviews to form the basis of a program theory model to identify program strategies and suggest logical links to program and long-term outcomes. No responses by individuals will be identified by name unless specific permission to do so is obtained.

I have sought to ask a standard set of questions to get a sense of the varying degrees of stakeholder knowledge about the program. Thus at times, I may ask a question that you may have some or little background information about; at other times a particular question likely will generate a great deal of discussion. Please feel free to proffer ideas or recommendations not asked if you think these are germane or critical to QuarkNet.

Background

I want to start with a few quick background questions.

Please give a brief professional sketch of yourself (as this pertains to your involvement in *QuarkNet*).

Organizationally, how does *QuarkNet* relate to, interconnect or fit within your institution?

Your Role

What is your role in *QuarkNet*? What are your main responsibilities in this program?

Program

Development/Historical Perspective

What ideas, resources, and/or materials were initially used to develop this program? Who was involved in the initial planning of this program?

How or in what ways has *QuarkNet* changed or evolved over the past several years? If relevant please talk about the process as to how this change occurred.

Target Audience/Recruitment

Who do you see as the target audience(s) (in terms of teachers, students, centers, others) of *QuarkNet*?

How are new centers added to *QuarkNet*? What process is or has been used to recruit teachers for in this program? What criteria are used? Is the program reaching the "right" teachers; others?

Program Components

Briefly describe the program strategies or core activities that you think are essential to *QuarkNet*. (Reference either the national program or center-level program or both.) Which of these do you think are most important? Are there program strategies that are not used during the implementation of the program or that could/should be strengthened?

Program Outcomes

I'd like to talk about your perceptions regarding program outcomes for participating teachers, students and participating centers?

What program outcomes do you believe are the most important for teachers to gain from this program? What are the long-term outcomes you believe would result from program participation by teachers? How do identified program outcomes link to core program components?

What outcomes do you believe are the most important to gain for the national program? What outcomes do you believe are the most important for participating centers? How about students? Any others?

What level of evidence of program impact do you and/or your institution need to sustain your involvement in the program?

Partnership/Sustainability

What are the barriers or challenges to an institution's participation in *QuarkNet*? What program or infrastructure components do you think need to be put in place in order for an institution to sustain its participation in this program within the 5-year grant period or beyond?

What criteria or measures do you think we should used to gauge program sustainability among program centers? For the national program?

What do you think the program can do to help assist centers in their efforts to sustain *QuarkNet* through their own funding efforts?

Is there anything else that you want to share regarding the program or your involvement?

QuarkNet Partners

NSF: The National Science Foundation is an independent federal agency created by Congress in 1950 "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense…" NSF supports basic research and people to create knowledge that transforms the future. QuarkNet is funded through NSF's Integrative Activities in Physics Program.

Fermilab: America's particle physics and accelerator laboratory whose vision is to solve the mysteries of matter, energy, space and time for the benefit of all. Fermilab, a co-sponsor of QuarkNet, hosts Data Camp held each summer and supports the cosmic ray studies program. Fermilab hosts DUNE and the Long-Baseline Neutrino Facility. DUNE brings together over 1,000 scientists from more than 175 institutions in over 30 countries.

Diversity – Women and Minorities: QuarkNet partners with other STEM organizations to reach more students underrepresented in STEM, either through their teachers or directly. Recent partners are *Step Up 4 Women,* an American Physical Society program to increase the representation of women amongst physics bachelor's degrees and *STEAM Workshop at NACA,* a program of the Native American Community Academy, Albuquerque, in which students create visual stories using projection art about ideas in Western science and indigenous culture. An example of being nimble to respond to opportunities is the *i.am. Angel Foundation,* transforming lives through education inspiration and thinking. Also, some centers partner with other organizations to reach beyond QuarkNet schools to students traditionally underrepresented in STEM.

Advisory Board: Seven or eight individuals both familiar with and new to the program meet annually to review QuarkNet program achievements and make recommendations for future plans and objectives. Members represent a diverse mix of high school physics teachers, education administrators, research physicists and physics outreach leaders.

QuarkNet: The QuarkNet Collaboration is a long-term, national program that *partners high school science teachers with particle physicists* working in experiments at the scientific frontier. A professional development program, QuarkNet 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.

QuarkNet Centers: Centers both form the essential backbone of and are partners in QuarkNet. A center is housed at a university or laboratory, serving high school physics and physical science teachers; active local centers number 50+.

U.S. ATLAS: A collaboration of scientists from 45 U.S. institutions. ATLAS is one of two general-purpose detectors at the Large Hadron Collider in Geneva, Switzerland. The ATLAS experiment investigates a wide range of physics, from the search for the Higgs boson to extra dimensions and particles that could make up dark matter. U.S. ATLAS is a co-sponsor of QuarkNet.

U.S. CMS: A collaboration of more than 900 scientists from 50 U.S. institutions who make significant contributions to the Compact Muon Solenoid (CMS) detector. Discoveries from the CMS experiment are revolutionizing our understanding of the universe. USCMS is a co-sponsor of QuarkNet.

Broader Impacts and Community Outreach: QuarkNet efforts extend beyond the program. Often, centers integrate QuarkNet in other community outreach and broader impact efforts. QuarkNet has led in facilitating the public use of large particle physics databases. QuarkNet staff and teachers attend and present at meetings of the American Association of Physics Teachers and the American Physical Society. At International Particle Physics Outreach Group (IPPOG) meetings QuarkNet presentations have highlighted how QuarkNet works, e-Labs, the Data Activities Portfolio and scientific discovery for students. QuarkNet has developed and coordinated the CMS masterclass, led the global cosmic ray studies project, and provided a wealth of information for other IPPOG members to consider in their own education and outreach programs.

QuarkNet Program Theory Model

Program Statement: The QuarkNet Collaboration is a long-term, national program that partners high school science teachers with particle physicists working in experiments at the scientific frontier. A professional development program, QuarkNet 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.

Centers: QuarkNet delivers its professional development program in partnership with local centers.

Program Goals
- Goal 1
- Goal 2
- Goal 3
- Goal 4

Participant Selection
- Mentors
- Teachers
- Fellows

Anchors
- Effective PD
- NGSS Alignment
- Guided Inquiry

Program Structure
- Data Camp
- Data Activities Portfolio
- e-Lab
- Masterclasses
- Workshops

Strategies
- Teachers
- Local Centers

Outcomes
- Teachers
- Students
- Local Centers

Enduring Understandings

Sustainability

Antecedents

Outcomes

Core Values/Assumptions

QuarkNet Program Theory Model

Program Statement: The QuarkNet Collaboration is a long-term, national program that partners high school science teachers with particle physicists working in experiments at the scientific frontier. A professional development program, QuarkNet 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 classroom.

QuarkNet delivers its professional development program in partnership with local centers.
QuarkNet Centers: Centers both form the essential backbone of and are partners in QuarkNet. A center is housed at a university or laboratory, serving primarily teachers who live within reasonable commuting distances. An online center, the Virtual Center, provides a home for teachers who no longer live close to a particle physics research group. At the center, program leaders include one or two particle physicists who serve as mentor(s) and team up with one or two lead teacher(s). Each center seeks to foster lasting relationships through collaboration at the local level and through engagement with the national program.

Program Goals

Measurable professional development (PD) goals are:
Goal 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.

Goal 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.

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

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

Participant Selection

Teachers: High school physics/physical science teachers who express interest in QuarkNet and/or who are invited to participate through staff, fellows, or mentors/ center teachers. Mentors may know high school teachers who would be good additions to their research team and/or who may become associate teachers at the center.

Mentors: Particle physics researchers working at a university or laboratory who have expressed interest in participating in QuarkNet. Mentors propose a research project, identify a mentor team, and describe previous outreach experience. Staff and PIs approve before adding the mentors/centers to the QuarkNet network.

Fellows: QuarkNet teachers who are invited by staff to become fellows based on participants' experiences working with a local center or on national programs such as Data Camp.

Program Anchors

Characteristics of Effective Professional Development[1]

- Is content focused
- Incorporates active learning utilizing adult learning theory
- Supports collaboration, typically in job-embedded contexts
- Uses models and modeling of effective practice
- Provides coaching and expert support
- Offers opportunities for feedback and reflection
- Is of sustained duration

[1]Darling-Hammond, L., Hyler, M.E., & Gardner, M. (2017, June). Effective teacher professional development. Palo Alto, CA: Learning Policy Institute.

Pedagogical and Instructional Best Practices
Aligns with the **Science and Engineering Practices** of the NGSS. APPENDIX F – Science and Engineering Practices in the NGSS (2013, April). As suggested, these practices are intended to better specify what is meant by inquiry in science.
https://www.nextgenscience.org

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

Content addresses **Disciplinary Core Ideas and Crosscutting Concepts** (NGSS):

1. Patterns
2. Cause and Effect
3. Scale, Proportion and Quantity
4. Systems and System Models
5. Energy and Matter in Systems
6. Structure and Function
7. Stability and Change of Systems

Guided Inquiry
Guided inquiry (teacher provides problem or question) and Structured inquiry (where teacher provides problem and procedure) [Herron, M.D. (1971). The nature of scientific enquiry. *School Review, 79*(2), 171- 212.] **Guided Inquiry** - The **solution is not already existing/known in advance** and could vary from student to student. **Students EITHER investigate a teacher-presented question** (usually open-ended) **using student designed/selected procedures OR investigate questions that are student formulated** (usually open-ended) **through a prescribed procedure** (some parts of the procedure may be student designed/selected). (2007 Jan-Marie Kellow)

Program Structure

Data Camp: A 1-week program offered annually in the summer at Fermilab. It is an introductory workshop for teachers of physics and physical science who either have had little-to-no experience with particle physics and/or who have had little experience with quantitative analysis of LHC data. The camp emphasizes an authentic data analysis experience, in which the teachers are expected to engage as students as active learners of a challenging topic they may initially have known very little about. In the beginning of the week, teachers receive an authentic CMS dataset and work in small groups to analyze the dataset. Groups use these data to determine the mass of particles produced during LHC proton-proton collisions. Successful completion of this phase of the workshop culminates in each group presenting and explaining their data. Then, teachers explore various instructional materials in the Data Activities Portfolio that offer them help in incorporating particle physics concepts into their everyday lessons and propose an implementation plan for their classrooms. Throughout the week, teachers take tours (e.g., LINAC tunnel, MINOS experiment) and participate in seminars held by theoretical and experimental physics.

Data Activities Portfolio: An online compendium of particle physics classroom instructional materials organized by data strand and expected level of student engagement. These materials are based on authentic experimental data used by teachers to give students an opportunity to learn how scientists make discoveries. Strands include LHC, CMS, Cosmic Ray Studies, and neutrino data. Activities increase in complexity, sophistication and expected student engagement from Levels 0 to 4. Curriculum topics provide guidance for teachers to develop a sequence of lessons or activities appropriate for their students. Draft instructional materials are reviewed based on specified instructional design guidelines and are aligned with NGSS, IB, and AP science standards (Physics 1 and Physics 2) as relevant.

Through guidance from teachers, students are provided the opportunity such that:
Level 0 – Students build background skills and knowledge needed to do a Level 1 activity. Students analyze one variable or they determine patterns, organize data into a table or graphical representation and draw qualitative conclusions based on the representation of these data.
Level 1 – Students use the background skills developed in Level 0. They calculate descriptive statistics, seek patterns, identify outliers, confounding variables, and perform calculations to reach findings; they may also create graphical representations of the data. Datasets are small in size. The data models come from particle physics experimentation.
Level 2 – Students use the skills from Level 1 but must apply a greater level of interpretation. The analysis tasks are directed toward specific investigations. Datasets are large enough that hand calculation is not practical, and the use of statistics becomes central to understanding the physics. They perform many of the same analysis tasks but must apply a greater level of interpretation.
Level 3 – Students use the skills from Level 2. They develop and implement a research plan utilizing large datasets. They have choices about which analyses they do and which data they use; they plan their own investigations. The level and complexity of the Level 3 investigations is generally higher than in Level 2.
Level 4 – Students use the skills from Level 3. They identify datasets and develop code for computational analysis tools for the investigation of their own research plan.

e-Lab: A browser-based online platform in which students can access and analyze data in a guided-inquiry scientific investigation. An e-Lab provides a framework and pathway as well as resources for students to conduct their own investigations. e-Lab users share results through online plots and posters. In the CMS e-Lab, data are available from the Compact Muon Solenoid (CMS) experiment at CERN[2]'s Large Hadron Collider (LHC). In the Cosmic Ray e-Lab, users upload data from QuarkNet cosmic ray detectors located at high schools, and once uploaded, the data are available to any and all users.

[2]Conseil Européen pour la Recherche Nucléaire

Masterclass, U.S. Model: A one-day event in which students become "particle physicists for a day." Teachers and mentors participate in an orientation by QuarkNet staff or fellows. Teachers implement about three hours of classroom activities prior to a masterclass. Then, during the masterclass that usually takes place at a center, mentors introduce students to particle physics and explain the measurements they will make using authentic particle physics data. Working in pairs, students are expected to analyze the data in visual event displays; to characterize the events; pool their data with peers; and draw conclusions, helped by one or more particle physicists and their teacher. At the end of the day, students may gather by videoconference with students at other sites to discuss results with moderators, who are particle physicists, at Fermilab or CERN. Some masterclasses take place at school with teachers providing the particle physics and measurement information. U.S. Masterclasses are part of a larger program, International Masterclasses.

Workshops: The primary vehicle through which participating QuarkNet teachers receive professional development.

Center-run Workshop: A center's second year involves new associate teachers in a multi-week experience that focuses on a research scenario prepared by their mentor(s) with support from lead teacher(s). The mentor models research, similar to Data Camp, where teachers, as students and active learners, have an opportunity to engage in an experiment, receive and analyze data, and present results. Then teachers have time to create a plan to share their experiences with their students and often use instructional materials from the Data Activities Portfolio in this planning.

During a center's third year and after, lead teacher(s) and mentor(s) have flexibility to organize 4-to-5 day workshops to meet local needs and interests. These workshops vary in content and structure. Centers may meet only during the summer, only during the school year or both during the summer and school year. Some centers meet even more frequently depending upon interest and availability of teachers. These workshops may include a national workshop[3] and offer a learning-community environment with opportunities for teachers to interact with scientists, and learn and share ideas related to content and pedagogy.

[3]**National Workshop:** On request, QuarkNet staff and/or fellows conduct workshops held at local centers. These workshops typically occur during the summer and can vary in length from several days to a week period. Content includes, for example, cosmic ray studies, LHC or neutrino data, and related instructional materials from the Data Activities Portfolio. National workshops support opportunities for teachers to work in a learning-community environment, learn and share ideas related to content and pedagogy, and develop classroom implementation plans.

Program Strategies

QuarkNet is not static but evolves to reflect changes in particle physics and the education context in which it operates.

Teachers

Provide opportunities for teachers to be exposed to:

- Instructional strategies that model active, guided-inquiry learning (see NGSS science practices).
- Big Idea(s) in Science (cutting-edge research) and Enduring Understandings (in particle physics).

Provide opportunities for teachers to:

- Engage as active learners, as students.
- Do science the way scientists do science.
- Engage in authentic particle physics investigations (that may or may not involve phenomenon known by scientists).
- Engage in authentic data analysis experience(s) using large data sets.
- Develop explanations of particle physics content.
- Discuss the concept of uncertainty in particle physics.
- Engage in project-based learning that models guided-inquiry strategies.
- Share ideas related to content and pedagogy.
- Review and select particle physics examples from the Data Activities Portfolio instructional materials.
- Use the pathways, suggested in the Data Activities Portfolio, to help design implementation plan(s).
- Construct classroom implementation plan(s), incorporating their experience(s) and Data Activities Portfolio instructional materials.
- Become aware of resources outside of their classroom.

Local Centers

Each center seeks to foster lasting relationships through collaboration at the local level and through engagement with the national program.

In addition, through sustained engagement provide opportunities for teachers and mentors to:

- Interact with other scientists and collaborate with each other.
- Build a local (or regional) learning community.

Program Outcomes

Teachers

Translate their experiences into instructional strategies, which reflect guided inquiry and NGSS science and engineering practice and other science standards as applicable.[4, 5] Specifically:

- Discuss and explain concepts in particle physics.
- Engage in scientific practices and discourse.
- Use particle physics examples, including authentic data, when teaching subjects such as momentum and energy.
- Review and use instructional materials from the Data Activities Portfolio, selecting lessons guided by the suggested pathways.
- Facilitate student investigations that incorporate scientific practices.
- Use active, guided-inquiry instructional practices in their classrooms that align with NGSS and other science standards.
- Use instructional practices that model scientific research.
- Illustrate how scientists make discoveries.
- Use, analyze and interpret authentic data; draw conclusions based on these data.
- Become more comfortable teaching inquiry-based science.
- Use resources (including QuarkNet resources) to supplement their knowledge and instructional materials and practices.
- Increase their science proficiency.
- Develop collegial relationships with scientists and other teachers.
- Are lifelong learners.

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[4] College Board Advanced Placement science standards and practice; and AP Physics; International Baccalaureate Science standards and practices.
[5] To the extent possible in their school setting.

(And their) Students will be able to:

- Discuss and explain particle physics content.
- Discuss and explain how scientists develop knowledge.
- Engage in scientific practices and discourse.
- Use, analyze and interpret authentic data; draw conclusions based on these data.
- Become more comfortable with inquiry-based science.

Local Centers

- Model active, guided-inquiry instructional practices that align with NGSS and other science standards that model scientific research.

Through engagement in local centers

Teachers as Leaders:

- Act in leadership roles in local centers and in their schools (and school districts) and within the science education community.
- Attend and/or participate in regional and national professional conferences sharing their ideas and experiences.

Mentors:

- Become the nexus of a community that can improve their teaching, enrich their research and provide broader impacts for their university.

Teachers and Mentors:

- Form lasting collegial relationships through interactions and collaborations at the local level and through engagement with the national program.

Enduring Understandings (See last page.)

Sustainability[a]

Antecedents

Characteristics of the Specific Program

1. Fidelity to PTM core strategies as implemented (national or center level)[b]
2. Evidence of flexibility/adaptability at the center level (if/as needed)
3. Evidence of effectiveness

Organizational Setting at the Center-level Program[c]

1. (Good) fit of program with host's organization and operations
2. Presence of an internal champion(s) to advocate for the program
3. Existing capacity and leadership of the organization to support program
4. Program's key staff or clients believe in the program (believe it to be beneficial)

Specific Factors Related to the Center-level Program

1. Existing supportive partnerships of local organizations (beyond internal staff)
2. Potentially available/existing funders or funding
3. Manageable costs (resources and personal; supported by volunteers)[d]

Outcomes

1. Program components or strategies are continued (sustained fidelity in full or in part).[e]
2. Benefits or outcomes for target audience(s) are continued.[e]
3. Local/center-level partnerships are maintained.[f]
4. Organizational practices, procedures and policies in support of program are maintained.
5. Commitment/attention to the center-level program and its purpose is sustained.[f]
6. Program diffusion, replication (in other sites) and/or classroom adaptation occur.[f]

Core Values/Assumptions

QuarkNet provides opportunities:

1. That seek to meet the needs and interests of participating teachers.
2. For participating teachers and mentors to form collegial relationships that are an integral part of the QuarkNet experience.
3. Where participating teachers are professionals.
4. For teachers to get together to discuss physics and to form learning communities.
5. Where QuarkNet centers are central to building a national program and are an effective way to do outreach.
6. Where QuarkNet fellows are integral in helping the program reach teachers.
7. To help keep high school physics teachers interested and motivated in teaching and to help teachers avoid burnout.
8. Where a diversity of ideas is brought into the program to help the long-term commitment by teachers/mentors to the program.
9. To help build and improve science literacy in teachers and their students.
10. To help teachers build confidence and comfort in teaching guided-inquiry physics.

The program is based on the premise that:

11. All students are capable of learning science.
12. Science is public, especially in physics where many researchers collaborate together on the same experiments.
13. The program should strive to achieve equity in language and behavior relative to race, ethnicity and gender.
14. Through the program, teachers are able to go back to their classroom with enthusiasm and with ideas that they can use to appeal to the imagination of their students.
15. Master teachers as staff are effective PD facilitators and center contacts.

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[a]This framework is based on the work of Scheirer and Dearing (2011); adopting their definition of sustainability, as well: "Sustainability is the continued use of program components and activities for the continued achievement of desirable program and population outcomes" (p. 2060). The QuarkNet Sustainability framework has been modified to better reflect the QuarkNet program (as recommended by Scheirer, et al., 2017). (See notes below.)

[b]Program fidelity, as *implemented*, has been added as a program characteristic.

[c]The language used to describe these organizational characteristics has been modified slightly to better fit the *QuarkNet* program.

[d]This cost component was moved to environmental or contextual concerns of the specific program.

[e]The order of these two outcomes are reversed from the original.

[f]The language of this characteristic was modified to better fit the QuarkNet program.

Enduring Understandings of Particle Physics

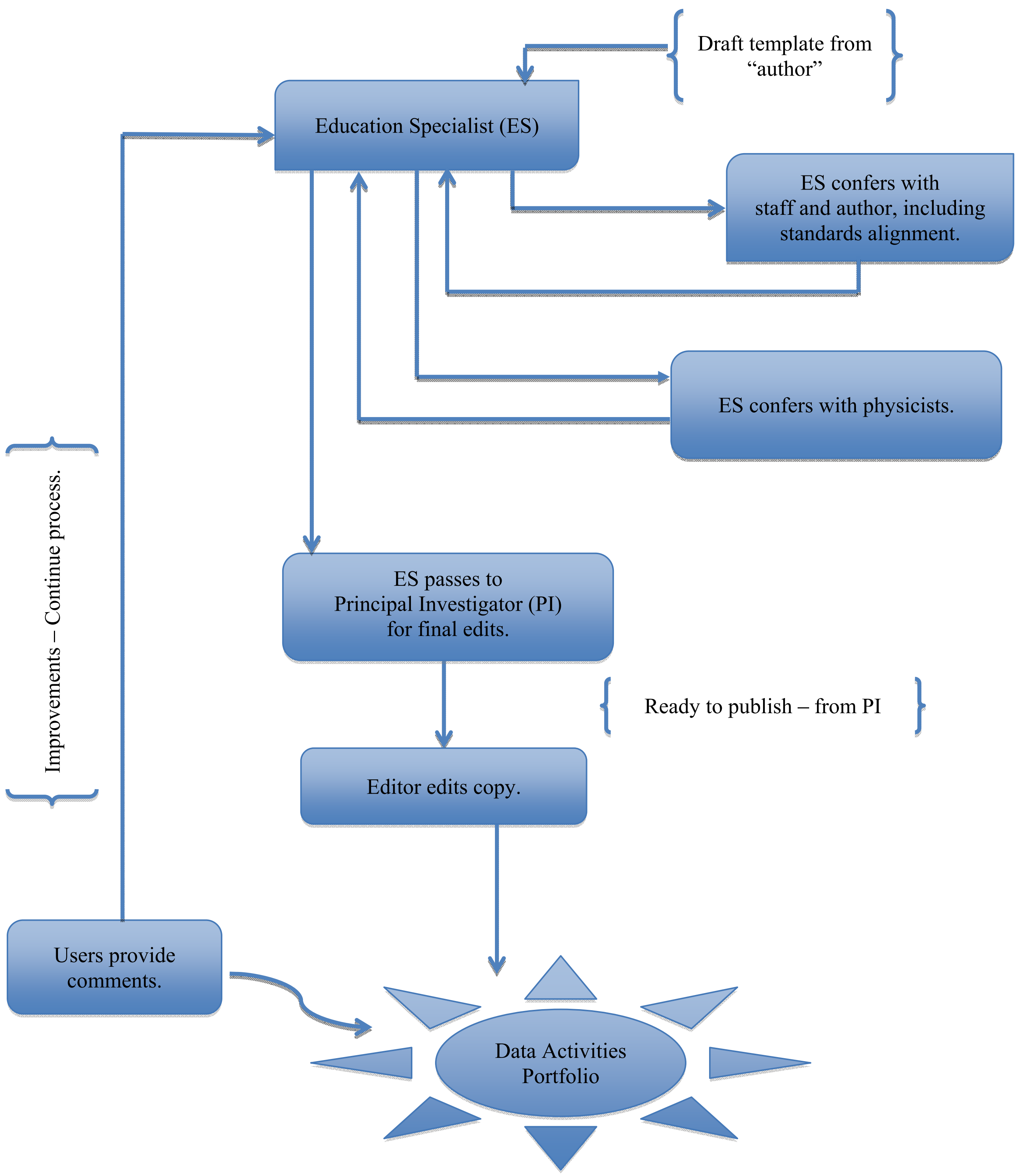
1. Scientists make a claim based on data that comprise the evidence for the claim.
2. Scientists use models to make predictions about and explain natural phenomena.
3. Scientists can use data to develop models based on patterns in the data.
4. Particle physicists use data to determine conversation rules.
5. Indirect evidence provides data to study phenomena that cannot be directly observed.
6. Scientists can analyze data more effectively when they are properly organized; charts and histograms provide methods of finding patterns in large datasets.
7. Scientists form and refine research questions, experiments and models using observed patterns in large data sets.
8. The Standard Model[6] provides a framework for our understanding of matter at its most fundamental level.
9. The fundamental particles are organized according to their characteristics in the Standard Model.
10. Particle physicists use conservation of energy and momentum to measure the mass of fundamental particles.
11. Fundamental particles display both wave and particle properties, and both must be taken into account to fully understand them.
12. Particle physicists continuously check the performance of their instruments by performing calibration runs using particles with well-known characteristics.
13. Well-understood particle properties such as charge, mass, momentum and energy provide data to calibrate detectors.
14. Particles that decay do so in a predictable way, but the time for any single particle to decay, and the identity of its decay products, are both probabilistic in nature.
15. Particle physicists must identify and subtract background events in order to identify the signal of interest.
16. Scientists must account for uncertainty in measurements when reporting results.

Developed by Young, Roudebush, Smith & Wayne, 2019, revised 2021

[6] The Standard Model of Particle Physics: the current theoretical framework that describes elementary particles and their forces (six leptons, six quarks and four force carriers). Physicists (and other scientists) can understand every phenomenon observed in nature by the interplay of the elementary particles and forces of the Standard Model. The search beyond the Standard Model of Particle Physics may lead to a larger, more elegant "theory of everything." (http://www.fnal.gov/pub/science/inquiring/matter/ww_discoveries/index.html)

Instructional Design Pathway and Templates for Data Activities Portfolio

PROCESS: To ensure what we publish is of highest quality.



Criteria Used at Instructional Design Stage – Annotated

In line with the NGSS Framework*

Exemplars:

1. Includes a question to address and/or problem to solve; could be developing a model to explain a phenomenon or test a model. – Science Practices
2. Students gather data and/or test solutions; provide claims, evidence and reasoning. – Science Practices
3. Addresses crosscutting concept(s) and disciplinary core ideas

In line with the Common Core Literacy Standards**

Reading Exemplars:

1. 9-12.4 Determine the meaning of symbols, key terms . . .
2. 9-12.7 Translate quantitative or technical information . . .

In line with the Common Core Mathematics Standards**

Exemplars:

1. MP2. Reason abstractly and quantitatively.
2. MP5. Use appropriate tools strategically.
3. MP6. Attend to precision.

In line with AP Physics 1 Curriculum Framework Standards***

Exemplars:

1. EK 3.A.2: Forces are described by vectors.
2. EK 3.B.1: If an object of interest interacts with several other objects . . .
3. EK 3.C.3: A magnetic force results from the interaction of a moving . . .

In line with AP Physics 2 Curriculum Framework Standards****

Exemplars

1. EK 1.E.6.a: Magnetic dipole moment is a fundamental source . . .
2. EK 3.A.2: Forces are described by vectors.
3. EK 3.C.3: A magnetic force results from the interaction of a moving . . .

In line with IB Physics Standards*****

Standard 1: Measurement and Uncertainty
Standard 5: Electricity and Magnetism

*<u>A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas</u>, National Research Council, 2012. https://www.nextgenscience.org/

**The Common Core State Standards for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects, Council of Chief State School Officers (CCSSO) and the National Governors Association (NGA), 2019. http://www.corestandards.org/read-the-standards/

***AP Physics 1: Algebra-Based Course and Exam Description, College Board, 2017. https://secure-media.collegeboard.org/digitalServices/pdf/ap/ap-physics-1-course-and-exam-description.pdf

****AP Physics 2: Algebra-Based Course and Exam Description, College Board, 2017. https://secure-media.collegeboard.org/digitalServices/pdf/ap/ap-physics-2-course-and-exam-description.pdf

*****International Baccalaureate Physics (SL) Standards, IB Diploma Programme, 2016. https://www.ibo.org/globalassets/publications/recognition/physicssl2016englishw.pdf

International Baccalaureate Physics (HL) Standards, IB Diploma Programme, 2016. https://www.ibo.org/globalassets/publications/recognition/physicshl2016englishw.pdf

Macro Design

1. Activity addresses a ‘big idea’ (core idea); sub-ideas support the big idea (can be concepts and/or principles).

   Often, this is the same as or similar to the enduring understanding. A core idea can be as basic as “calibration,” a classic physics concept such as “momentum,” or a principle (law) such as $E = mc^2$. Research indicates that students come away from a well-structured lesson/activity with an understanding that they maintain even through life (it “endures”). Over time they lose the details but not the enduring understanding.

2. Students apply science process skills and/or design technology.

   There are a variety of skills that students learn in *doing* science. These include all the ways students use data as well as thinking/reasoning skills such as compare/contrast, infer/predict. Design technology means the process of design-develop-test-redesign-redevelop-retest . . . i.e., engineering.

3. Format is guided inquiry.

   Over the years, QuarkNet teachers have developed the understanding that in doing particle physics, students and teachers can learn best facilitated by guided, not open, inquiry. While leading/facilitating is important, such as asking clarifying questions, learning particle physics depends on difficult concepts, principles and procedures that need more guidance than some other science fields.

4. The conceptual framework is from simple to complex and supports activities that can include an “enrichment” or follow-on section.

   The conceptual framework is embodied in the Data Activities Portfolio (DAP). The DAP organizes activities by data strand, pathway and level of student engagement. Activities differ in complexity and sophistication—tasks in Level 0 are designed to build skills needed for higher levels. Level 1 activities are simpler than those in Levels 2 and 3. While each level can be explored individually, students who start in one level and progress to more complex levels experience increasingly challenging tasks. Pathways suggest activity sequences designed to develop understanding of a particular concept. Also, teachers can select activities to offer a learning experience of an appropriate length and level for their students.

Level Definitions

Level 0 Students builds background skill and knowledge needed to do a Level 1 activity. Students analyze one variable or they determine patterns, organize data into a table or graphical representation and perform simple calculations.

Level 1 Students use background skills developed in Level 0. They calculate descriptive statistics, seek patterns, identify outliers, confounding variables, and perform calculations to reach findings; they may also create graphical representations of the data. Datasets are small in size. The data models come from particle physics experimentation.

Level 2 Students use skills from Level 1. They perform many of the same analysis tasks but must apply a greater level of interpretation in order to distinguish between signal and background. Datasets are medium in size so that mathematical calculations are too large to be done using pencil and paper.

Level 3 Students use the skills from Level 2. They develop and implement a research plan utilizing large datasets. They make decisions in their analysis by taking into consideration complications such as background, signal to noise, and instrumentation effects.

Level 4 Students use the skills from Level 3. They identify datasets and develop analysis tools for the investigation of their own research plan.

Micro Design

1. There are behavioral objectives.

   The objectives start with a verb (what you want students to know and be able to do) and/or the action (behavior) is implicit in the objective. The objectives should ALL be measurable since they will drive what is in the assessment: Did students learn what you wanted them to know? Did they exhibit the skill you wanted them to learn?

2. There are connections to the real world such as awareness of scientific exploration, contemporary physics research, the skills that scientists use, and the importance of scientific literacy.

   Since one of the QuarkNet goals is for students to become more scientifically literate, it is important that the activities help them better understand what doing science actually involves and how scientists pursue science. This may include statements such as "This is what they do at CERN" or "This is how scientists do . . ." to ensure these data are useable/reliable/accurate."

3. Students analyze data to come up with a hypothesis/solution/explanation; they apply reasoning including critiquing their ideas; e.g., identify flaws in their argument.

   A main focus of the NGSS, Common Core, AP Physics 1, AP Physics 2, and IB is for students to be able to make a claim based on evidence and reasoning. Often, the final "reasoning" part is missing. They can describe the evidence, but they fail to make the logical reasoning to connect the data with the conclusion they draw. Students must be able to back up their conclusion with an evaluation of the extent to which their data is "good" evidence to support the conclusion.

4. Evaluation/assessment is based on whether or not the objectives are achieved; questions refer directly to the objectives. There are no distractions or extraneous ideas.

   Several activities will have a student report sheet. This could be used as the summative assessment if the objectives are aligned with the report sheet. Learning a skill, such as developing a histogram, can be a formative assessment that may or may not become part of the report sheet but is nonetheless assessed. Formative assessment may be just checking student work informally. If there is more that can be added to the activity, there might be an enrichment section. Adding extra ideas at the assessment stage, distractions and extraneous ideas, confuses the students about what you want them to know and be able to do.

   A sample template for an activity follows; this sample shows font size, type and other formatting that your activity must follow.

Title (Times New Roman, 18)

Teacher Notes (Times New Roman, 16)

(Times New Roman, 12)

Description (This type of style can be found under *Format, Font, Small Caps.*)

Briefly provide an overview and purpose of the activity. *For example:* From where do cosmic rays come? Can they be from the sun? Or are they from elsewhere but blocked by the sun? Students search for a specific data file in the Cosmic Ray e-Lab and look for evidence of the passage of the sun in the flux measurements derived from this file. Many people new to studying cosmic rays initially *think* that cosmic rays originate in our sun. This activity allows students to investigate this idea and study evidence that can confirm or refute their original understanding. An e-Lab user collected data with the detector in a configuration that allowed the detector's axis to sweep across the sun at local solar noon including data before and after the sun's transit. Data collected at the beginning and end of the sweep provide the "control" or no effect from the sun, while solar noon provides data on effect of the sun. (*Layout, after, 5 pt* between paragraphs)

Standards Addressed (Fill in as appropriate. This list shows format.)

Next Generation Science Standards

Science and Engineering Practices

4. Analyzing and interpreting data
5. Using mathematics and analytical thinking

Crosscutting Concepts

1. Observed patterns

Common Core Literacy Standards

Reading

9-12.4 Determine the meaning of symbols, key terms . . .

9-12.7 Translate quantitative or technical information . . .

Common Core Mathematics Standards

MP2. Reason abstractly and quantitatively.

AP Physics 1 Standards

Exemplars

AP Physics 2 Standards

Exemplars

IB Physics Standards

Exemplars

Enduring Understandings

- One EU per activity

Choose from one of the following:

1. Scientists make a claim based on data that comprise the evidence for the claim.
2. Scientists use models to make predictions about and explain natural phenomena.
3. Scientists can use data to develop models based on patterns in the data.
4. Indirect evidence provides data to study phenomena that cannot be directly observed.
5. Scientists can analyze data more effectively when they are properly organized; charts and histograms provide methods of finding patterns in large data sets.
6. Scientists form and refine research questions, experiments and models using observed patterns in large data sets.

7. The Standard Model provides a framework for our understanding of matter at its most fundamental level.
8. The fundamental particles are organized according to their characteristics in the Standard Model.
9. Particle physicists use conservation of energy and momentum to measure the mass of fundamental particles.
10. Fundamental particles display both wave and particle properties, and both must be taken into account to fully understand them.
11. Particle physicists continuously check the performance of their instruments by performing calibration runs using particles with well-known characteristics.
12. Well-understood particle properties such as charge, mass, momentum and energy provide data to calibrate detectors.
13. Particles that decay do so in a predictable way, but the time for any single particle to decay, and the identity of its decay products, are both probabilistic in nature.
14. Particle physicists must identify and subtract background events in order to identify the signal of interest.

LEARNING OBJECTIVES (BEGIN WITH VERB THAT CAN BE MEASURED.)

As a result of this activity, students will know and be able to:

- xxx

PRIOR KNOWLEDGE

What students should probably know before they engage in this activity

BACKGROUND MATERIAL

This is content information for the teacher, often including links for where to get more information.

RESOURCES/MATERIALS

IMPLEMENTATION

Guidelines for the teachers, activity sequence; basically, write-up of the activity – procedure. Think of this section as annotated student notes.

ASSESSMENT

Formative assessment includes discussion questions to ask students to increase conceptual understanding. Summative assessment includes tests, quizzes, oral and/or written report including the activity report that focuses on claims, evidence and reasoning. **Note:** Any assessment must address the learning objectives which means assessing what you want them to know and be able to do. Just indicating that students will write a report is insufficient. If a report is the best option, include some idea of what the report would be about. For example, an assessment about cosmic rays which follows from the questions raised in the sample description might be: What would you tell people who believe that cosmic rays originate from our sun? What evidence and reasoning would you provide to support your claim?

NOTE: WE PROVIDE TWO TEMPLATES FOR STUDENT PAGES.

GUIDELINES FOR WHICH TEMPLATE TO USE:

- For a level two or three activity, use a student report sheet and template two.
- For complex activities that require students to make a claim and provide evidence and reasoning, use a student report sheet and template two.
- An activity that addresses a claim based on observed data, such as *Mapping the Poles*, does not need a student report sheet because it is not complex. Contrast this with *Calculate the Z Mass* which requires analysis that is more complex.

- For an activity that focuses on learning a skill and/or exploring a model, a report sheet may be the only thing necessary, e.g., *Quark Workbench 2D/3D*; students make “rules” and have to back them up with reasoning, but not in the context of a scientific investigation. The activity *Dice, Histograms and Probability* explores histograms, so does not need a student report sheet: template one.

Clearly these guidelines are not hard and fast rules. Authors will have to decide for themselves which template to use. Luckily, there are several people in the review process who can act as consultants. NOTE: Some activities do not even need a student report sheet; e.g., *Dice, Histograms & Probability*. Those activities are explorations of a topic with the teacher acting as facilitator.

TITLE (TEMPLATE FOR STUDENT PAGES)
STUDENT PAGE

Template One:
Question(s), problem to solve; overall purpose of doing the activity - INTRODUCTION
Steps/guidelines; supporting content, materials, resources (including websites)

Claims, Evidence, Conclusions
For example, when the students have finished the activity, project on the screen the Elementary Particles chart again. Discuss the fact that they have investigated a small part of the Standard Model—one that describes formation of baryons and mesons. There is more to learn about the Standard Model—both for the students and for physicists.

- What rules did you discover that determine the composition of baryons? Mesons? What is the evidence for the rules? (Hint: Describe quark properties.)
- What role did quarks play in forming the mesons and baryons?
- In addition to quarks, what other particles are "fundamental"?
- What do physicists call the current theoretical framework for our understanding of matter?

The learning objectives were:
As a result of this activity, students will know and be able to:

- Identify the fundamental particles in the Standard Model chart.
- Describe properties of quarks, including color, spin, and charge.
- Describe the role of quarks in forming particles that are part of the Standard Model.
- State the rules for combining quarks to make mesons and baryons.

Template Two:
Question(s), problem to solve; overall purpose of doing the activity – INTRODUCTION
Objectives: Could be as simple as what is their task; does not have to be the learning objectives, but could be.
Student pages currently include (after a brief overview of the activity):

- What do we know?
- What tools do we need for our analysis?
- What do we do?
- What are our claims? What is our evidence?

Assessment is a student report.

Note: Edit the gray boxes to specifically address the questions in your activity. See *Calculate the Z Mass* for an example of a good report.

TITLE (TEMPLATE FOR STUDENT REPORT SHEET)

STUDENT REPORT

Research question:

Reason:

Physics principles:

Hypothesis and reasoning:

Claim:

Evaluate the accuracy of your hypothesis as an answer to the research question.

Evidence:

2–3 pieces of evidence (data, observations, calculations) that support the claim

Questions to consider: How did we test the hypothesis? What data supports the claim?

Reasoning:

Justify how and why the evidence backs up the claim. Use scientific principles to explain ***why*** you got this data. Use and explain relevant scientific terms.

Questions to consider: Why does the data compel this claim? Is anything left out?

Sources of Uncertainty in Measurement:

How much do results vary in calculation of the Z mass? Why? Are their outliers? Why?

Question to consider: Why and to what extent can we trust your results?

Practical Applications:

What is the value of what you learned?

Questions to consider: How might this information be useful to the ATLAS and/or CMS collaborations? To the future runs of the LHC?

Now, write your formal scientific conclusion statement. Combine your ideas from the previous pages into two or three well-constructed paragraphs that include the research question, your hypothesis, your evaluation of the hypothesis providing claim, evidence and reasoning, possible sources of uncertainty specific to your data and practical applications for your discovery.

ARCS Action, Relevance, Confidence, Satisfaction

Review Protocol – Revised 5/15/17

Name of Activity ____

Teacher pages _____   Student Pages _____

Date of Review ________________________________

Review Status (e.g., 2nd review) ____

General Note: Including their own wording in the review helps make the point.

Is in line with the NGSS Framework

1 – Includes a question to address and/or problem to solve; could be developing a model to explain a phenomenon or test a model

Notes: Should be engaging/attention-getting (A in ARCS model). Sets the stage for what students will be doing. Should be on Teacher Pages somehow but crucial that it is at the start of the Student Pages.

2 – Students gather data and/or test solutions; provide claims, evidence and reasoning.

Notes: Students are asking a question, solving a problem or creating a model. For asking a question or solving a problem, CER is obvious. For creating a model they should be describing why/how it is a model and its' limitation.

3 – Students use Science and Engineering Practices (Framework p. 3)

Notes: These may agree or somewhat disagree with what the author says they are. I find authors over-sell what they address.

4 – Address Cross Cutting Concept(s) and Core Idea (Framework p. 3)

Notes: See above

Macro Design

1 – A 'big idea' (core idea) is addressed; sub-ideas support the big idea (can be concepts and/or principles)

Notes: A 'concept' is a human-made idea, usually a definition. A 'principle' is a law such as F=MA, or rule such ' I before e except after c.' QN authors most often miss this most important part of the designing an activity. This is related to but not always exactly the same as the Enduring Understanding. In science, this is most often a principle. Instructional design suggests a principle be taught using cause-effect or effect-cause analyses; concepts using examples and non-examples.

ARCS Action, Relevance, Confidence, Satisfaction

2 – Students apply science process skills and/or design technology
Notes: process skills are -–observe, contrast, evaluate, etc. Design technology is engineering so its: design, test, re-design, re-test…. These are usually addressed very well by QN authors but it's important to check. Also, an easy "very good" which is especially important if they don't do well in other categories.

3 – Format is guided inquiry
Notes: Awhile ago, most QN folks agreed that the accepted level for activities is 'guided inquiry; because the content is so advanced/complex. Now that there are '0' level activities, that might not be as important for those particular activities but should continue to be a guideline for other levels. Guided inquiry includes a lot of questions to guide understanding.

Micro Design
1 - There are behavioral objectives
Notes: Always a challenge. See below for what MJY sent to QN regarding developing objectives (easy five steps). Sometimes the biggest challenge is have authors address the objectives in their assessments,

<u>If there is an objective, it should show up in the assessment.</u>

2 – There are connections to the 'real-world' such as actual scientific exploration (modern physics) and/or skill that scientists use and/or promoting scientific literacy
Notes: Usually fairly well done. Is part of the 'R' in the ARCS model (relevance). When authors 'get into the weed' they frequently forget that not all students may think this is the greatest thing since sliced bread. Authors need to hang their enthusiasm on something real-world, which they know, but the students are unlikely to.

4 – Evaluation/assessment is based on whether or not the objectives are achieved; questions asked directly refer to the objectives (there are no distractions such as extraneous ideas)
Notes: "Write a report,' unless it is one of those developed for the activity that includes CER, will not suffice. Authors cannot be lazy about addressing the objectives. Also it is probably important to have something that addresses the EU as well. Especially for longer activities, look for formative evaluation that may include a discussion, completing a part of the report sheet for that activity, and/or reporting out.

OVERALL:
Notes: Consider which aspects of the activity are likely to lead to confidence and satisfaction ("C" and "S" of the ARCS model), Point out what was good, bad, ugly, beautiful… Let author know if you want to see it again.

ARCS Action, Relevance, Confidence, Satisfaction

Easy Five-Step Tutorial for Developing and Using Objectives:

1. What do you want teachers/students/participants to know and be able to do? (This step will be revisited as the assessment is developed, i.e., the assessment will determine the extent to which the participants have achieved the objectives.) Decide among objectives for content, skills, pedagogy (for teachers).
2. Determine which active/behavioral verb is best for assessing each behavior, which might include: explain, list, describe, interpret, compare, contrast, evaluate, predict, analyze, decide (NEVER 'understand'). Each objective must be measurable – in the assessment. If you have to ask yourself "how can I measure this?" you are on the wrong track. It should be obvious.
3. Look at your objectives to see if it isn't just a list of what you will do during the workshop. Example: look at the list of objectives for cosmic ray from Emanuel. If they are, think again—what do you actually want them to know and be able to do when they are finished with the workshop.
4. Pare objectives down to the essential four to six. You might have to think about the larger idea for some of them. Are they going to "develop a histogram" or "organize data"? But remember, again, these are what you will assess.
5. Figure out within the workshop and/or at the end how you will assess the extent to which the objectives have been achieved. It doesn't require a test but you might just have participants post how they have organized data, reported out their claims and provided evidence, listed crucial rules/principles, provided ideas for implementing in the classroom.

SHARE THE OBJECTIVES WITH PARTICIPANTS

As you continue to develop workshops and write activities, please remember to "start with the end in mind." Development comes ***after*** Step 1 (above).

QuarkNet Activity Review Narrative

March 8, 2019

Background

Jean Young, Instructional Designer, and Tom Jordan, Staff Coordinator, developed the activity templates. Jean oversaw activity review until Spring 2017 when the responsibility passed to Deborah Roudebush, Education Specialist. Jean trained Deborah in 2016. Included in the review and approval process were editors Marge Bardeen, PI, and LaMargo Gill. Jean, Marge, Deborah and Jeremy Smith, Education Specialist, developed a standard list of enduring understandings. Table 1 shows the status of the Data Activities Portfolio during 2016.

Table 1
Activity Review Status 2016

Activity	Review	#2 Review	Done	Posted
Calculate the Z Mass (T, S, R)	7/22/14	3/20/26		✓
Plotting LHC Discovery (T and S pages)	3/29/14	2/25/16	✓ 4/16	✓
Calculate the Top Quark Mass (T and S)	3/21/14	3/20/16		✓
Quark Workbench	3/20/14	3/15/16	✓	✓
Mass of U.S. Pennies (T notes, S handout)	3/10/14	2/25/16	✓	✓
Making it ‘Round the Bend (3 activities)	7/25/14	3/18/16		✓
Rolling with Rutherford (T notes)	3/10/14	2/25/16	✓ 4/16	✓
Dice, Histograms & Probability	3/19/15	4/27/16	✓	✓
Seismology				
Cosmic Muon Lifetime	8/2/16	10/11/16		
ATLAS Masterclass				
ALICE Masterclass				
CMS Masterclass				
LHCb Masterclass				
CMS Data Express *(Shift Report 8/2/16)*	7/21/14	3/15/16	✓ 4/16	✓
Cosmic Rays and the Sun (T notes)	3/17/15	2/25/16	✓	✓
TOTEM Data Express (T, S pages; report)	5/12/15	2/25/16	✓	✓
ATLAS Data Express	3/23/15	10/11/16	✓	✓
Cosmic Ray e-Lab				
LIGO e-Lab				
CMS e-Lab				

Activity Review 2017

In Spring 2017, Jean passed the review responsibilities to Deborah. Deborah focused the reviews and activity development on matching content to the template, uniformity of layout, language level for teachers with less content training, behavioral objectives and assessments directly tied to objectives. Deborah, Ken Cecire, Staff Teacher, and Shane Wood, Staff Teacher, agreed that the masterclass activities should be split since centers choose to study ATLAS Z-path, ATLAS W-path, CMS WZH-path or CMS J/Ψ-path. The team reviewed several activities again to better align them with the new guidelines.

Table 2
Activity Review Status 2017

Activity	Posted
CMS Data Express	8/17
Plotting LHC Discovery	8/17
Calculate the Top Quark Mass (T and S)	8/17
Quark Workbench	8/17
Calculate Z Mass	9/17
ATLAS Z-path Masterclass	11/17
Mass of U.S. Penny	11/17
CMS ZWH-path Masterclass	12/17

Ken, Shane and Deborah decided we could facilitate teacher usage by identifying pathways or a series of activities that follow a theme. While these pathways were a desirable goal, it became clear that there were many gaps in the skills students needed to use higher-level activities. This led to the development of new activities.

The team documented the meaning of activity levels, the list of enduring understandings, and the pathway guidance. They posted these documents in the Data Activities Portfolio in the introductory paragraphs of the webpage.

Activity Review 2018

The focus in 2018 for Deborah, Ken and Shane was on finishing the review of the previously posted activities and filling in the gaps for improved pathway guidance. The team brainstormed methods of making the pathways more accessible for teachers as well as easier to edit and maintain. Deborah worked with Joel Griffith, IT Staff, to design a modification to the Data Activities Portfolio pages to allow teachers to use a pull-down menu of topics to select a pathway. The target for completion of this feature is Summer 2019.

Table 3 lists the activities posted in 2018.

Table 3
Activity Review Status 2018

Activity	Posted
ATLAS W-path Masterclass	1/18
CMS J/Ψ	2/18
Shuffling the Particle Deck	2/18
Making It ‘Round the Bend: Qualitative*	4/18
Making It ‘Round the Bend: Quantitative*	5/18
Mapping the Poles	6/18
Signal and Noise: The Basics	6/18
Quark Workbench 2D/3D**	8/18
Signal and Noise: Cosmic Muons	9/18
Mean Lifetime Part 2: Cosmic Muons***	9/18

*Jeff Rodriguez, University of Cincinnati QuarkNet Center, developed the simulation that made these activities possible.

**Lachlan McGinness is an Australian physics teacher and visiting fellow at the Australian National University. He created the 3D puzzle activity while appointed as Teacher in Residence at CERN in 2018.

***Originally posted as Cosmic Mean Lifetime.

Activity Review 2019

The focus in 2019 for Deborah, Ken and Shane is on developing neutrino activities to support a neutrino strand and neutrino pathways. There are still five posted activities that have not undergone full review. Deborah continues to work with Joel to design a modification to the Data Activities Portfolio pages to allow teachers to use a pull-down menu of topics to select a pathway. The target for completion of this feature is Summer 2019.

Table 4 lists the activities under review in 2019.

Table 4
Activity Review Status 2019

Activity	Posted
ALICE Masterclass	
LHCb Masterclass	
Cosmic Rays and the Sun	
Cosmic Ray e-Lab	
CMS e-Lab	

Table 5 contains a list of activities currently under development. These activities are primarily to support a neutrino strand as well as strands for special relativity and uncertainty. The staff is developing a draft Level 4 activity to test with teachers and students.

Table 5
Activities Under Development 2019

Activity	Posted
Mean Lifetime Part 3: MINERvA	
Feynman Diagrams	
To Catch a Speeding Muon	
Neutrino Hide & Seek (a reworked Calculate Top Quark Mass)	
Special Relativity Holds the Answers	

Table F-1
2018-2019 QuarkNet National Workshops

QuarkNet Center	Workshop Type (e.g., Cosmic, Data, CMS e-Lab)	Workshop Dates (Chronological Order)	Staff/Fellow Leading Workshop
Kansas State University	LIGO	June 4-5	Shane Wood
Kansas State University	Cosmic	June 6-8	Martin Shaffer
University of Minnesota	Neutrino Prototype	June 13-14	Shane Wood/Ken Cecire
Texas Tech University	Cosmic	June 13-14	Martin Shaffer
Rice University/ University of Houston	CMS Data	June 25-26	Shane Wood
Rice University/ University of Houston	Neutrino Prototype	June 27-28	Shane Wood
University of Iowa/Iowa State University	CMS e-Lab	July 9-10	Marla Glover
Black Hills State University	Neutrino Prototype	July 18-19	Shane Wood
Fermilab/University of Chicago	LIGO	July 18-19	Shane Wood
Johns Hopkins University	LIGO	July 25-26	Marla Glover
Virginia Center	Neutrino Prototype	August 6-7	Shane Wood
Colorado State University	LIGO	August 8-10	Ken Cecire
University of Washington	ATLAS Data	August 17-19	Shane Wood
University of Florida	Neutrino Prototype	August 25-26	Ken Cecire

[a]Hampton, George Mason and W&M Universities

2018- 2019 Program Year

A list of nationally-led QuarkNet Workshops (led by QuarkNet staff) during the 2018-2019 program year by QuarkNet staff is shown in Table F-1. Data Camp was implemented at Fermilab from July 16-20, 2018. These are considered nationally-run workshops.

Table F-2 lists the meetings and workshops held as Center-led QuarkNet workshops and those led by the *individual centers*. Together for both tables, this represents a total of 55 centers (50 centers in year 3+ of the program); 1 virtual center; and 4 sabbatical centers (based on emails from S. Wood, K. Cecire; M. Bardeen, June 21, 2019).

2019-2020 and 2020-2021 Program Years

Table F-3 lists the meetings and workshops held during the 2019-2020 program year for both nationally- and center-led events. Similarly, F-4 lists the workshops and meeting during the 2020-2021 program years (again for both nationally- and center-led events).

The focus of these workshop summary tables is on teachers' exposure to Data Activities Portfolio activities (DAP) as evidence in support of subsequent classroom implementation. Important content and materials are likely part of these workshops as well (such as select talks on cutting edge particle physics topics and tours of labs/ experiments), but are not reflected.

Table F-2

2018-2019 QuarkNet Center-led Meetings and Workshops

Center	**2018** Meeting Dates (All days)	Center	**2018** Meeting Dates (All days)
Black Hills State University	July 10-14	University of California, Riverside	
Boston area	August 14-15	University of California, Santa Cruz	
Brookhaven National Laboratory	June 25-29	University of Cincinnati	Summer (no dates specified in annual report)
Catholic University of America	August 13-17, plus 3 days in fall	University of Florida	August 25-26
Colorado State University	August 8-10	University of Hawaii	June 2-3
Fermilab/University of Chicago	July 18-19	U of Illinois Chicago/Chicago State University	June 25-29
Florida Institute of Technology		University of Iowa/Iowa State	July 9-13
Florida International University		University of Kansas	June 11-13
Florida State University	August 1-2	University of Minnesota	June 12-14
Idaho State University	July 9-13	University of Mississippi	June 25-26
Johns Hopkins University	July 23-27	University of New Mexico	May 4 and one fall day
Kansas State University	June 4-8	University of Notre Dame	July 30 - Aug 3
Lawrence Berkeley National Laboratory/ Stony Brook University	June 18-22	University of Oregon	June 20-21
Northern Illinois University	June 25-29	University of Pennsylvania	
Oklahoma State University/University of Oklahoma	July 24-27	University of Puerto Rico-Mayaguez	Dec. 8-9; April 6, 2019
Purdue University		University of Rochester	
Purdue University Northwest	June 18-22	University of Tennessee, Knoxville	
Queensborough Community College		University of Washington	August 17-19
Rice University/University of Houston	June 25-29	University of Wisconsin-Madison	
Rutgers University	July 9-13	Vanderbilt University	June 25-29
Southern Methodist University	Aug 6-10	Virginia Center (Hampton, George Mason and William and Mary Universities)	Aug 6-8
Syracuse University	Aug 8-10	Virginia Tech University	July 23-26
Texas Tech University	June 13-15	Virtual Center	July 11-14
University at Buffalo	Aug 21-22	Wayne State University	

Table F-3

2019 QuarkNet Workshops and Meetings: National- and Center-led

Center	**2019 Dates (All days)**	**Workshop/Meeting**	**Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
Black Hills State University	No activity		
Boston area	August 14-15	**Neutrino Workshop** (co-led by Center)	Mean Life Part 3: Minerva (2) Mean Life Part 2: Cosmic Muons (2) What Heisenberg Knew (1) MINERvA masterclass measurement
Brookhaven National Laboratory/ Stony Brook University	July 3	**MINVERvA Neutrino Masterclass**	MINERvA Neutrino measurement (2)
The Catholic University of America	August 5-7	CMS and Cosmics **(CMS Data Workshop)**	Shuffling the Particle Deck (0) Rolling with Rutherford (1) Calculate the Z Mass (1)
Colorado State University	July 29-31	**Neutrino Data Workshop**	Mean Lifetime Part 1: Dice (1) Mean Lifetime Part 2: Cosmic Muons (2) Shuffling the Particle Deck (0) What Heisenberg Knew (1) The Case of the Hidden Neutrino (1) Histograms: Uncertainty (1) Mean Lifetime Part 3: MINERvA (2) Implementation Plans
Fermilab/University of Chicago	July 24-26	**Neutrino Data Workshop & Student Presentations**	Shuffling the Particle Deck (0) The Case of the Hidden Neutrino (1) Mean Lifetime Part 1: Dice (1) Mean Lifetime Part 3: MINERvA (2) MINERvA Masterclass measurement (2) Histograms: The Basics (0) Histograms: Uncertainty (1) What Heisenberg Knew (1) Implementation Plans
Florida Institute of Technology	No activity		

Note. National-led QuarkNet workshops are in a bold-face font.

Information compiled from the workshop agenda posted on individual center pages on QuarkNet website.

Table F-3

2019 QuarkNet Workshops and Meetings: National- and Center-led (con't.)

Center	**2019 Dates (All days)**	**Workshop/Meeting**	**Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
Florida International University	August 5-7	**CMS Workshop**	Shuffling the Particle Deck (0) Rolling with Rutherford (1) Calculate the Z Mass (1)
Florida State University	July 31- August 2	**CMS Workshop**	Shuffling the Particle Deck (0) Rolling with Rutherford (1) Calculate the Z Mass (1) Making it Round the Bend (Qualitative) (1) Making it Round the Bend (Quantitative) (2) CMS Masterclass Measurement (2)
Idaho State University Pocatello (co-conducted workshop with the University of Cinncinnati)	June 17-20	Cosmic Ray Muon Detectors (CRMD) **Neutrino Masterclass**	Assemble a complete CRMD Neutrino Masterclass
Johns Hopkins University	July 22-26	JHU Workshop	Create videos for use in the classroom Develop lesson plan/approach based on transcribed lecture recorded from a theoretical physicist
Kansas State University	March 2 April 5	Masterclass Orientation Masterclass	
	May 28-31	Cosmic Ray Workshop	Configure a cosmic ray detector Identify and describe cosmic ray e-Lab tools Create, organize and interpret a data plot Develop a plan to increase current use of data by students
Lawrence Berkeley National Laboratory	June 24-28	Physics in and through the Cosmology	The Case of the Hidden Neutrino (1) What Heisenberg Knew (1) Shuffling the Particle Deck (0) MINERvA Masterclass Measurement (2)
Northeastern University	No activity		
Northern Illinois University	June 24	Cosmic Ray Workshop	Mean Lifetime Part 1: Dice (1) Mean Lifetime Part 2: Cosmic Muons (2)

Note. National-led QuarkNet workshops are in a bold-face font.
Information compiled from the workshop agenda posted on individual center pages on QuarkNet website.

Table F-3

2019 QuarkNet Workshops and Meetings: National- and Center-led (con't.)

Center	**2019 Dates (All days)**	**Workshop/Meeting**	**Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
Purdue University	No activity		
Purdue University Northwest	June 13	CMS Masterclass Mini-Workshop	CMS Masterclass Measurement
Queensborough Community College		No workshop	CMS tracking detection and GPS data postings
Rice University/University of Houston	June 17-21	**CMS Data Workshop**	Shuffling the Particle Deck (0) Histograms: Uncertainty (1) TOTEM Data Express (2) Making it Round the Bend (Qualitative) (1) Making it Round the Bend (Quantitative) (2) Calculate the Z Mass (1) or Calculate the Top Quark Mass (1) CMS WWDD Measurement
Rutgers University	No date specified	Summer Research Program and 1-day Workshop	Focus on transferring summer-research material into their classrooms
Southern Methodist University	July 29-31	**Neutrino Data Workshop** (July 29-30) Center-led Workshop (July 31)	Shuffling the Particle Deck (0) The Case of the Hidden Neutrino (1) Mean Lifetime Part 1: Dice (1) Mean Lifetime Part 3: MINERvA (2) Histograms: The Basics (0) Histograms: Uncertainity (1) What Heisenberg Knew (1) MINERvA Masterclass Measurement (2)
Syracuse University	August 15-16	**Workshop with STEP UP**	Mean Lifetime Part 1: Dice (1) Mean Lifetime Part 3: MINERvA (2) New York Science Learning Standards 3D e-Lab (North County 3D Café)

Note. National-led QuarkNet workshops are in a bold-face font.

Information compiled from the workshop agenda posted on individual center pages on QuarkNet website.

Table F-3
2019 QuarkNet Workshops and Meetings: National- and Center-led (con't.)

Center	2019 Dates (All days)	Workshop/Meeting	Data Activities Portfolio (Level) [and/or classroom use/implementation plans]
Texas Tech University	June 3-7	Summer Workshop (first 3 days) **CMS Workshop** (last 2 days)	Rolling with Rutherford (1) Shuffling the Particle Deck (1) or Quark Workbench 2D/3D (1) Calculate the Z Mass (1) CMS Masterclass Measurement (2) Exploration of Level 3 DAP (CMS e-lab)
University of Buffalo, SUNY	March 30	**CMS Masterclass**	
	August 19-20	CMS Workshop	Several new ideas for cosmic data analysis with e-Lab were presented.
University of California, Riverside	No activity		
University of California, Santa Cruz	No activity		
University of Cincinnati (Workshop co-conducted with Idaho State Pocatello)	March 8	**LCHb Masterclass**	
	June 19-20	**Neutrino Data Workshop** (2 days) 1-day Workshop	Shuffling the Particle Deck (Level 0) What Heisenberg Knew (Level 1) The Case of the Hidden Neutrino (Level 1) Mean LifeTime Part 3: MINERvA (Level 2) MINERvA Masterclass Measurement (Level 2) During 1-day Workshop (and LCHb Masterclass): Rolling with Rutherford (Level 1) Marking it 'Round the Bend QuarkBench Workbench 2D/3D (Level 0) Calculate the Z Mass (Level 1) Implementation Plans
University of Florida	No activity		
University of Hawaii	No activity		
University of Illinois at Chicago/ Chicago State University	July 8-12	**CMS Workshop**	Rolling with Rutherford (1) Two separate studies (the speed of muons and the rate of multiple muons in cosmic ray air showers)
University of Iowa/Iowa State University	No activity		

Note. National-led QuarkNet workshops are in a bold-face font.
Information compiled from the workshop agenda posted on individual center pages on QuarkNet website.

Table F-3
2019 QuarkNet Workshops and Meetings: National- and Center-led (con't.)

Center	**2019 Dates (All days)**	**Workshop/Meeting**	**Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
University of Kansas	June 12-14	Computing in the Physics Classroom	Construct lesson plan Each group constructs student computing exercises Try out student computing exercise on other groups Groups report out on classroom exercise
University of Minnesota	April 6	**Neutrino Masterclass**	MINERvA Analysis
	June 12-14	**Minnesota Workshop: Neutrinos, CMS & e-Labs**	Histograms: Uncertainty (1) What Heisenberg Knew (1)
University of Mississippi	No activity		
University of New Mexico	September 7	Tour	Technical and historical tour of scientific heritage sites of Los Alamos, NM.
University of Notre Dame	Summer Weekly Meetings Special Events	**Weekly Teacher Meetings** **Summer Research** **QuarkNet Week** **ATLAS Masterclass** (March 15)	Discussions about physics and teaching ATLAS Masterclass.
University of Oklahoma/Oklahoma State	July 17-19	Workshop ATLAS Masterclass	Discussed QuarkNet materials in the classroom Conducted a masterclass for teachers and demonstrated how they can use a masterclass with their students.
University of Oregon	June 20-21	**ATLAS Data Workshop**	Rolling with Rutherford (1) Quark Workbench (1) or Shuffling the Particle Deck (1) Calculate the Z Mass (1) Mass of US Pennies (0) Atlas Z-path Masterclass Measurement
University of Pennsylvania	No activity		
University of Puerto Rico	November 2-3	Cosmic Ray	
University of Rochester	No activity		

Note. National-led QuarkNet workshops are in a bold-face font.
Information compiled from the workshop agenda posted on individual center pages on QuarkNet website.

Table F-3

2019 QuarkNet Workshops and Meetings: National- and Center-led (con't.)

Center	**2019 Dates (All days)**	**Workshop/Meeting**	**Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
University of Tennessee, Knoxville	July 12-13	**MicroBooNE Masterclass Development Workshop**	Neutrino Masterclass Status μβ Masterclass
University of Washington	No activity		
University of Wisconsin Madison	No activity		
University of Wisconsin River Falls	No activity		
Vanderbilt University	June 24-28	CMS Workshop	Using CRMD and e-lab facilities. Set up a standard CRMD in telescope configuration.
Virginia Center (College of William and Mary, Hampton University, and George Mason University)	March 9 April 6 August 5-7	**CMS Masterclass** **Neutrino Masterclass** **Workshop: Theme Data Analysis CMS**	Histograms: Uncertainty (1) Making it Round the Bend (Qualitative) (1) Making it Round the Bend (Quantitative) (2) What Heisenberg Knew (1) Energy, Momentum, and Mass (1) TOTEM Data Express (2) CMS Masterclass Measurement (2) Signal & Noise Reflections and Brainstorming
Virginia Tech	August 5-7	Catching Gravitational Waves	LIGO e-Labs Create lesson plans for e-Labs incorporated into classrooms.
Virtual Center	August 12-13	CMS Analysis and Step UP	CMS Masterclass Measurement
Wayne State	No activity		
National Program held at Fermilab	July 15-19, 2019	**Data Camp**	Rolling with Rutherford (1) Shuffling the Particle Deck (0) QuarkNet Workbench 2D/3D (0) Mass of U.S. Pennies (0) Calculate the Top Quark Mass (1)

Note. National-led QuarkNet workshops are in a bold-face font.

Information compiled from the workshop agenda posted on individual center pages on QuarkNet website (February 15, 2020)

Table F-4

2020 QuarkNet Workshops and Meetings: National- and Center-led (December 2019-September 2020)

Center	2020 Dates (All dates except where noted)	Workshop/Meeting	Brief Summary of Activities and Data Activities Portfolio (Level) [and/or classroom use/implementation plans]
Black Hills State University	No activity		
Boston area/Brown University	December 10 (2019)	Fall Meeting	STEP UP presentation Review of activities in the Data Activities Portfolio.
	February 25	Winter Meeting	New features of iSpy software were presented (planned to be used in a masterclass on March 28; which was cancelled because of COVID-19). Newtonian analysis applied to recent observations.
	May 5	**Wednesday Webinars** (QW2) (Zoom)	History of neutrino experiences and discoveries
	Summer	Neutrino Virtual Workshops (Six, 1.5 hour Zoom sessions)	First tried on June 22-24 (see Kansas State). Also participated in six on-line talks about the Standard Model of Particle Physics.
Brookhaven National Laboratory	No activity		
The Catholic University of America	No activity	Because of COVID-19, the center did not hold a workshop during the summer. When they reached out to teachers at the beginning of the summer; they found that most teachers were overwhelmed doing training at their schools to prepare for teaching on-line in the fall; thus no workshop.	
Colorado State University	August 5	**STEP UP Virtual Workshop** (1-day)	QuarkNet: Changing the Culture (0) QuarkNet STEP UP: Careers in Physics (1) QuarkNet STEP UP Women in Physics (2) Presentation on DUNE experiments. Implementation plans developed by teachers.
Fermilab/University of Chicago	July 28-30 (half-days)	**Muon Virtual Workshop**	Remote use of: Mean Lifetime Part 1: Dice (1) Mean Lifetime Part 3: MINERvA (2) Mean Lifetime Part 2: Cosmic Muons (2) Also engaged in Big Analysis of Muons (BAMC) and STEP UP activities in the DAP. Implementation plans developed by teachers.

Note. National-led QuarkNet workshops are in a bold-face font. Compiled from agenda and final reports posted on QuarkNet website by individual center.

Table F-4 (con't.)

2020 QuarkNet Workshops and Meetings: National- and Center-led (December 2019-September 2020)

Center	**2020 Dates (All dates except where noted)**	**Workshop/Meeting**	**Brief Summary of Activities and Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
Florida Institute of Technology	No activity		
Florida International University	No activity		
Florida State University/ (University of Florida)	July 22-24 (half days)	**Virtual Workshop** (last day of workshop shared with University of Florida)	Focus on distance learning adapting: Rolling with Rutherford (1) The Case of the Hidden Neutrino (1); and, other activities Share-A-Thon Machine learning and artificial intelligence. Implementation plans developed by teachers.
Idaho State University	No activity		
Johns Hopkins University	August 3-6	Summer Workshop	A series of talks, e.g., introduction to particle physics; machine learning in particle physics; dark matter; gravity waves; and sharing of best practices and favorite tools/tech. Simulation activity with a partnering teacher.
Kansas State University	February 29	Masterclass Orientation	In preparation for CRMD research project.
	June 22-24 (half days)	**Neutrino Virtual Workshop**	Mean Lifetime Part 1: Dice (1) Mean Lifetime Part 3: MINERvA (2) The Case of the Hidden Neutrino (1) Histograms Uncertainty (1) What Heisenberg Knew (1) Share-A-Thon Implementation plans developed by teachers.

Note. National-led QuarkNet workshops are in a bold-face font. Compiled from agenda and final reports posted on QuarkNet website by individual center.

Table F-4 (con't.)

2020 QuarkNet Workshops and Meetings: National- and Center-led (December 2019-September 2020)

Center	2020 Dates (All dates except where noted)	Workshop/Meeting	Brief Summary of Activities and Data Activities Portfolio (Level) [and/or classroom use/implementation plans]
Lawrence Berkeley National Laboratory	June 29 to July 24	Physics in and Through Cosmology (Virtual Workshop) 3 times a week for 3 hours	Rolling with Rutherford (1) Presentations by several LBNL scientists. Small group work included creating a 60-second History of the Universe; a Scientist Interview Project; and, analyzing data from ATLAS. Also a cosmic ray detector demonstration.
	July 13, 15, 16	**Big Analysis of Muons (ATLAS) BAMA**	
Northern Illinois University	No activity		
Oklahoma State University/University of Oklahoma	July 29-31 (half days)	**STEP UP Virtual Workshop**	QuarkNet: Changing the Culture (0) QuarkNet STEP UP: Careers in Physics (1) QuarkNet STEP UP Women in Physics (2) Share-A-Thon (distance learning successes) Implementation plans developed by teachers.
Purdue University	No activity		
Purdue University Northwest	No activity		
Queensborough Community	Summer	Virtual Workshop 2-week workshop with a 3-hour session each day	Activities included for example: learning about the design, assembly, and functionality of a cosmic ray data acquisition circuit, DAQ, being built by students and teachers in the QCC cosmic ray lab.
Rice University/University of Houston	No activity		
Rutgers University	Summer	Virtual Workshop	Introducing the basic concepts of quantum mechanics and quantum computing and developing methods for introducing this material into high school classrooms. Unable to hold masterclass or 2-week high school student program because of COVID.

Note. National-led QuarkNet workshops are in a bold-face font. Compiled from agenda and final reports posted on QuarkNet website by individual center.

Table F-4 (con't.)
2020 QuarkNet Workshops and Meetings: National- and Center-led (December 2019-September 2020)

Center	2020 Dates (All dates except where noted)	Workshop/Meeting	Brief Summary of Activities and Data Activities Portfolio (Level) [and/or classroom use/implementation plans]
Southern Methodist University	July 13-15 (afternoons) July 16-17	**STEP UP Virtual Workshop**	QuarkNet: Changing the Culture (0) QuarkNet STEP UP: Careers in Physics (1) QuarkNet STEP UP Women in Physics (2) Teachers shared physics activities for the remote classroom, e.g., electricity role cards; electric circuits; virtual lab on measurement error and the Hydrogen Spectrum.
Syracuse University	August 20-21 (half days)	**CMS Data Virtual Workshop**	Activities for remote learning: Shuffling the Particle Deck (0) Rolling with Rutherford (10 Making Trends I: Cloud Chamber (0) Making Trends II: Bubble Chamber (1) Calculating the Z Mass (1) BAMC (Big Analysis of Muons in CMS) Implementations plans developed by teachers.
Texas Tech University	No activity		
SUNY University at Buffalo	No activity		
University of California at Riverside	No activity		
University of California Santa Cruz	No activity	No program this year because of COVID but the center is looking forward to launching new remote programs in 2020-2021.	
University of Cincinnati	August 3-5	Virtual Workshop Not able to participate in LHCb Masterclass because of COVID.	Remote learning and how to use Python-based Jupyter Notebooks to engage physics students in high school. Implementation plans developed by teachers.

Note. National-led QuarkNet workshops are in a bold-face font. Compiled from agenda and final reports posted on QuarkNet website by individual center.

Table F-4 (con't.)
2020 QuarkNet Workshops and Meetings: National- and Center-led (December 2019-September 2020)

Center	**2020 Dates (All dates except where noted)**	**Workshop/Meeting**	**Brief Summary of Activities and Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
University of Florida	July 22-24 (half days)	**CMS Data Analysis Virtual Workshop**	Making Tracks I (0) Rolling with Rutherford (1) Shuffling the Particle Deck (0) Calculating the Z Mass (1) Implementation plans developed by teachers.
University of Hawaii	~~March 14~~ ~~March 15~~	~~**CMS Masterclass**~~ ~~**Muons in the Classroom Workshop**~~	Both of these programs were cancelled because of COVID.
University of Illinois Chicago/ Chicago State University	July 13-15 (half days)	**Cosmic Ray Virtual Workshop**	Performed analyses and plotted data. Implementation plans developed by teachers.
University of Iowa/Iowa State University	No activity		
University of Kansas	July 7-8	Modeling Random Processes Virtual Workshop	Focus on computing physics in the classroom (e.g., particle decay and math behind exponential decays and half lives). Computational exercises including random numbers and exponential decays. Share-A-Thon on-line teaching.
University of Minnesota	~~April 4~~	~~**Neutrino Masterclass MINERvA Analysis**~~	Masterclass cancelled because of COVID.
	July 13-15 (half days)	**STEP UP Virtual Workshop**	QuarkNet: Changing the Culture (0) QuarkNet STEP UP: Careers in Physics (1) QuarkNet STEP UP Women in Physics (2) NOvA Detector Neutrino Oscillation Share-A-Thon (engaging students in distance or hybrid learning environments) Implementation plans developed by teachers.
University of New Mexico	No activity		

Note. National-led QuarkNet workshops are in a bold-face font. Compiled from agenda and final reports posted on QuarkNet website by individual center.

Table F-4 (con't.)

2020 QuarkNet Workshops and Meetings: National- and Center-led (December 2019-September 2020)

Center	**2020 Dates (All dates except where noted)**	**Workshop/Meeting**	**Brief Summary of Activities and Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
University of Notre Dame	July 6-10 (half days)	Course 1	Rolling with Rutherford (online) (1) Calculating the Z Mass (1) Basic physics and up to particle physics using data from the BAMC (Big Analysis of Muons CMS) Masterclass.
	July 13-17 (half days)	Course 2	Deep study of particle physics; programming and analyses using CMS data and Python
	August 3-5	QuarkNet Week	Learning to use Phyphox and Colab to collect, visualize and analyze phone sensor data. Review activities in Data Activities Portfolio. Implementation plans developed by teachers.
University of Pennsylvania	No activity		
University of Puerto Rico - Mayaguez	June 20		
University of Rochester	No activity		
University of Tennessee Knoxville	No activity		
University of Washington	September 10-11	CMS Virtual Masterclass	Conducted muon and electron data analysis; discussed with QuarkNet staff and lead teachers.
University of Wisconsin - Madison	No activity		
Vanderbilt University	June 22-24 (half days)	Virtual Workshop	Talks on CMS (gravitational wave detection) and relativistic heavy ion experiments. Using Cosmic Ray Muon detectors
	June 25-26 (half days)	**Neutrino Data Virtual Workshop**	understanding flow to signal. The Case of the Hidden Neutrino (1) What Heisenberg Knew (1) MINERvA masterclass measurement Implementation plans developed by teachers.

Note. National led QuarkNet workshops are in a bold face font. Compiled from agenda and final reports posted on QuarkNet website by individual center.

Table F-4 (con't.)

2020 QuarkNet Workshops and Meetings: National- and Center-led (December 2019-September 2020)

Center	**2020 Dates (All dates except where noted)**	**Workshop/Meeting**	**Brief Summary of Activities and Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
Virginia Center (Hampton University, the William and Mary, and the George Mason University)	February 6	CMS J/Psi Masterclass	Teachers and students conducted data analysis and sharing of data through J/Psi masterclass.
	February 29	Spring Meeting	New features of the Data Activities Portfolio Teachers worked on implementation plans.
	August 3-5	Summer Virtual Workshop	Talks on future colliders; Xeonon IT. QuarkNet: Changing the Culture (0) QuarkNet STEP UP: Careers in Physics (1) QuarkNet STEP UP Women in Physics (2) BAMC (Big Analysis of Muons in CMS) masterclass measurement
Virginia Tech University	No activity	The summer workshop was cancelled because teachers were working on-line with their individual schools to prepare for on-line learning in the fall.	
Virtual Center	August 12-14 (2½ days)	Neutrino Data, STEP UP and Online Learning Workshop	Group met monthly throughout the year. Mean Lifetime Part 1: Dice (1) Mean Lifetime Part 3: MINERvA (2) The Case of the Hidden Neutrino What Heisenberg Knew (1) Histograms: Uncertainty (1) MINERvA masterclass measurement Implementation plans developed by teachers.
Wayne State University	No activity		
Data Coding (Data Camp)	July 6-10 July 23-31	Coding Camp: Virtual	Introducing Jupyter notebook; coding and machine learning. Implementation plans developed by teachers.

Note. National-led QuarkNet workshops are in a bold-face font. Compiled from agenda and final reports posted on Quark

Table F-5

2021 QuarkNet Workshops and Meetings: National- and Center-led (December 2020-September 2021)

Center	**2021 Dates (All dates except where noted)**	**Workshop/Meeting**	**Brief Summary of Activities and Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
Black Hills State University	June 21-25	QN Cosmic, QN Neutrino Data & Dark Matter	Shuffling the Particle Deck (0) Making Tracks I (Cloud Chamber) (0) Making Tracks II (Bubble Chamber) (1) The Case of the Hidden Neutrino (1) Mean Life Part 1: Dice (1) Mean Life Part 2: MINERvA (2) Mean Life Part 3: Cosmic Ray Muons (2) Implementation discussion and plan
Boston Area/Brown University	May 18	QuarkNet Zoom Meeting	
	August 3-4	Summer Workshop (in-person)	Implementation discussion and plans
Brookhaven National Laboratory	July 6-9	Summer Virtual Workshop	Coding exercises for Artificial Intelligence/machine learning/quantum computing, MINERvA Masterclass Implementation discussion and plans
The Catholic University of America	August 16-18	Summer Workshop (August 16, 18 online August 17 in person)	Cosmic Ray e-Lab (3) Implementation discussion and plans
Colorado State University	July 26-27	**CMS Data Workshop**	Shuffling the Particle Deck (0) Rolling with Rutherford (1) Calculate the Z Mass (1) Quark Workbench 2D/3D (0) Making Tracks I (Cloud Chamber) (0) Making Tracks II (Bubble Chamber) (1) Implementation discussion and plans

Note. National-led QuarkNet workshops are in a bold-face font. Compiled from agenda and final reports posted on QuarkNet website by individual center.

Table F-5 (con't.)

2021 QuarkNet Workshops and Meetings: National- and Center-led (December 2020-September 2021)

Center	**2021 Dates (All dates except where noted)**	**Workshop/Meeting**	**Brief Summary of Activities and Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
Fermilab/University of Chicago	August 3-5 (half days)	Teaching with Data Virtual Workshop	Introduction to Coding Practice Coding for Physics Classes Implementation discussion and plans
Florida Institute of Technology	No activity		
Florida International University	~~August 5-6~~	~~Neutrino Data~~	
Florida State University/(University of Florida)	July28-30	**CMS Update & Coding Workshop**	Shuffling the Particle Deck (0) Rolling with Rutherford (1) Making Tracks I (0) Quark Workbench (0) Making Tracks II (1) Signal to Noise: The Basics (0)
Idaho State University	June 28-July 1	Summer Workshop	Shuffling the Particle Deck (online) (0) Quark Workbench (online) (0) What Heisenberg Knew (1) Totem Data Express (2)
Johns Hopkins University	July 26-30	Summer Workshop: Astrophysics	Select 3 DAP Activities Level 0: Mapping the Poles; Signal & Noise; Making Tracks I; Histograms; STEP UP Select 2 DAP Activities Level 1: Particle Transformation and Signal & Noise II or the Case of the Hidden Neutrino; or What Heisenberg Knew; STEP UP II or Making Tracks II CMS Express Data (2)
Kansas State University/University of Kansas	March 13	Masterclass Orientation	In preparation for CRMD research project.
	April 23	Orientation	
	August 2-4	Cosmic Ray Workshop the Storm Project	CMS activities and Cosmic Ray Muon detectors

Note. National-led QuarkNet workshops are in a bold-face font. Compiled from agenda and final reports posted on QuarkNet website by individual center.

Table F-5 (con't.)

2021 QuarkNet Workshops and Meetings: National- and Center-led (December 2020-September 2021)

Center	**2021 Dates (All dates except where noted)**	**Workshop/Meeting**	**Brief Summary of Activities and Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
Lawrence Berkeley National Laboratory	June 28-July 23	Four Week Virtual Workshop	A total of 7 teachers and 59 students participated.
	July 12 (prep) July, 16, 19, 21	Summer Workshop (3 days, 3 hours each)	Teachers engaged in fundamental particle activity and analyzed data from ATLAS
Northern Illinois University	No activity		
Oklahoma State University/University of Oklahoma	July 20-22	**ATLAS Data Workshop**	Rolling with Rutherford (1) Shuffling the Particle Deck (0) Mass of U. S. Pennies (0) Calculate Mass of Z (1) Quark Workbench (0) Making Tracks I (cloud chamber) (0) Making Tracks II (bubble chamber) (1) Signal to Noise: Basics (0) Particle Transformation (1) Implementation discussion and plan
Purdue University	No activity		
Purdue University Northwest	June 21-25	Workshop	Rolling with Rutherford (1) Quark Workbench (0) CMS data collection and analysis (masterclass-like_
Queensborough Community	No dates	Workshop	Focus of workshop: How to program an Arduino Mega microcontroller board.

Note. National-led QuarkNet workshops are in a bold-face font. Compiled from agenda and final reports posted on QuarkNet website by individual center.

Table F-5 (con't.)

2021 QuarkNet Workshops and Meetings: National- and Center-led (December 2020-September 2021)

Center	**2021 Dates (All dates except where noted)**	**Workshop/Meeting**	**Brief Summary of Activities and Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
Rice University/University of Houston	June 14-18	**CMS, Cosmic and STEP UP**	Shuffling the Particle Deck (0) Rolling with Rutherford (1) Calculate the Mass of Z (1) Signal and the Noise: The Basics (0) Making Tracks I (Cloud Chamber) (0) QuarkNet STEP UP: Careers in Physics (1) QuarkNet STEP UP: Women in Physics (2) Implementation discussion and plans
Rutgers University	No dates	2-week introductory workshop	Quantum computing
	No dates	1-week advanced workshop	Topics included quantum information and black holes
Syracuse University	August 16-18	**Particles, Detectors, and Neutrino Data**	Shuffling the Particle Deck (0) Quark Workbench (0) Making Tracks I (Cloud Chamber) (0) Making Tracks II (Bubble Chamber) (1) The Case of the Hidden Neutrino (1) What Heisenberg Knew (1) Histograms: Uncertainty (1)
Southern Methodist University	July 12-14	**Enquiry-based Learning Virtual Workshop (Coding)**	On-line activities: Shuffling the Particle Deck (0) Quark Workbench (0) Rolling with Rutherford (1) MINERvA masterclass intro
Texas Tech University	June 29- July 2 July 1 July 6	Annual Workshop **STEP UP Workshop** Virtual Workshop	STEP UP: Women in Physics (2) STEP UP: Changing the Culture (0) Classroom Implementation discussion and plans

Note. National-led QuarkNet workshops are in a bold-face font. Compiled from agenda and final reports posted on QuarkNet website by individual center.

Table F-5 (con't.)

2021 QuarkNet Workshops and Meetings: National- and Center-led (December 2020-September 2021)

Center	**2021 Dates (All dates except where noted)**	**Workshop/Meeting**	**Brief Summary of Activities and Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
University at Buffalo –SUNY	February 27	Masterclass No workshop due to COVID	
University of California at Riverside	No activity		
University of California Santa Cruz	No activity		
University of Cincinnati	~~Aug 3, 4or 5~~	**~~STEP UP Workshop~~**	Because of COVID no workshops or masterclasses were held
University of Florida	No activity		
University of Hawaii	No activity		
University of Illinois Chicago/ Chicago State University	July 9-12	**Virtual Workshop**	Assessing the design of the moon shadow experiment
University of Iowa/Iowa State University	July 5-9	Summer Workshop	Mean Lifetime Part 1: Dice (1) Mean Lifetime Part 2: MINERvA (2) Mean Lifetime Part 3: Cosmic Muons (2) Implementation discussion and plans
University of Kansas	No activity		
University of Minnesota	March 6	Virtual MINERvA Workshop	Masterclass analysis
	August 11-13	Summer Workshop	Totem I-III activities (in development) Implementation discussion and plans
University of New Mexico	Sept 18-19	Summer Workshop	Shuffling the Particle Deck (0) Rolling with Rutherford (1) Making Tracks I (0)

Note. National-led QuarkNet workshops are in a bold-face font. Compiled from agenda and final reports posted on QuarkNet website by individual center.

Table F-5 (con't.)

2021 QuarkNet Workshops and Meetings: National- and Center-led (December 2020-September 2021)

Center	**2021 Dates (All dates except where noted)**	**Workshop/Meeting**	**Brief Summary of Activities and Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
University of Mississippi	June 21	Ole Miss Workshop	Implementation notes
University of Notre Dame		Cosmic Watch Project	
	July 16	Discovery at LHC	Shuffling the Particle Deck (virtual) (0) Quark Workbench (virtual) (0)
University of Oregon	No activity		
University of Pennsylvania	No activity		
University of Puerto Rico - Mayaguez	March 3	MINERvA Masterclass	
University of Rochester	No activity		
University of Tennessee Knoxville	No activity		
University of Washington	No activity		
University of Wisconsin - Madison	No activity		
Vanderbilt University	June 21-25 June 23-24	Summer Workshop Coding Portion	Speed of light experiment General reintroduction to CRMDs Introduction and Coding with Phyton
Virginia Center (Hampton University, the William and Mary, and the George Mason University)	August 2-4	Coding Virtual Workshop	Totem Data Express (2) Particle Transformation (1) Implementation discussion and plans
Virginia Tech	August 2-4	Virtual Workshop	STEP UP: Changing the Culture (0) STEP UP: Careers in Physics (1) STEP UP: Women in Physics (2)
Virtual Center	July 22-23	Quantum Computing and Coding	
Wayne State University	No activity		
Data Coding (Data Camp)	June 21-25 and June 28-July 2	Coding Camp: Virtual	Probability and histograms using dice Modeling and graphing projectiles with air resistance Calculate the mass of a muon using CMS data Big CMS dataset analysis

Note. National led QuarkNet workshops are in a bold face font. Compiled from agenda and final reports posted on QuarkNet website by individual center.

QuarkNet and COVID-19
May 1, 2020

Introduction: The COVID-19 crisis has profoundly affected QuarkNet and our teachers. Summer workshops at centers and other opportunities have been cast in doubt, re-imagined, or postponed. Almost all of our teachers have had to cope with a shift to online remote teaching. Quickly, staff realized that it would be important to maintain contact and support our teachers. Working from home, as the teachers and their students are, staff adjusted and created offerings to help teachers engage students with meaningful learning in physics. This report shows what we have done and how.

Before addressing the issues and initiatives related to the crisis, we note that the staff has maintained contact with one another and continued routine aspects of QuarkNet. Tuesday staff conferences and Wednesday technical conferences which are conducted remotely continue unabated. The weekly newsletter, the *Friday Flyer*, continues and has, if anything, taken on a stronger role to connect QuarkNet members. Staff continue to field questions from and check in with mentors and teachers. Next week, staff will contact all mentors to get updates on summer plans in light of the crisis and offer support. Staff still meet remotely with fellows—perhaps more than ever. For example, the monthly LHC and Neutrino Fellows monthly videoconference has become weekly so that Ken Cecire and Shane Wood can consult with them on the initiatives below. With the whole group mostly limited to home, it has become their virtual "night out."

Support for Teachers: As schools moved to remote online learning in March, staff realized that teachers were entering a new world and needed support. Staff built and continue to support online resources to assist teachers in remote teaching and maintaining their access to QuarkNet content and practices:

- Resources for Physics Teaching Online. This page has resources on remote online learning, physics simulations and online lessons, and more. We have propagated it outside QuarkNet; as of May 1, teachers have accessed it over 900 times.
- QuarkNet Zoom Channels for Videoconferencing. We opened six Zoom channels on the Notre Dame Zoom account for QuarkNet teachers who might not otherwise have a robust way to communicate with students or colleagues.
- Resources for Cosmic Ray Analyses Online. Using the Cosmic Ray e-Lab, teachers can engage students remotely in physics research projects with data from QuarkNet cosmic ray detectors. This "how to" guide includes instructions and pre-selected useful data files.
- Using the CMS e-Lab. Using the CMS e-Lab, teachers can engage students remotely in physics research projects with data from CERN's Large Hadron Collider. This "how to" guide includes instructions and suggestions for meaningful studies.
- Comments on Adapting Data Activities to Teaching Online. Staff and LHC fellow Jeremy Wegner added comments to the Data Activities Portfolio to explain how students can engage in 16 different data activities at home in collaboration with teachers and often peers. To see such comments, one must log into the QuarkNet website. This page was added to make these comments available to all teachers, logged in or not. Mr. Wegner also contributed a Visual Python simulation online so the popular Rolling with Rutherford activity could be included.

Staff adapted the weekly QuarkNet newsletter, the *Friday Flyer (FF)*, for the current crisis. While the sections are familiar, much of the content shifted to making teachers aware of the support and new activities that have become available. *FF* has kept up with particle physics news, opportunities for teachers, and even a little humor throughout the crisis while being a conveyor of information QuarkNet teachers need. (Read the May 1 issue.)

Staff announced another project for teachers and students on May 1: the QuarkNet Wednesday Webinars (QW2). Experts will give webinars on particle physics-related topics between May 6 and June 10. Teachers and students will connect from home to learn new things about particle and contemporary physics. Like all of the Zoom webinars mentioned above, these will be recorded to widen their usefulness.

Cosmic Ray Studies: With many cosmic ray detectors inaccessible while teachers and students work from home, the total number of cosmic ray data file uploads is down. The number of cosmic ray analyses on the e-Lab, however, has increased as several teachers have challenged their students to perform measurements with existing data. Staff created a page containing resources for cosmic ray analyses online (see section above) to support teachers and students during this time of distance learning. Additionally, a few detectors continue to upload data. A staff member moved one of the detectors at Fermilab to his home in order to provide an updated standard data set for the e-Lab.

Masterclasses: International Masterclasses (IMC) run each year in and around March; they were just starting as the COVID-19 crisis set in. Masterclasses began to shut down and by March 18, further IMC videoconferences were canceled, effectively ending IMC 2020. One of the last masterclasses in the U.S. was done remotely by LHC fellow Jeremy Wegner and his students in rural Indiana. A few other groups also attempted remote masterclasses with varying success.

QuarkNet took the next step modifying the current CMS masterclass for remote learning. The simplified measurement focuses on muon tracks, and new online support enabled students to learn what to do via four screencasts and to complete the measurement with some coaching from their teachers. The result was a new remote learning masterclass, the Big Analysis of Muons in CMS (BAMC). Staff built a support infrastructure with student and teacher pages on the QuarkNet website, Zoom Q&A sessions for teachers, an April 15 webinar talk on the Standard Model and CMS by a Kansas State University particle physicist, ample tables for recording results online in the CMS Instrument for Masterclass Analysis (CIMA), and an April 17 webinar to discuss the data with three particle physicists. About 180 teachers and students attended each of the webinars and an estimated 240 students analyzed over 11,000 CMS events, one-by-one in the iSpy event display. BAMC provided a robust stress test for CIMA (which it passed), an opportunity for teachers to do a meaningful remote project with their students, and the chance for hundreds of students to be "particle physicists for a day" at home. Along the way, Staff developed capacities with webinars and designing remote learning experiences. And it all worked very well, with ample compliments from teachers and students.

With the success of BAMC in April, staff has started another session for May, opening this session up to more international participation. There are still details to sort, but the masterclass talk will take place on May 19 with the videoconference to follow later that same week.

Fellows Workshop: Meetings of QuarkNet fellows are vital to their development and foster communication among the groups. These meetings have maintained the coherence of their work. Staff had planned an in-person workshop for fellows who present our national workshops for May 15-17 at Fermilab. Now, staff is planning a virtual workshop. The primary goal is to enable select fellows to create remote online workshops that will be offered to teachers through our centers in Summer 2020. The fellows virtual meeting will also provide the opportunity to share ideas among groups of fellows and continue the focus on research-based best practices in offering professional development.

Data Camp: Each year, Data Camp brings 24 teachers from around the country to Fermilab for a week-long, multi-faceted workshop that includes tours, talks, particle physics data analyses, and the exploration of data activities to bring back to the classroom. This "classic" Data Camp will not be offered in 2020; instead, the Teaching and Learning Fellows will conduct a virtual/remote workshop that emphasizes the use of coding skills as they pertain to physics in general and particle physics in particular. Another goal of this virtual workshop, still under development, is to give teachers some comfort and confidence that, if remote learning is continued in the fall, they will have the skills and resources to implement something interesting, challenging, and useful with their students.

Summer 2020 Workshops at Centers: Summer workshops at many centers are among the QuarkNet highlights for teachers, mentors and staff. These meetings are the primary pathway to offer teachers at QuarkNet centers opportunities to develop professionally, build community, learn new physics, and improve their teaching. At this point, there is much uncertainty regarding these workshops. Staff, mentors, and lead teachers are discussing possibilities, which so far include:

- Rescheduling the workshop for late summer and/or fall in hopes that face-to-face meetings will be possible then.
- Offering a virtual workshop, in which centers would meet for at least a portion of their workshop time remotely.
- Cancelling the 2020 workshop, with a plan to meet again in 2021.
- Other creative solutions.

Staff is working with fellows to re-tool some of our national workshops in order to offer them remotely. Virtual summer meetings could also allow teachers to share successful strategies and tools with each other for teaching in a virtual setting, as the possibility of teaching this way may extend into the next academic year for at least some teachers.

STEP UP: In 2019, QuarkNet began a partnership with STEP UP, a program that supports teachers to encourage more women and minorities to pursue physics as a career. As part of this partnership, nine QuarkNet leaders, including staff, educational specialists, fellows and teachers, attended the 2019 STEP UP Summer Institute to become ambassadors for the program. Deborah Roudebush, QuarkNet Educational Specialist and STEP UP ambassador, has taken the lead in coordinating work that is beneficial to both organizations. As part of this work, several STEP UP classroom activities have been edited to fit our format. Soon, we will post these activities in the Data Activities Portfolio. The 2020 STEP UP Summer Institute will be virtual, and Deborah is helping STEP UP leaders plan for this event. Several QuarkNet STEP UP ambassadors from 2019 plan to attend the 2020 institute as well. In addition, Deborah and the staff are coordinating QuarkNet STEP UP ambassador efforts to arrange virtual STEP UP workshops open to all QuarkNet teachers.

IT Infrastructure: Support for remote teaching and learning and carrying out new initiatives online only work if the IT infrastructure is strong. Fortunately, QuarkNet has been in a very good position in this regard. The QuarkNet servers at Notre Dame were not significantly affected by the COVID-19 crisis. IT staff was already working remotely, and Notre Dame has provided ongoing support. ND Studios assisted the staff in setting up webinars and exploring the capabilities of Zoom. The IT staff continues to work on development and maintenance of QuarkNet resources such as e-Labs and masterclass tools. One area of concern in International Masterclasses was the response of the CMS Instrument for Masterclass Analysis (CIMA) to large numbers of students; this eased when IMC 2020 was canceled and gave IT staff time to fix problems. The first BAMC masterclass in April served as a stress test for CIMA: it passed and the few non-critical issues that remained were identified. The current situation did delay the installation of new QuarkNet servers to improve capacity and performance. As the old servers are still working well, this has not been a problem.

Evaluation: Given that many centers do not have plans for the summer yet, we were able to reach out to more than the planned centers to obtain information about center-level outcomes and sustainability factors. We contacted a total of ten centers, with all but two either completing or in the process of completing this. The unexpected effect of these conversations, especially for the six centers we have recently contacted, have been reflections on how each center might incorporate virtual workshops or other outreach to their teachers as necessary now and in the future

Going forward, evaluation plans will include possibly “observing” virtual workshops, attending some in person events if this becomes possible; and urging workshop participants to complete the new abbreviated (short ten questions) Teacher Survey. The external evaluator also plans on incorporating implementation plans as part of the evaluation effort as well as the new information we glean from the short Teacher Survey. If we are forced to engage in virtual workshops as the usual means of implementing workshops, then she would like to work with staff to glean how and what formative evaluation efforts would be helpful for them.

2019 QuarkNet Teacher Survey

QuarkNet Survey

We appreciate your participation in this survey and we will use this information to inform the funders of the program as well as to help guide our thinking about program changes and improvements. Please take the time to tell us about your QuarkNet experience(s) and how and in what ways your QuarkNet engagement may have helped to change or improve your classroom instruction. Please answer all questions to the best that you can; your answers will be kept confidential. We ask that you provide your name for tracking and follow-up purposes only.

1. Today's Date

2. Your Email Address *(optional)*

3. Your Name *(optional)*

4. Your Gender

5. For how many years (approximately) have you participated in QuarkNet (including today or your most recent participation)?

6. What is the name/brief description of the QuarkNet program/workshop that you participated in today (or most recently)?

7. What is the name of the QuarkNet center (university/institution) where you have participated?

8. What is the name of the school (or district) where you teach?

9. What best describes the location of your school?

○ Rural ○ Urban, central city ○ Urban ○ Suburban

10. For how many years have you been at this school?

11. How many years have you been teaching?

12. Do you teach physics?

○ Yes ○ No

13. *If yes, please specify year (e.g., 9th, 10th) and whether General or Conceptual, AP, Honors.*

14. Can we contact you for a follow-up interview to talk with you about your approach to teaching?

○ Yes ○ No

○ Other (please specify)

Your Participation in QuarkNet Workshops/Programs

15. Which QuarkNet Workshops or Programs have you participated in? *(Check all that apply. If not on the list, please provide a brief description.)*

- [ ] Data Camp
- [ ] ATLAS Data Workshop
- [ ] CMS Data Workshop
- [ ] CMS e-Lab Workshop
- [ ] Cosmic Ray e-Lab Intro Workshop
- [ ] Cosmic Ray e-Lab Advanced Topics Workshop
- [ ] Neutrino Data Workshop
- [ ] ATLAS Masterclass
- [ ] CMS Masterclass
- [ ] Neutrino Masterclass
- [ ] CERN Summer Program
- [ ] W2D2
- [ ] International Cosmic Day
- [ ] International Muon Week
- [ ] Other (please specify)

16. Of these, which do you think have been most helpful to you in your teaching? *Please briefly describe why.*

Your Use of the Data Activities Portfolio

The Data Activities Portfolio is QuarkNet's online compendium of instructional materials and suggested instructional pathways.

17. Have you used any of the activities in the Data Activities Portfolio in your classroom?

◯ Yes ◯ No

18. Please give us an example(s) of which of these activities in the Data Activities Portfolio you have used most often and/or that you think have been most helpful in teaching physics related to content and/or pedagogy.

19. Would you recommend (or have you recommended) the Data Activities Portfolio to other high school physics or physical science teachers?

◯ Yes ◯ No

20. Please tell us why you would or would not recommend instructional materials in the Data Activities Portfolio.

Your Assessment of QuarkNet

Please rate the following strategies based on your current QuarkNet program experience and, if applicable, on your previous involvement in QuarkNet programs to date. If you have participated in QuarkNet for many years, please respond based on what you think the cumulative effect of this participation has been over the past two years.

21. QuarkNet provides opportunities for me to:

	Poor	Fair	Average	Good	Excellent	N/A
a. Engage as an active learner, as a student.	○	○	○	○	○	○
b. Do science the way scientists do science.	○	○	○	○	○	○
c. Engage in authentic particle physics investigations (that may or may not involve phenomenon known by scientists).	○	○	○	○	○	○
d. Engage in authentic data analysis experiment(s) using large data sets.	○	○	○	○	○	○
e. Develop explanations of particle physics content.	○	○	○	○	○	○
f. Discuss the concept of uncertainty in particle physics.	○	○	○	○	○	○

22. QuarkNet provides opportunities for me to:

	Poor	Fair	Average	Good	Excellent	N/A
a. Engage in project-based learning that models guided-inquiry strategies.	○	○	○	○	○	○
b. Share ideas related to content and pedagogy.	○	○	○	○	○	○
c. Review and select particle physics examples from the Data Activities Portfolio instructional materials.	○	○	○	○	○	○
d. Use the pathways, suggested in the Data Activities Portfolio, to help design classroom instructional plan(s).	○	○	○	○	○	○
e. Construct classroom implementation plan(s), incorporating experience(s) and Data Activities Portfolio instructional materials.	○	○	○	○	○	○
f. Become aware of resources beyond my classroom.	○	○	○	○	○	○

23. Please use the space below to tell us anything you would like us to know regarding your ratings of the strategies mentioned above.

Your Assessment of QuarkNet (con't.)

Please rate the following big-picture strategies based on your current QuarkNet experience and, if applicable, on your previous involvement in QuarkNet programs to date. If you have participated in QuarkNet for many years, please respond based on what you think the cumulative effect of this participation has been over the past two years.

24. QuarkNet provides opportunities for me to be exposed to:

	Poor	Fair	Average	Good	Excellent	N/A
a. Instructional strategies that model active, guided-inquiry learning (related to NGSS science and engineering practices).	○	○	○	○	○	○
b. Big Idea(s) in Science (cutting-edge research) and Enduring Understandings (in particle physics).	○	○	○	○	○	○

25. Provide opportunities for teachers and mentors to:

	Poor	Fair	Average	Good	Excellent	N/A
a. Interact with other scientists and collaborate with each other.	○	○	○	○	○	○
b. Build a local (or regional) learning community.	○	○	○	○	○	○

26. Please use the space below to tell us anything you would like us to know regarding your ratings of the big-picture strategies mentioned above.

Your Assessment of QuarkNet *(con't.)*

The next set of questions will ask about classroom instruction and QuarkNet's influence.

27. In thinking about your approach to teaching, please rate the frequency in which you engage in each of the following in your classroom.

	Almost Always	Very Often	Sometimes	Not Very Often	Rarely	N/A
a. Discuss and explain concepts in particle physics.	◯	◯	◯	◯	◯	◯
b. Engage in scientific practices and discourse.	◯	◯	◯	◯	◯	◯
c. Use particle physics examples, including authentic data, when teaching subjects such as momentum and energy.	◯	◯	◯	◯	◯	◯
d. Review and use instructional materials from the Data Activities Portfolio.	◯	◯	◯	◯	◯	◯
e. Selecting these lessons guided by the suggested pathways.	◯	◯	◯	◯	◯	◯
f. Facilitate student investigations that incorporate scientific practices.	◯	◯	◯	◯	◯	◯

28. Now, indicate the degree to which you think QuarkNet has contributed to your implementation of these instructional strategies in your classroom.

	Very High	High	Moderate	Low	Very Low	N/A
a. Discuss and explain concepts in particle physics.	◯	◯	◯	◯	◯	◯
b. Engage in scientific practices and discourse.	◯	◯	◯	◯	◯	◯
c. Use particle physics examples, including authentic data, when teaching subjects such as momentum and energy.	◯	◯	◯	◯	◯	◯
d. Review and use instructional materials from the Data Activities Portfolio.	◯	◯	◯	◯	◯	◯
e. Selecting these lessons guided by the suggested pathways.	◯	◯	◯	◯	◯	◯
f. Facilitate student investigations that incorporate scientific practices.	◯	◯	◯	◯	◯	◯

29. In thinking about your approach to teaching, please rate the frequency in which you engage in each of the following in your classroom.

	Almost Always	Very Often	Sometimes	Not Very Often	Rarely	N/A
a. Use active, guided-inquiry instructional practices that align with science practice standards (NGSS and other standards).	◯	◯	◯	◯	◯	◯
b. Use instructional practices that model scientific research.	◯	◯	◯	◯	◯	◯
c. Ilustrate how scientists make discoveries.	◯	◯	◯	◯	◯	◯
d. Demonstrate how to use, analyze and intepret authentic data.	◯	◯	◯	◯	◯	◯
e. Demonstrate how to draw conclusions based on these data.	◯	◯	◯	◯	◯	◯
f. Become more comfortable teaching inquiry-based science.	◯	◯	◯	◯	◯	◯

30. Now, indicate the degree to which you think QuarkNet has contributed to your implementation of these instructional strategies in your classroom.

	Very High	High	Moderate	Low	Very Low	N/A
a. Use active, guided-inquiry instructional practices that align with science practice standards (NGSS and other standards).	○	○	○	○	○	○
b. Use instructional practices that model scientific research.	○	○	○	○	○	○
c. Illustrate how scientists make discoveries.	○	○	○	○	○	○
d. Demonstrate how to use, analyze and interpret authentic data.	○	○	○	○	○	○
e. Demonstrate how to draw conclusions based on these data.	○	○	○	○	○	○
f. Become more comfortable teaching inquiry-based science.	○	○	○	○	○	○

Your Assessment of QuarkNet (con't.)

31. Please respond to the following statements.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
a. I use resources (including QuarkNet resources) to supplement my knowledge and instructional materials and practices.	◯	◯	◯	◯	◯
b. I have increased my science proficiency.	◯	◯	◯	◯	◯
c. I have developed collegial relationships with scientists and other teachers.	◯	◯	◯	◯	◯
d. I think my students have become more comfortable with inquiry-based science.	◯	◯	◯	◯	◯

Your Assessment of QuarkNet (con't.)

This last set of questions asks about your students' classroom engagement and how QuarkNet may have influenced (through your participation and/or your students) this engagement. In your judgment, please indicate ...

32. My students are able to:

	Almost Always	Very Often	Sometimes	Not Very Often	Rarely	N/A
a. Discuss and explain concepts in particle physics.	○	○	○	○	○	○
b. Discuss and explain how scientists develop knowledge.	○	○	○	○	○	○
c. Engage in scientific practices and discourse.	○	○	○	○	○	○
d. Use, analyze and interpret authentic data.	○	○	○	○	○	○
e. Draw conclusions based on these data.	○	○	○	○	○	○

33. Now, indicate the degree to which QuarkNet (either because of your participation and/or theirs) has contributed to your students' engagement. QuarkNet has helped my students to:

	Very High	High	Moderate	Low	Very Low	N/A
a. Discuss and explain concepts in particle physics.	○	○	○	○	○	○
b. Discuss and explain how scientists develop knowledge.	○	○	○	○	○	○
c. Engage in scientific practices and discourse.	○	○	○	○	○	○
d. Use, analyze and interpret authentic data.	○	○	○	○	○	○
e. Draw conclusions based on these data.	○	○	○	○	○	○

34. Please use the space below for anything else you would like us to know about your QuarkNet experience or your approach to teaching science in your classroom. *Thank you for your participation. We appreciate it!*

UPDATE: QuarkNet Teacher Survey

IMPORTANT. ***Please complete this UPDATE only if you have completed the 2019 QuarkNet Teacher Survey, which you should complete only once. Please answer all questions (a total of 10) to the best that you can; your answers will be kept confidential. We ask that you provide your name for tracking and follow-up purposes only. Thank you for your participation, we appreciate it!***

1. Today's Date

2. Your E-mail Address (Optional)

3. Your Name (Optional but very helpful to know)

4. What is the name of the QuarkNet Center where you have participated today (or most recently)?

UPDATE: QuarkNet Teacher Survey

The next set of questions asks about how you intend to use (or have used) QuarkNet content and materials as a teacher in your classroom.

5. Briefly describe how you intend to incorporate (or have incorporated) your QuarkNet experiences into your classroom (e.g., Cosmic Ray, LHC, neutrinos, e-labs; masterclass) when teaching, for example, conservation laws, uncertainty, the standard model or something else.

6. Using QuarkNet content and materials in my classroom, when teaching physics (or related science) I am able to: (*Check all that applies*.)

	Almost Always	Very Often	Sometimes	Not Very Often	Rarely	N/A
a. Discuss and explain concepts in particle physics.	○	○	○	○	○	○
b. Engage in scientific practices and discourse.	○	○	○	○	○	○
c. Use particle physics examples, including authentic data, when teaching subjects such as momentum and energy.	○	○	○	○	○	○
d. Review and use instructional materials from the Data Activities Portfolio (DAP).	○	○	○	○	○	○
e. Select (DAP) lessons guided by suggested sequencing.	○	○	○	○	○	○
f. Faciliate student investigations that incorporate scientific practices.	○	○	○	○	○	○

7. *To Continue*: Using QuarkNet content and materials in my classroom, when teaching physics (or related science) I am able to: (*Check all that applies.)*

	Almost Always	Very Often	Sometimes	Not Very Often	Rarely	N/A
g. Use active, guided-inquiry instructional practices that align with science practice standards (NGSS and other standards).	○	○	○	○	○	○
h. Use instructional practices that model scientific research.	○	○	○	○	○	○
i. Illustrate how scientists make discoveries.	○	○	○	○	○	○
j. Demonstrate how to use, analyze and interpret authentic data.	○	○	○	○	○	○
k. Demonstrate how to draw conclusions based on these data.	○	○	○	○	○	○
l. Become more comfortable teaching inquiry-based science.	○	○	○	○	○	○

Other (please specify)

UPDATE: QuarkNet Teacher Survey

The last set of questions asks about the use of activities from the Data Activities Portfolio, your perceptions about student engagement, and final thoughts.

8. Which activities from the Data Activities Portfolio have you used (or will use) in your classroom? *(Please list up to three activities. If you don't plan or haven't used these activities, please provide a short explanation as to why not.)*

9. Using QuarkNet content and/or materials, which of these behaviors do you think your **students** will be able to do (or are able to do) in your classroom? *(Check all that applies.)*

	Almost Always	Very Often	Sometimes	Not Very Often	Rarely	N/A
a. Discuss and explain concepts in particle physics.	◯	◯	◯	◯	◯	◯
b. Discuss and explain how scientists develop knowledge.	◯	◯	◯	◯	◯	◯
c. Engage in scientific practices and discourse.	◯	◯	◯	◯	◯	◯
d. Use, analyze and interpret authentic data.	◯	◯	◯	◯	◯	◯
e. Draw conclusions based on these data.	◯	◯	◯	◯	◯	◯

Other (please specify)

10. What else would you like to tell us about your QuarkNet experience as you reflect on applications in your classroom?

QuarkNet Center Feedback

Your help is important. Please respond to this information request based on your current QuarkNet program experience and, if applicable, on your previous involvement in QuarkNet programs at your Center. If your Center has participated in QuarkNet for many years, please respond based on what you think the cumulative effect of this participation has been over the ***past two years****. We will ask you to complete this form only once. We can help clarify something if needed and we can aid in helping you complete this form if necessary.*

We are asking that this form be completed only once. With help from QuarkNet staff and the evaluator, we are asking for a conference call with person(s) at your center most familiar with these program efforts, such as the mentor(s), fellows and/or lead teachers in order to complete the requested information. Section I asks for information about you, your Center and who is completing this form and for what time period. Section II asks to specify what QuarkNet events your Center has participated in; we have started this process by including engagement information based on agendas from previous workshops and past annual reports that your Center has posted on the QuarkNet website. Section III asks for a reflection on outcomes; and Section IV asks about effective practices that align with the sustainability of the program. (Use an additional page for any comments you may have.) If you have any questions, please email Kathryn Race at race_associates@msn.com.

I. **Center Information**: *Please provide information about the Center and who is completing this form.*

Date:

Which Center? (*please specify name and location of center*):

Who completed this form? (*Please indicate all individuals who helped to complete this form):*

What time period is covered by these observations? (*e.g., 2017-2018; 2018-2019*):

How many years (approximately) has your Center participated in QuarkNet?

II. **QuarkNet Program Activities**: *Please indicate which of the following QuarkNet programs have been implemented at your Center in the past two years, based on your Center's typical engagement in this program. (Check all that apply).*

Check, if yes ✔	*QuarkNet Program Component*	*Held during the summer (✔ or indicate dates)*	*Held during the calendar year (✔ or indicate program year)*	*Other (please specify)*
	National Workshop (facilitated by national program staff or fellows) Workshop list at https://quarknet.org/page/summer-workshop-opportunities-quarknet-centers			
	Center-run Workshop (facilitated by center with center-focused topics/interests)			
	Data Camp:			
	1. Center-level teacher(s) participates at Fermilab			
	2. Teacher(s) introduces activity/methods at Center (based on Data Camp experience)			
	Data Activities Portfolio: Activities at https://quarknet.org/data-portfolio			
	1. Work through and reflect on activity/ities (in the portfolio) at the center.			
	2. Present/discuss examples of classroom implementations based on these activities			
	Masterclass(es): Held one or more at center			
	Cosmic Ray Detector *(e.g., assemble, calibrate)*			
	Other *(please specify any other center-led or center-wide event)*			

QuarkNet Websites: https://quarknet.org/; https://quarknet.org/page/summer-workshop-opportunities-quarknet-centers; https://quarknet.org/data-portfolio

III. **Center-level Outcomes**: *Please indicate which of the following QuarkNet program outcomes have been evident, by whom and the degree of QuarkNet's influence at your Center in the past two years. (Check all that apply.)*

Center-level Outcomes	Who?						QuarkNet's Influence?					
	Almost All	Most	Some	A Few	Rarely	Don't Know	Very High	High	Moderate	Low	Very Low	Does Not Apply
Engage Teachers as Active Learners, as Students (across workshops/events)												
During National/Center-run Workshops or Programs, Teachers Experience Active, Guided-inquiry Instruction through:												
1. Asking questions and defining problems.												
2. Developing and using models.												
3. Planning and carrying out investigations.												
4. Analyzing and interpreting data.												
5. Using mathematics and computational Thinking.												
6. Construct explanations and designing solutions.												
7. Engaging in argument from evidence.												
8. Obtaining, evaluating, and communicating information.												
Networking/Community Building:												
1. Teachers engage/interact with mentors and other scientists.												
2. Teachers engage/interact with other teachers.												
Teachers as Leaders:												
1. Provide leadership at local centers.												
2. Attend and/or participate in regional and national professional conferences sharing their ideas and experiences.												
Teachers and Mentors: Form lasting collegial relationships through interactions and collaborations at the local level and through engagement with the national program.												
Mentors: Become the nexus of a community that can improve their teaching, enrich their research and provide broader impacts for their university.												

IV. **Center-level Success Factors:** *Please view the center's QuarkNet engagement through the lens of the Success Factors related to effective practices as described below.*

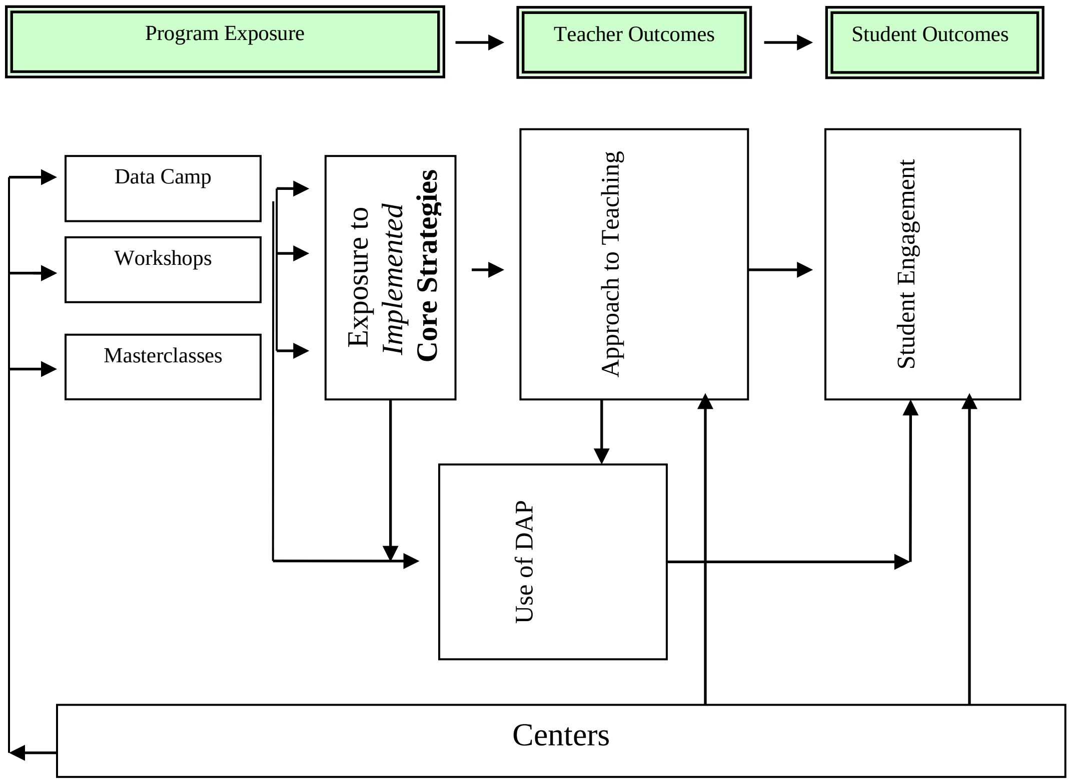
Effective Practices/Success Factors[a]	Meets Criteria?				Comments: Please use this space (and additional space if needed) to explain your ratings or to indicate action that may need to occur.
	Yes	Yes, but[1]	No	Unsure	
1. *Program provides opportunities for a* ***strong teacher leader***. (Teacher provides leadership in areas of content and/or is a technical expert; models exemplary pedagogical skills; able to provide organizational skills. These characteristics may be present in one or a team of teacher leaders.)					
2. *Program provides opportunities for a* ***strong mentor***. (Mentor provides leadership skills mainly of content and/or technical expertise; understands education and professional development -- working with teacher leaders as needed; models research.)					
3. *Participants meet regularly*. (QuarkNet model is for a summer session with follow-up during the academic year or sessions during the academic year. Follow up includes working with the national staff and collaboration within and across centers. Mentors and teachers have flexibility to set the annual program locally.)					
4. *Meaningful activities* (The standard for meaningful activities is focusing topics in modern physics, discussing how to implement this content in classrooms, conducting research and discussing scientific inquiry methods; using Data Activities Portfolio instructional materials.)					
5. *Directly addresses classroom implementation of instructional materials for all teachers.* (Time for teachers to discuss Data Activities Portfolio instructional materials and pathways; to consider NGSS, AP, IB or other science standards; presentation(s) from veteran teachers on classroom implementation experiences or similar engagement.)					
6. Program is able to provide regular contact and support with teachers. (Specific support and or follow up from staff; staff teachers are available and/or volunteers who support teachers, especially related to classroom implementation.)					
7. Money for additional activities or additional grants. (Seeking additional funding to fulfill the mission/objectives of the center; providing supplemental or complementary support for QuarkNet e.g., providing transportation, lodging, buying equipment; providing food.)					
8. Stable participant base.(A stable participant base can provide an expert group that can help other teachers, support outreach, and provide organizational leadership.)					
9. Addresses teacher professionalism. (The standard is to provide opportunities for at least a few teachers to attend professional meetings; support teachers taking leadership roles in their school, school districts, outreach, and highlight PD opportunities for continuing development.)					
10. Establish a learning community. (The standard is forming a cohesive group where teachers learn from one another; engage with mentors and other scientists; provide outreach to other teachers.)					

[a]This section of the protocol has been adapted from M.J. Young & Associates (2017, September). *QuarkNet: Matrix of Effective Practices.*

[1]Needs work or fine tuning; or, there are notable caveats.

Please use an additional page for any comments you may have. Thank you for your participation.

Scale Development in Support of Analyses Related to Teacher (and their Students) Outcomes



As stated in the narrative of this report, we have explored the relationship between engagement in QuarkNet and exposure to core program strategies; and, subsequently the potential impact this involvement may have on teacher outcomes and student engagement outcomes. And as stated, at times a given measure may serve as the dependent measure in a set of analyses; and in turn, a given measure may be used as a “predictor” variable as we build a model toward understanding teachers’ approach to teaching and use of activities in the Data Activities Portfolio. Because of this complexity, Figure 10 (noted here and in the narrative of the report) provides an overview of these analyses as a means of offering a road map to their logic.

To help simplify these analyzes and to use data with measured reliability (internal consistency) several scale scores were created. These are: Core Strategies; Approach to Teaching; QuarkNet’s Influence on Teaching; Student Engagement; and, QuarkNet’s Influence on Student Engagement. A *new* scale score has been added, that is, Long-term Outcomes: Teachers. All are based on self-reported responses by teachers to individual items from the full Teacher Survey. Each of these analyses is presented and discussed separately in the next several sections. Please keep in mind that these scale scores help us explore the association of exposure to core strategies through QuarkNet programs and outcomes; and, that this association is not intended to imply causality.

Program Fidelity:
Perspective of Teachers on Exposure to Program Core Strategies

Given the logically links between articulated core program strategies and expected program outcomes as suggested by the PTM, teachers were asked about their exposure to such strategies during their QuarkNet program engagement. This is seen as a measure of the fidelity of the *implemented* program as compared to the program as *designed*. To this end, in the Full Teacher Survey, teachers were asked to reflect on their exposure to core program strategies; the instructions were:

> *Please rate the following strategies based on your current QuarkNet program experience and, if applicable, on your previous involvement in QuarkNet programs to date. If you have participated in QuarkNet for many years, please respond based on what you think the cumulative effect of this participation has been over the past two years.*

Table K-1
Items Used to Form a **Core Strategies** Scale based on Teacher Responses

Exposure to QuarkNet Strategies
QuarkNet provides opportunities for me to:
21a. Engage as an active learner as a student.
b. Do science the way scientists do science.
c. Engage in authentic particle physics investigations.
d. Engage in authentic data analysis experiments using large data sets.
e. Develop explanations of particle physics content.
f. Discuss the concept of uncertainty in particle physics.
QuarkNet provides opportunities for me to:
22a. Engage in project-based learning that models guided-inquiry strategies.
b. Share ideas related to content and pedagogy.
c. Review and select particle physics examples from the Data Activities Portfolio instructional materials.
d. Use the pathways, suggested by the Data Activities Portfolio, to help design classroom instructional plan(s).
e. Construct classroom implementation plan(s) incorporating experience(s) and Data Activities Portfolio instructional materials.
f. Become aware of resources beyond my classroom.

The items in Table K-1 (Q21 and Q22 from the survey) align with the core program strategies presented in the PTM. These items were rated on a 5-point, Likert-like scale from (1= Poor, 2 = Fair, 3= Average, 4 = Good, and 5= Excellent). For analysis purposes, items were summed to create a **Core Strategies** scale, with *the higher the scale score, the more positive the response.* Descriptive statistics based on actual scores from this 12-item scale, based on an N=464, ranged from 12 to 60, with a Mean = 54.10 (Standard Deviation, SD = 6.97); and an alpha = 0.86 (reliability coefficient, Cronbach's alpha).

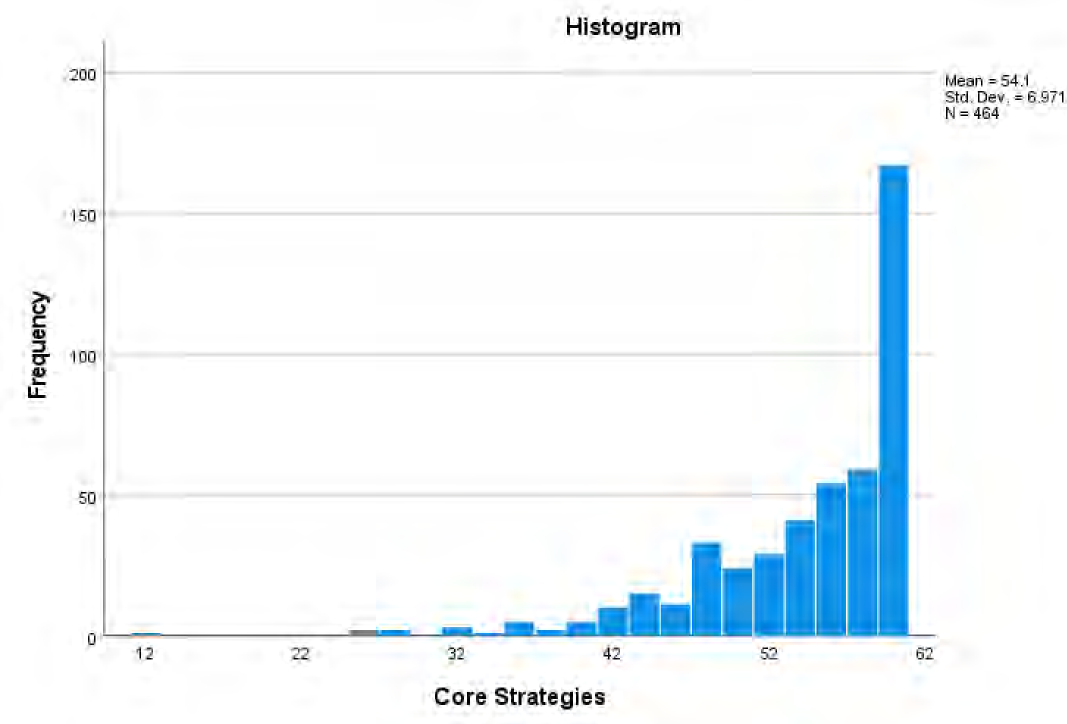


Figure K-1. Distribution of Core Program Strategies scale scores.

These statistics suggest that this scale can be used as a measure of program fidelity, with a skewed distribution as shown in Figure K-1. These data suggest that participating teachers were exposed to a high level of core program strategies (based on their perceived experiences).

Program Outcomes: Approach to Teaching and QuarkNet's Perceived Influence

Several scales were created from questions in the Teacher Survey related to teacher (and their students) outcomes and the perceived influence of QuarkNet on these behaviors. The first of these scales was **Approach to Teaching**, directed toward teacher-outcomes articulated in the PTM. To this end, in the full Teacher Survey, teachers were asked to reflect on classroom instruction, as follows:

> *In thinking about your approach to teaching, please rate the frequency in which you engage in each of the following in your classroom.*

Table K-2/K-3
Items Used to Form an **Approach to Teaching/QuarkNet's Influence**
Scale based on Teacher Responses

Approach to Teaching Outcomes
27a. Discuss and explain concepts in particle physics.
b. Engage in scientific practices and discourse.
c. Use physics examples including authentic data when teaching subjects such as momentum and energy.
d. Review and use instructional materials from the Data Activities Portfolio.
e. Selecting these lessons guided by the suggested pathways.
f. Facilitate student investigations that incorporate scientific practices.
29a. Use active guided-inquiry instructional practices that align with science practices standards (NGSS and other standards).
b. Use instructional practices that model scientific research.
c. Illustrate how scientists make discoveries.
d. Demonstrate how to use, analyze and interpret authentic data.
e. Demonstrate how to draw conclusions based on these data.
f. Become more comfortable teaching inquiry-based science.

The items in Table K-2 (Q27 and Q29 from the survey) were rated on a 5-point, Likert-like event scale from (5= Almost Always, 4 = Very Often, 3= Sometimes, 2= Not Very Often, and 1= Rarely. (A "Not Applicable" option was scored as a zero.) Similarly, for analysis purposes, items were summed to create an **Approach to Teaching** scale, with *the higher the scale score, the more positive the response.* Descriptive statistics based on actual scores from this 12-item scale, based on an N=447, ranged from 17 to 60, with a Mean of 42.85 (SD = 8.38); and an alpha of 0.87 (reliability coefficient). Figure K-2 shows the distribution of these scores, suggesting an approximate normal distribution. We have concluded that this scale can be used as a measure in subsequent analyses (either as an outcome or a predictor).

QuarkNet's Influence on Approach to Teaching

In the Teacher Survey, teachers were asked:

> *Now, indicate the degree to which you think QuarkNet has contributed to your implementation of these instructional strategies in your classroom.*

The items in Table K-3 (now Q28 and 30) were repeated but this time these items were rated on a 5-point, Likert-like scale from (5= Very High, 4 = High, 3= Moderate, 2 = Low, 1= Very Low) measuring the perceived QuarkNet influence on these behaviors. (A "Not Applicable" option was scored as zero.) As in previous scales, items were summed to create a **QuarkNet's Influence on Approach to Teaching** score, with *the higher the score, the more positive the response.* Descriptive statistics based on actual scores from

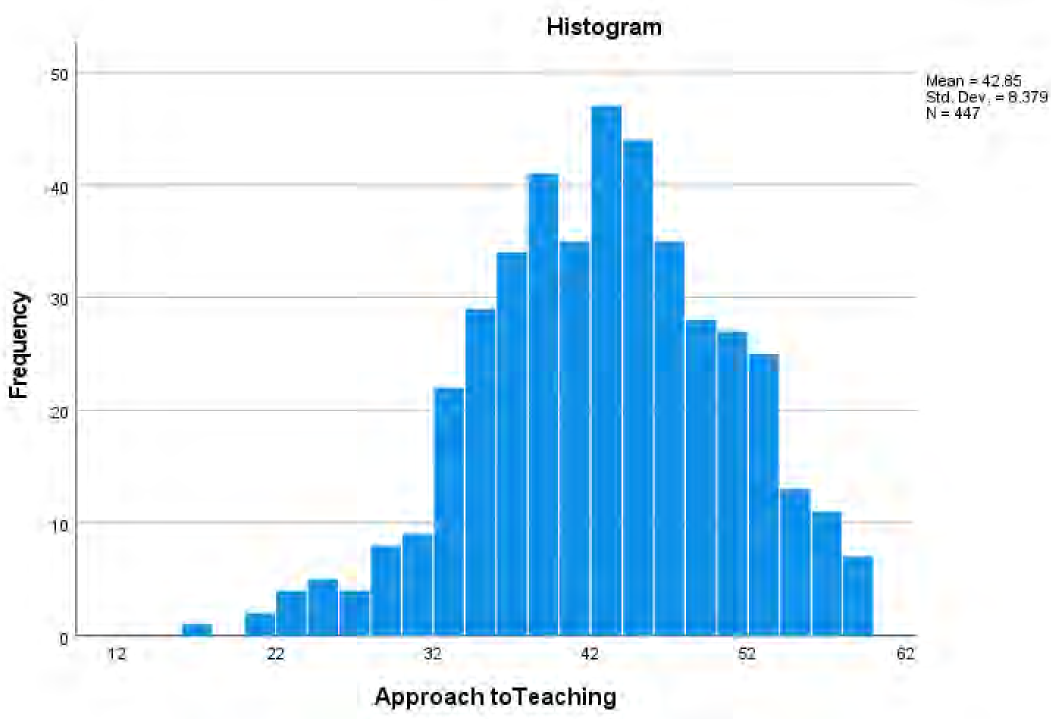


Figure K-2. Distribution of Approach to Teaching scale scores.

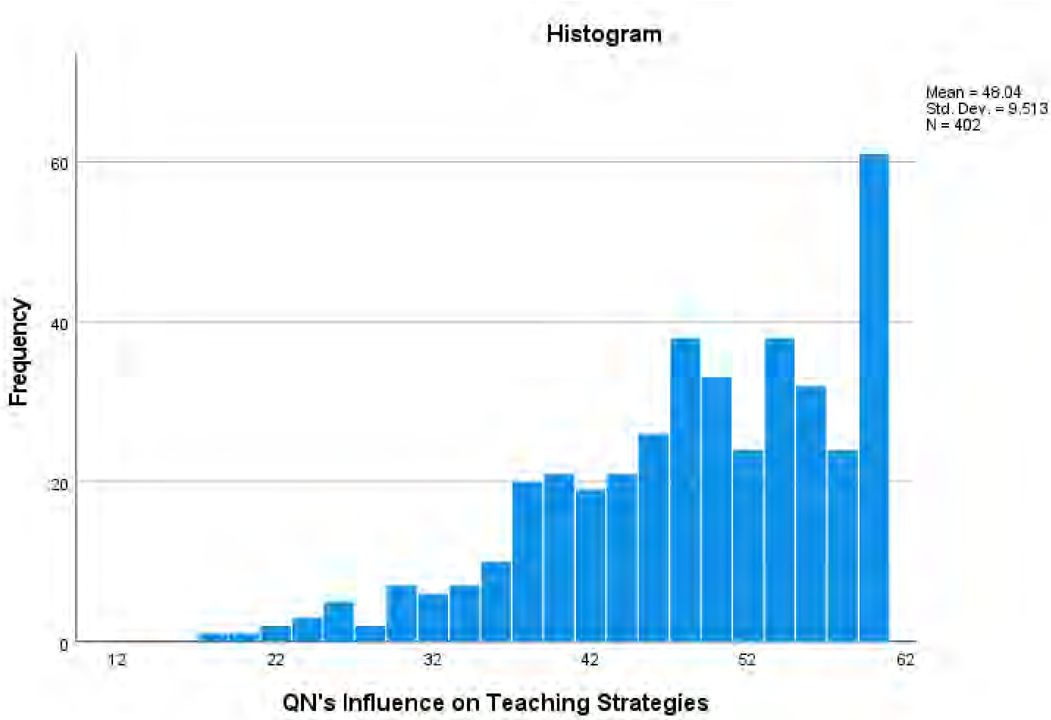


Figure K-3. Distribution of QuarkNet's Influence of Teaching scale scores.

this 12-item scale, based on an N= 402, ranged from 4 to 60, with a Mean of 48.04 (SD = 9.51); and an alpha of 0.91 (reliability coefficient). (See Figure K-3 previous page.)

Student Engagement

In the Teacher Survey, teachers were asked to assess perceptions of their Student Engagement in their classrooms, and their judgment as to QuarkNet's Influence on this engagement. Accordingly, teachers were instructed:

> *This last set of questions asks about your students' classroom engagement and how QuarkNet may have influenced (through your participation and/or your students) this engagement. In your judgment, please indicate ...*

Table K-4/K-5
Items Used to Form a **Student Engagement/QuarkNet's Influence**
Scale based on Teachers' Perceptions

Student Engagement (*My students are able to* …)
32a. Discuss and explain concepts in particle physics.
b. Discuss and explain how scientists develop knowledge.
c. Engage in scientific practices and discourse.
d. Use, analyze and interpret authentic data.
e. Draw conclusions based on these data.

The items in Table K-4 (Q32 from the survey) were rated on a 5-point, Likert-like scale from (5= Almost Always, 4 = Very Often, 3= Sometimes, 2= Not Very Often, and 1= Rarely. (A "Not Applicable" option was scored as zero.) Again, for analysis purposes, items were summed to create a **Student Engagement** scale, with *the higher the scale score, the more positive the response.* Descriptive statistics based on actual scores from this 5-item scale, based on an N=425, ranged from 2 to 25, with a Mean of 18.38 (SD = 3.66); and an alpha of 0.84 (reliability coefficient). Figure K-4 shows the distribution of these scores, suggesting a measure with natural variability that is approaching a normal distribution.

QuarkNet's Influence on Student Engagement

The items in Table K-5 (now Q33) were repeated but this time these items were rated on a 5-point, Likert-like scale from (5= Very High, 4 = High, 3= Moderate, 2 = Low, 1= Very Low) measuring the perceived QuarkNet influence on these behaviors. (A "Not Applicable" option was scored as zero.) As in previous scales, items were summed to create a **QuarkNet's Influence on Student Engagement** score, with *the higher the score, the more positive the response.* Descriptive statistics based on actual scores from this 5-item scale, based on an N= 357, ranged from 2 to 25, with a Mean of 19.63 (SD = 4.06); and an alpha of 0.91 (reliability coefficient). (See Figure K-5.)

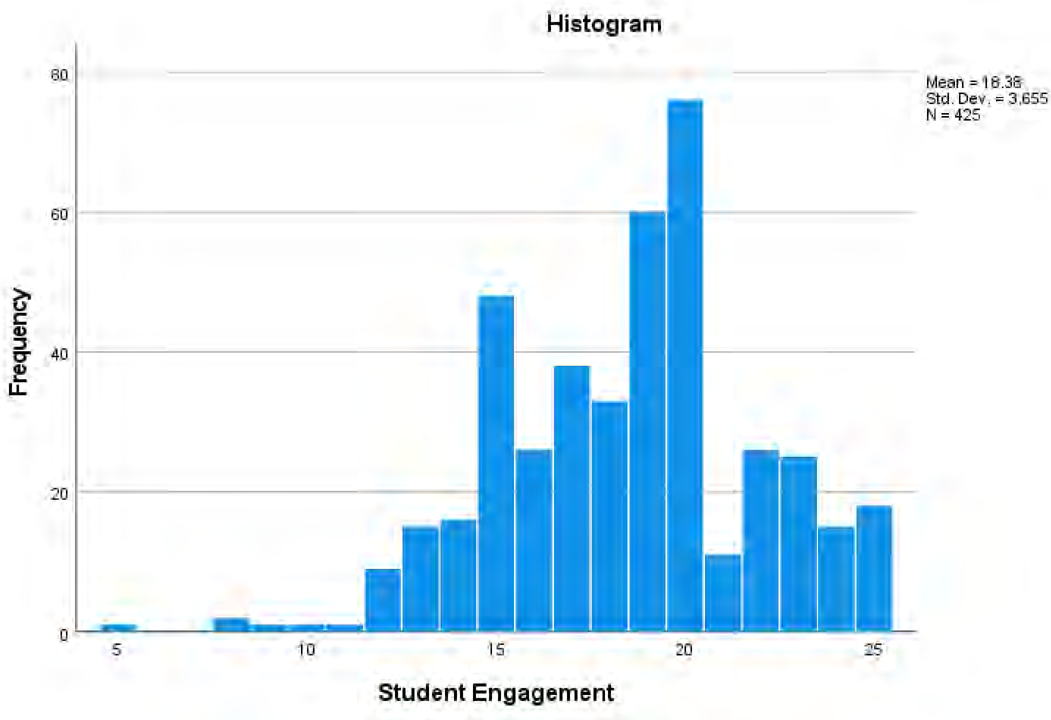


Figure K-4. Distribution of Student Engagement scale scores.

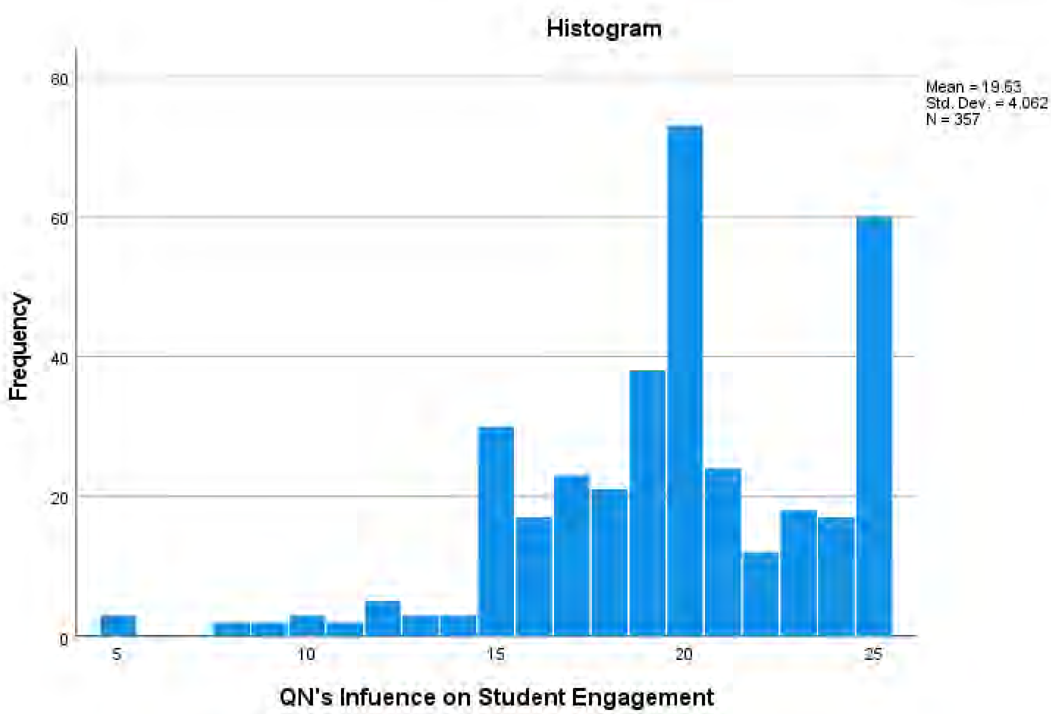


Figure K-5. Distribution of QuarkNet's Influence on Student Engagement scale scores.

Table K-6
Items Used to Form a **Long-term Outcomes: Teachers** Scale based on Teachers' Responses

31. Please respond to the following statements: a. I use resources (including QuarkNet resources) to supplement my knowledge and instructional materials and practices. b. I have increased my science proficiency. c. I have developed collegial relationships with scientists and other teachers. d. I think my students have become more comfortable with inquiry-based science.

Long-term Outcomes: Teachers

In the full Teacher Survey, teachers were asked to reflect on longer-term outcomes with items that describe overarching behaviors that relate to use of resources, development of collegial relationships, increasing one's science proficiency, and students' comfortable with engagement in inquiry-based sciences. These items are shown in Table K-6. Each was rated on a 5-point, Likert-like scale from 5= Strongly Agree, 4 = Agree, 3= Neutral, 2= Disagree, and 1= Strongly Disagree. As for all previous scales, items were summed with *the higher the scale score*, *the more positive the response*. This scale has been named, **Long-term Outcomes: Teachers.** Descriptive statistics based on actual scores from this 4-item scale, based on an N=450, ranged from 6 to 20, with a Mean of 17.53 (SD = 2.56); and an alpha of 0.82 (reliability coefficient). See Figure K-6.

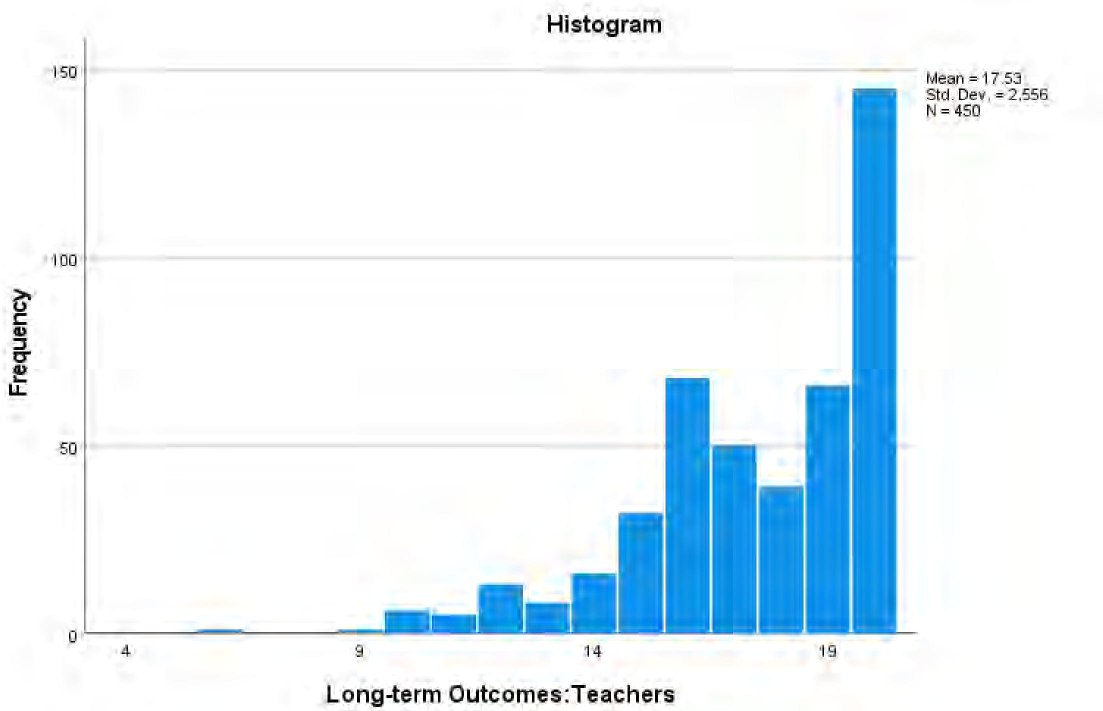


Figure K-6. Distribution of Long-term Outcomes: Teacher scale scores.

Table K-7
Perceived Exposure to QuarkNet **Core Program Strategies** Compared to
Type and Variety of Program Engagement and Use of Data Activities Portfolio

Comparison	N	Mean	SD[a]	Analysis Results
Data Camp				
Yes	179	55.25	5.72	$F_{(1, 462)} = 8.05$, $p < .005$
No	285	53.38	7.57	
Variety of Workshops[b]				
No workshops	185	52.25	8.34	$F_{(2, 461)} = 12.12$, $p < .001$
One workshop[c]	134	54.79	5.90	
Two or more[c]	145	55.82	5.23	
Masterclasses				
None	308	53.29	7.45	$F_{(1, 462)} = 12.76$, $p < .001$
One or More	156	55.37	5.58	
Used DAP Activities				
Yes	212	56.14	4.86	$\chi^2_{(1, 457)} = 34.60$, $p < .001$[c]
No	245	52.28	8.02	

[a]Standard deviation
[b]This variable refers to the variety of workshops not the total number of events.
[c]Based on a binary, logistic regression analysis.

Table K-8
Approach to Teaching Outcome Related to
Type and Variety of Program Engagement and Use of Data Activities Portfolio

Comparison	N	Mean	SD[a]	Analysis Results
Data Camp				
Yes	174	44.85	7.81	$F_{(1, 445)} = 17.68$, $p < .001$
No	273	41.47	8.58	
Variety of Workshops[b]				
No workshops	177	41.30	8.20	$F_{(2, 444)} = 10.47$, $p < .001$
One workshop[b]	129	41.98	9.07	
Two or more[b]	141	45.39	7.49	
Masterclasses				
None	294	41.62	8.64	$F_{(1, 445)} = 16.85$, $p < .001$
One or More	153	45.02	7.52	
Used DAP Activities				
Yes	206	45.63	7.38	$F_{(1, 439)} = 51.44$, $p < .001$
No	235	40.16	8.47	

[a]Standard deviation
[b]This variable refers to the variety of workshops not the total number of events.

There were no statistically significant differences noted across program years nor gender so these variables were dropped from analyses with cases collapsed across program years and by gender.

Center-specific Tables: Descriptive Summaries of Teacher Reported Uses of QuarkNet Content and Materials in their Classrooms

The narrative of the 2023 Evaluation Report based on results from quantitative analyses suggests that QuarkNet centers *matter* when teacher-level and student-level outcomes are analyzed. Relative to outcomes data, reported usage by teachers of Data Activities Portfolio (DAP) activities is shown to be positively related to *higher* Core Strategies scores (program exposure) and *higher* Approach to Teaching scores (classroom practices). Reported use of DAP activities informs the results from the hierarchical linear regression analyses of teacher and student outcomes based on 24 (31 combined) QuarkNet centers. The variables used in these hierarchical regression analyses serve as underlying "markers" of the use of DAP activities and the degree type of engagement in QuarkNet programs by participating teachers.

To better understand these differences, Figures 13, 14 and 15 (from the full report and repeated here) suggest what this center-level variability (center means) looks like across these outcomes for the 24 (31 combined) centers included in these analyses. These figures help facilitate comparisons between quantitative and qualitative results. Figure 14 presents a breakdown of the number of teachers who reported using DAP activities in their classroom and Figure 15 shows both teachers who reported using and not using DAP activities in their classrooms. This suggests that the use (and non-use) of DAP activities also varies by center and may contribute to the outcomes differences noted by centers.

To take a deeper dive into QuarkNet content and material uses, we have conducted descriptive analyses of responses to open-ended questions that explore this usage. Each center-specific table provides individual teacher comments to questions as to how QuarkNet content and materials are used in his or her classroom (or planned use). We have focused on the same 24 centers that were included in these quantitative analyses (representing 80% of the teachers who completed their surveys).

Each center-specifc table is coded by a number – the same number used to code centers in Figures 13, 14 and 15. Thus, if desired the reader can review what the outcomes data suggest about this center and then review what teachers at that center reported about QuarkNet classroom use. These descriptions are based on survey responses from the full Teacher Survey and any subsequent Update Survey that an individual teacher completed; each row represents responses from the same teacher. Each table starts with responses to the full survey (by program year); and then responses from an update survey. Blank cells likely mean that a given teacher did not participate in a QuarkNet program that year (or perhaps did not respond to either the question or complete their survey for that year).

Table C-1
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #1**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #1	2019	2020	2021	2022
	I have used the deck of cards (subatomic particles) with students to prepare for the masterclass	I mostly use these tools in my after-school club 'Theoretical Physics Club'. Students present topics and activities on a different subject each week. Examples: Rolling for Rutherford; Dice Decay Probability	The physics classes I teach do not end up reaching most topics covered by QuarkNet experiences, so I plan to use these mostly for the after-school science club that I will be running. Examples: Rolling with Rutherford; Mass of a Penny; Step Up Physics	Used activities for my science club very frequently. A few times a year I will incorporate into my Honors Physics curriculum during conservation of momentum energy units. Examples: Rolling with Rutherford, Mean Lifetime, STEP UP activities.
	N/A			I expect the information on fusion this summer will be very helpful for my AP as I cover modern physics with my students at the beginning of the year (while they are learning calculus in math classes). I am not familiar with method of accessing DAP.
	I'm not sure what Data Activities Portfolio is, but I use the cosmic ray detectors in my classes and I have my students do the CMS data analysis on CIMA.			Cosmic ray experiments in all physic classes. Masterclass CMS analysis in all physics classes. Masterclass attendances once it resumes. Teaching particle physics and nuclear physics in all classes. Students do cosmic ray experiments outside of class during the school year and during the summer. Examples: Shuffling the Particle Deck, Calculating Z Mass and Top Quark Mass, Histograms; Uncertainty.
			Coding Camp (Google Colab Notebooks), Standard Model. Have not used DAP materials yet, I was remote the entire school year.	
	The Rutherford activity is used at all levels. It is engaging, challenging and gives great insight into indirect observations.			
	I used a variation of the Mean Lifetime Part 1: Dice Activity with my Physics students to explore the idea of radioactive decay. I used (and still use) the Calculate the Z Mass and Top Quark Mass activities with the Advanced Topics students. I used Rolling with Rutherford and Quark Workbench activities to prepare students for participation in Particle Physics Masterclasses at Northeastern University.	I incorporated QuarkNet-related exercises in my Advanced Physic Topics class and brought students in that course and in my Honors Physics course to Particle Physics Masterclasses. Examples: Calculate the Z Mass, Calculate the Top Quark Mass, Mean Lifetime: (1) Dice) and (2) Muons	I frequently used QuarkNet materials and ideas in my physics teaching, particularly with my Advanced Topics in Physics class. I am currently retired. Examples: Rolling with Rutherford, Calculate the Z Mass, Calculate the Top Quark Mass, and several others. I have continued to host and promote QuarkNet meetings for the Boston group in order to share.	I used QuarkNet materials for masterclass preparation and for students in the Particle Physics portion of my Advanced Topics in physics class. Examples: : Rolling with Rutherford, Calculate the Z Mass, Calculate the Top Quark Mass,
	The Rutherford activity is used at all levels. It is engaging, challenging and gives insight into indirect observations.			

Table C-1
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #1**

Center	Program Year (Year of Full Survey)	Subsequent Program Year
Center #1	2021	2022
	Top quark, Alas Master class - both contribute to how data is used to understand nature, understanding role of error in experiment and excellent applications of conservation principles	
		QuarkNet has deepen my understanding of modern physics, but, to date this hasn't been a specific focus of my classes. This material mostly comes into the classroom during "off topic" class discussions. A student asks a question, then my answer spawns another student question, then we end up talking about Cosmic Rays or something else like that. I haven't used any of the Data Activities Portfolio, and that has more to do with me than the activities. I think I'll experiment with them a bit this semester.
	I have not had the opportunity to use these yet.	
	Momentum Conservation top quark activity (in class). It's a bit high-level for some of the courses but it's a great way to incorporate actual data into class and to gain some relevance.	Fusion Materials from today will help with MA frameworks for intro physics. Examples: Penny Mass, Quark Workbench, Mapping Poles.
	I used the data from bootcamp when teaching conservation laws.	Rolling with Rutherford, collision data
	I haven't used them yet (I'm new to QuarkNet) so I wouldn't recommend something that I haven't tried out.	
	Rolling with Rutherford great for using probability trials to determine real data, the Missing Mass activity (great for vector addition	Masterclass, using finding of Z mass from vectors. Examples: Rolling with Rutherford and Calculating the Mass of Z.

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of a total of 16 teachers.)

Table C-2
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #2**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #2	2019	2020	2021	2022
			In the past I have used scintillator panel and discriminator boards to describe the behavior of Cosmic Rays and connect them to other vents, like lightning strokes. As a retired teacher I could see sharing what we learned through LIPTA (Long Island Physics Teachers Association) with other teachers.	
	N/A (but I plan to teach some of the topics in my physics classes!)		From this activity, I want to put coding specific-lesson design to my physics classes. I'd like to target on-level physics with coding-based activities. I was planning on using some of the activities in the past 2 years, but the pandemic unfortunately made it much more difficult to get through even the required curriculum with my students.	This coming year, I will be teaching Science Research for the 9th graders in addition to Regents and Conceptual Physics. I plan to use the QuarkNet e-Labs in my Science Research class to help students learn how to conduct their own experiments and think critically. I haven't used any of the activities yet as my curricula did not allow enough time to dedicate to the activities. I plan to use more often as I will be teaching Science Research next year.
		Info on the LHC is useful for discussing particle detectors. Details about the Standard Model go well above the New York State curriculum requirements, but adding in that info provides a more complete picture. When talking about background radiation, cosmic rays are an often overlooked factor that QuarkNet has enabled me to flesh out. As I am retired, I no longer work in the classroom. While I am familiar with some of the activities, I do not present them to my students.		
	I will be looking through the list and using some activities next year.	This year we will work on Jupyter notebooks. I will use this as a springboard to introduce Python in the engineering course that I teach. Additionally, I created an activity that can be done in the classroom or assigned virtual based on forces and a large data set from NASA. Examples: Will use Dice, histograms and probability to introduce Python and histograms. Have used Rolling with Rutherford.	This past year my physics class students participated in LHC masterclass and Big Analysis of Muons. I used Rolling with the Higgs as virtual lab. I will use the graphs of motion notebooks in AP Physics 1. Examples: Rolling with Higgs. I plan to use a few more but I am not sure which.	I would like to use a cosmic ray detector with my science research students. Examples: Quark Workbench, Shuffling the Particle Deck, Rolling with Rutherford.

Table C-2
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #2**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #2	2019	2020	2021	2022
			I plan to incorporate some of the Python coding from this week's workshop in my classes. Specifically, I would like to introduce Python coding during kinematics, then hopefully follow up with more Python coding during magnetism, and possibly during modern physics (neutrinos). I will talk to others at our center about whether we should do the neutrino MasterClass instead of the ATLAS W boson MasterClass next year. Examples: I may use Making it Round the Bend.	I have used and continue to use masterclass activities to teach the standard model. I plan to use the shuffling the particle deck to introduce the standard model. I think I'll also use the lifetime activity, with data online to show uncertainty and the importance of statistics. Examples: Masterclass, lifetime, STEP UP.
	Program Year (Year of Full Survey)	Subsequent Program Year		
	2021	2022		
	The Practical Code for Physics Class would definitely be the most helpful, in order to better visualize, interpret, and model motion.			
	Rolling with Rutherford Shuffling the Particle Deck Quark Workbench Atlas Z-path Masterclass			
	I have used the mass of a penny histogram activity. Until this workshop I really didn't know about all of the activities and I am excited to use them will ALL of my students next year			

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of a total of 14 teachers.)

Table C-3
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years **Center #3**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #3	2019	2020	2021	2022
	Data collection and analysis.			
	I plan to use 6 activities from the Data file (*not specified*). I learned so much and was welcome to wonder out loud. A safe space for learning and growing.			
	We are going to be using the class tool to create a camp. Last year was too overwhelming for me to do a project on my own, especially since I do not teach physics, but this year we have the building tools to create a physics camp for Title 1 students.			
	While this was my first year at QuarkNet, I plan to implement much of what I have learned! I also hope to take an on-line Particle Physics I class.			
	Data Analysis: AP Statistics Univariate data analysis, numerical summaries, boxplots, histograms, hypothesis testing Trigonometry: 4-vectors, right-triangle trigonometry (close & form the right triangle), component-wise addition Intro. to Computer Science: This has the potential of using Python to analyze the data contained in .csv files			
	My first year at QuarkNet, I plan to implement much of what I have learned. (My focus is as a STEM teacher - after-school and non-school hours)			
	Use of tracker. Z mass			
	Dice Histograms, Shuffling the Particle Deck, and Rolling with Rutherford			
	I have used the Mass of Pennies lab in chemistry previously for average mass determination. I have worked with something similar to the Mapping Magnetic Fields lab, but with electric fields and carbon paper.		Virtual Coding: From this activity, I want to pull in the coding-specific lesson design to my physics classes. I'd like to target on-level physics students with coding-based activities. Excited to use many of the histogram-related activities. I am also EXTREMELY excited to incorporate the STEP UP activities in my classroom and evangelize them to my department	Coding will come up in a big way in my AP Physics C classes this year. I intend to implement them as a standard way to do data analysis throughout the school yar. I hope to incorporate QuarkNet particle physics activities near the end of the year in my Honors Physics class. I also hope to incorporate some cross-curricular with our art department or marker space to bring particle physics forward in our community. I hope to use the Energy, Momentum and Mass activity (hopefully the quantitative version) with my AP students in this year. As time allows, I intend to use one or more of it Making It Round the Bend both in AP Physics but also honors physics at the end of the year when we reach magnetism.

Table C-3
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years **Center #3**

Center	Program Year (Year of Full Survey)	Subsequent Program Year
Center #3	2021	2022
	Classes have not yet begun, e-Labs and the data provided will be of great use; understanding detector construction will allow a more thorough explanation of function of iPad cosmic collection apps.	In discussion of em radiations during space unit (grade 6) and energy unit (grade 7). These factors play a role in the units previously discussed.
	Mass of a penny; shuffling the particle deck; rolling with Rutherford.	
	None at present as this is my first year.	
	Program Year (Year of Full Survey) 2022	
	I will. The program to present posters it will help the students with displaying the scientific method and presenting data.	

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of a total of 10 teachers.)

Table C-4
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #4**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #4	2019	2020	2021	2022
	Muon detection and analysis			
	I expect to use the Top Quark Collision and What Heisenberg Knew activities...			Conservation properties. Calculate boson Z mass.
	Shuffling the Particle deck to introduce the standard model and make parallels to pattern recognition, periodic table arrangement, etc. This allowed students to make connections with what is familiar to this new unfamiliar material.			
	Mystery Neutron, Rolling with Rutherford, Top Quark		Using terminology in many practice problems and hoping to use Rolling with Rutherford this coming year. Examples: Rolling with Rutherford, Minerva Activity	I currently use to top-antitop collision investigation for conservation of momentum as well as the MINERvA masterclass each year. Examples: Top antitop collision and MINERvA
	Mass of Z boson, Rolling with Rutherford, Totem Express			
	Rolling with Rutherford, Quark Workbench, Mass of Z	I will continue to use many QuarkNet resources. Examples: Rolling with Rutherford, Mass of Z, Quark Workbench	Continue to use the activities that I have been using. Determine what activities will fit into our freshman physics course. Examples: Quark workbench, Rolling with Rutherford, Mass of the Z	Most years I have one or two students that use the cosmic ray detector for a student designed physics project in my advanced physics classes. I regularly use many of the activities. Examples: Quark Workbench, Mass of Z, Rolling with Rutherford. Additionally, the chemistry teachers at my school are using a version of Rolling with Rutherford in their classes.
	Program Year (Year of Full Survey)			
	2020			
	This is my first one, but I think the STEP-UP workshop will indeed be beneficial in helping my students gain some context.			
	Mass of a penny			

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of a total of 12 teachers.)

Table C-4

Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #4**

Center	Program Year (Year of Full Survey)	Subsequent Program Year
Center#4	2021	2022
	Mass of Z	
	Have yet to have a chance to use them.	
	I have extensively used Shuffling the Particle Deck and Rolling with Rutherford in various classes. Sometimes I have used these as explicit ways of teaching content, but more often I use them as ways to show students what it is like thinking and problem solving like a scientist while using science content that they might not see normally. A lot of the pattern recognition and graphing skills involved help make these activities useful in many subject areas outside of physics (and in physics too!).	Using cosmic ray data, neutrinos, and particle physics deck to help students explore “strange” content but still form meaning from the unknown inquiry-focused instruction. Examples: Particle deck, Rolling with Rutherford, LHC data interpretation.

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of a total of 12 teachers.)

Table C-5
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #5**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #5	2019	2020	2021	2022
	No response.		I intend to use QuarkNet lessons for atomic modeling, data analysis, half-life, and diversity and inclusion. Examples: Dice, Histograms and Probability; Histograms: The Basics; Changing the Culture; Rolling with Rutherford; Mean Lifetime Part 1: Dice; Histograms: Uncertainty; Mean Lifetime Part 2: Muons; Mean Lifetime Part 3: MINERvA.	
	Dice, MINERvA, Particle family cards	Activities for my AP Physics and Honors Physics classes. Discussions about the standard model! Examples: Dice activity mean lifetime of muon from cosmic-ray detectors 2 muon and 4 muon analysis of CMS experiment.		Real life data analysis and experience with science. Data analysis of CMS neutrino data and analysis.
	This is my first time participating in QuarkNet. I thoroughly enjoyed my time in the QuarkNet workshop and plan to implement as much as I can this upcoming school year.			
	The half-life dice lab I believe would be the most helpful.		I have used the penny mass lab with my students. Graphing and bins discussed. Future examples: The introduction to coding. The graphing using coding. Penny lab both weight and half life.	Python notebooks, penny lab, Rolling with Rutherford.
	I hope to use the e-labs and data activities discussed in the Neutrino Data workshop in my classes. All of the various teaching methods were very helpful.			
	I'll be using a great deal of these... dice, basic histograms, missing neutrino.			
	I have used techniques that involve looking at real data.			I used a few of the data activities in class such as the conservation of momentum with the D-Zero detector, the quark zoo, and simulating decay with dice. Examples: I have used Conservation of Momentum, simulating decay with dice, the particle zoo.
	I have had students build histograms.			
	e-Lab and electronic posters			

Table C-5
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #5**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #5	2019	2020	2021	2022
	Mass of a penny, Histogram basics, and Dice, Histograms and Probability. These activities allow students to complete a lab without a lot of equipment or extensive understanding of physics while allowing students to get practice with skills they will need at high levels of all science and math.			
	Data analysis histogram making	I use the activities to assist lower-level ability students in graphing, data analysis and other low level of written work. Examples: Mean Lifetime Part 1; Mass of Pennies.	I intend to use these experiences to support career exploration, and to show students that what we cover in class is only a very small part of our world. Examples: Dice histograms, and Probability, Mass of Pennies.	I intend to use the information to supplement ideas on careers in science and current events. Example: Mass of Pennies.
	dice and pennies to demonstrate variety and mean and then gather in bar graphs. Philosophical openness to future answers via application of Physics to medicine, i.e. MRI technology. To encourage student who learn by different methods. Express what's in it for the students-promote careers in research, engineering and other applications of science. To encourage students and others science teachers to utilize resources available through NSA.			
	Pennies, dice, histograms, workbench, top quark, CRMD	Data activities, CMRD detector, Cosmic Ray e-lab, using in Physics and Chemistry classes, as well as club extracurricular, informal settings. Examples: Histograms, mean lifetimes, Heisenberg	Teaching with data, great stuff plan to incorporate google colab coding activities into Physics and Chemistry classes. Examples: Pennies, dice, histograms, STEP UP.	Portfolio activities into Modern/Honors/AP level Physics classes, Modern/Honors Chemistry classes. Examples: Mass of Pennies, STEP UP.
	Graphing, studying large quantities of data, statistics	I plan to use cosmic ray and first lab in my class. Examples: The coin measurement lab. The dice rolling lab. The BMC lab. I used them as data capture and analysis.	I have used the lessons on portability. I have used the data from various e-labs as analysis material for my class. I have used the analysis for the Boson Higgs. I have used the data analysis for dice rolling and coin flipping. I will use this this year again as the data is amazing for teaching graphing and data.	I have used the e-labs and masterclass lessons to teach statistics and data science as well as python and Jupyter notebooks. Examples: Use of Jupyter notebooks I use constantly to help students make a connection between math, science and computer science.
	Rolling with Rutherford; Quark Work Bench Histogram: the Basics Mean Lifetime Dice			
	Hands on analysis of data to understand neutrinos			
	Around the Bend (F=qvB) Quark Workbench (in prepping students for Masterclass) Top Quark (conservation of p) CMS e-Lab (extension for students who are ready to do mass reconstruction plots, usually post AP exam).	I have used particle colliders when discussing momentum conservation, I have used some e-labs and have brought students to Masterclasses over the year. Examples: Workbench to solidify thinking about quarks; Calculate the Z mass Mean lifetime and dice		

Table C-5
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #5**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year
Center #5	2020	2021	2022
		When teaching conservation of momentum and energy, I was able to use the Muon Decay CMS experiment with my students. This illustrated how these important laws of physics are used in current research. Examples: Muon Decay Radioactive Decay Dice Experiment.	I have used a few QuarkNet activities in my classroom, and I hope to use more in the future. I have used the histograms and probability activity, the muon decay activity and my students collected data for world wide data day. In the future, I hope to use what I have learned about Python in my classroom. The ultimate goal is to incorporate particle physics and coding activities throughout the entire year. Examples: Histograms and probability using dice, World Wide Data Day
	The dice and understanding half-life.	My intention is how do you intend to incorporate this summer QuarkNet experiences into your classroom by incorporating the simple coding schemes into the curriculum; e.g., when teaching statistics. This year I really like the Probability program that we did Wednesday. I can definitely incorporate this in my math class and the star catalog program for analysis and visualization.	I really like the ISLE curriculum, especially with motion and I like to use some of the materials (linear algebra) from Dr. X. I intend to use the material from the data lab in my class, especially when talking about conservation laws, application of basic science and creating histograms. Learn how to draw space-time diagrams particles, mass of U.S. pennies.
	I've used the penny activity for many years. This year I will add the dice half life activity and try to incorporate the MINERvA mean lifetime experiment.		
	I use the dice activity to teach histograms and probability.		
		I will use the Google Colaboratory Juptyer Notebooks to add a data science exploratory to principles of engineering. Examples: I will use the activities with Histograms and Dice, Mean Lifetime	
	I would like to intro the dice activity as well as the conservation of momentum properties of the muons during proton to proton collisions.		
	First time in QuarkNet, so I have not had the opportunity yet.		

Table C-5

Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #5**

Center	Program Year (Year of Full Survey)	Subsequent Program Year
Center #5	2021	2022
	I will use the half-life pennies this year.	
	Intend to use this WS right away but have done so yet.	
	I used material from the Cosmic Ray activities. My students built their own Cosmic Ray Cloud Chambers.	
	Not used any.	
	Program Year (Year of Full Survey)	
	2022	
	Rolling with Rutherford when I was teaching 8th grade, and the pennies one.	
	Rolling with Rutherford & Measuring the mass of a penny will be most helpful in my engineering classroom.	
	Quark puzzle, Rolling with Rutherford.	
	This is gonna be my first year.	
	I have used the 'Rolling with Rutherford' activity with my physical science class to understand how Rutherford's experiment worked. I have used card games to introduce quarks and how they combine to make particles.	

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of 43 teachers.)

Table C-6
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #6**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #6	2019	2020	2021	2022
	Rolling with Rutherford, and Pennies		I've used them before in just having the students look at real world data and how to analyze it. Examples: Rolling with Rutherford, Shuffling the Particle Deck. These experiences help to give new ideas on how to add in more real-world data and incorporate how science is collaborated around the world.	I intend to incorporate more histograms, go over the standard model and possibly try to do a masterclass this year. Examples: Mass of pennies.
	Quark workbench; Top Quark	I plan on using some of the great ideas for coding implementation from the other teacher participants. Examples: Top Quark, Quark Workbench, Muon Time of Flight, Rolling with Rutherford		
	I want to use the Rutherford activity and the card sort. I have not used them yet. I think these both are activities I think my students can grasp and have a conversation on. (*First year teaching general physics*)			
	Rolling with Rutherford is a great activity and shuffling particles is something I use in the classroom.	I will be implementing the Rolling with Rutherford activity and standard model activity in my classes. As well as the case of the hidden neutrino. Examples: I will use Rolling with Rutherford, case of the hidden neutrino, and standard model 2d/3d.		Penny mass, standard model, uncertainty, NOva neutrino oscillation data.
	Penny mass histogram activity, great for showing measurement variation and identifying peaks in histograms. Easy analogue to particle masses.	Google Science Journal for labs and science fair. Rolling with Rutherford virtual simulator is very convenient. Great way to do the activity if you are pressed for time or going virtual. Examples: Rolling with Rutherford Mass of U.S. Pennies Quark Workbench Case of Hidden Neutrino		Conservation of momentum and energy finding particle mass from LHC etc. data.
	Pennies, Z-mass, Rolling with Rutherford Vectors, conservation, energy, atomic models, ... Examples: Rutherford, topquark, pennies.	Rolling with Rutherford, topquark, pennies. Examples: Penny lab, Rolling with Rutherford, particle mass calculations, Jupyter notebooks.	Pennies, Probability, Rolling with Rutherford, Calculate the mass of a particle. Examples:	I have used data and topics related to: LHC, Conservation, uncertainty, standard model, histograms, data collection. Examples: Penny mass, film canister nickels, NOvA,Phython activities from Data Camp.

Table C-6
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #6**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year
Center #6	2020	2021	2022
	Rolling with Rutherford *(first year with QuarkNet*)		
	Program Year (Year of Full Survey)	Subsequent Program Year	
	2021	2022	
		I plan to adapt penny mass and rolling with Rutherford for middle school and use them as nature of science lessons.	
	Program Year (Year of Full Survey)		
	2022		
	I've used the Mass of Pennies and the Dice activities to introduce data analysis and histograms to my Physics Honors students. Most of my students don't have any prior experience in data analysis, so I like to start the year with helping them learn what we can do with data, how we can manipulate it. I'm excited to introduce a little coding.		

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of a total of 13 teachers.)

Table C-7

Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #7**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #7	2019	2020	2021	2022
	The time of Flight in the Cosmic Ray e-Labs will be very applicable to me and my students.			
	I do not know yet, since I have only barely learned of them, and will have to implement them in the upcoming school year.		Have used materials for conservation laws. I like to use cosmic ray detector as a final comprehensive lab.	Everton data for conversation law; Particle Deck.
		I use Time of Flight from the Cosmic Ray lab for kinematics. I use an intro- duction to the Standard Model with mass and the scientific method. This state does not allow students to provide names for accounts. Everything must be done as a guest.		
	Quark Workbench (annually) - good intro to standard model Rolling with Rutherford (annually) - good intro to particle physics and the atom. Everyone likes this one. Cosmic Ray E Lab (once a year but only for HL Students)	Unit on programming or particle physics unit. Examples: Pennies, Z boson, mass, several I can't recall the names.	I use particle physics for examples in both classical mechanics and modern physics (IB content), Examples: Pennies, Workbench, Heisenberg.	
	I use the histogram activities. Since I also teach Math, it allows me to relate "real-world" examples to the classes. They also provide a macro concept to what experiments measure on the nano scale.			
	Program Year (Year of Full Survey)		Subsequent Program Year	
	2021		2022	
	I have not dug into this resource due to time constraints but as I evolve away from my sports coaching it is my intent to make this happen.		I have implemented many items from the Teacher Institute; Rolling with Rutherford; the discussions on neutrinos. Model behavior of equity in the classroom. Examples: Dice, Histograms and probability, mass of U.S. Pennies, Step Up Women in Physics.	
	I will begin using these activities this year. Looking through some of them, I think the "Making it Around the Curve" activity would be great for AP Physics 2!			
	Program Year (Year of Full Survey)			
	2022			
	I haven't used them yet (early in the year) but I look forward to using the coding tools.			

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of a total of 13 teachers.)

Table C-8
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #8**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #8	2019	2020	2021	2022
	I think Rolling for Rutherford is an easy way for them to understand the experiment through experience and inquiry. I would adapt it to more than just rolling a marble at dice. I would also have them roll a marble at a mystery shape underneath a piece of cardboard and predict what the shape was.	This year, we did more related to online learning because of the circumstances related the pandemic. Having content that can be used virtually, like the QuarkNet e-Labs, will be super useful. Examples: Rolling with Rutherford; The one where you use the detector information.	Next year I will be teaching astronomy in addition to physics, so the cosmology topics and activities that we just happen to focus on this year will be particularly helpful. The new ones I will incorporate are: Mapping the Poles and Particle Transformation.	I was doing Coding Camp 1. The obvious thing from this experience is that I would incorporate is the coding in Python. I will have some introductory coding activities, but ultimately I envision it as a tool that they will be using to help them with labs, homework or projects. I would love to do the muon decays or the leptonic mass coding activities if we get that deep into particle physics.
	I have not had the opportunity to really share with other teachers and, unfortunately, in today's test happy society, it is difficult to fit these topics into class and to convince others to fit them into class.		I plan on using the spectral analysis activities we were working on this past week into my ninth-grade physics course. Examples: Mass of the pennies; What Heisenberg knew; CMS masterclass.	When teaching forces, I have a unit on the fundamental forces of nature where I present and the students explore the standard model and the reason why we have Fermilab and the LHC. The first lab is based on the Millikan experiment using histograms and searching for patterns.
	Rolling with Rutherford, calculating energy and momentum, quark puzzle activity	Conservation laws, the standard model. Examples: Rolling with Rutherford, conservation of energy and momentum, quark model	I plan to use the blackbody radiation activity and the Hubble's law activity as culminating activities for my introductory physics class. Examples: Cosmic microwaves, Hubble's law	
	Top Quark mass	I plan to teach a unit on particle physics using activities from the data portfolio and the cosmic ray detector in my classroom. Examples: Top quark mass, mean lifetime, shuffling the particle deck	I teach particle physics and astrophysics/ cosmology in my Physics course. I will use many of the activities we worked on this week including from the Data Portfolio and new activities developed at JHU. Examples: Top Quark Mass, Hidden Neutrino, Particle Transformations	I teach a unit on quantum physics including particle physics. This includes the standard model and activities from the data activities portfolio. Examples: Top quark mass, Hidden Neutrino, Quark workbench.
	The I2U2 site examples, specifically modern physics puzzle	1. Use of the materials in classroom is great: The subparticle puzzle to start modern physics 2. Masterclass involvement and implementation 3. Standard model discussions, etc. Examples: 1. Quark puzzle/map involving learning color charge, bosons, etc. 2. Penny/coin activity	I have used a significant number of resources involving the QuarkNet workbench, some investigations and more. Overall, my last 10+ years at QuarkNet have really increased my knowledge of certain areas. Examples: The quark workbench, masterclass, J psi (occasionally)	I intend to use my QuarkNet experiences in my own modern physics unit with all physics classes as well as having my Science National Honor Society students to listen to some of the speakers who come to our high school. Examples: The Quark Puzzle, Z mass activities, missing momentum, etc.
	Rolling with Rutherford. It's the most approachable, with a small amount of prep for students.	I am going to consider new physics principles, such as pulsars and microwave telescopes. Example: Rolling with Rutherford	I will use some of the new cosmology lessons with my Astronomy class. I teach them about the Big Bang, black body radiation and the HR diagram. I will use DAP activities as well as conservation tools. Examples: Signal and noise 1, signal and noise 2, and histograms. Rolling with Rutherford	

Table C-8

Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #8**

<table>
<tr><th>Center</th><th>Program Year (Year of Full Survey)</th><th>Subsequent Program Year</th><th>Subsequent Program Year</th></tr>
<tr><td rowspan="8">Center #8</td><td>2020</td><td>2021</td><td>2022</td></tr>
<tr><td>Indicated use of DAP activities but no examples provided.</td><td>We have discussed the standard model and uncertainty while describing atomic theory. Examples: Mass of Pennies, Dice, Histograms, and Probability and Signal and Noise.</td><td></td></tr>
<tr><td>Z Boson - It serves as a great conservation of momentum 2-D lab. I can also have students research particle physics before or after.</td><td></td><td>I have used coding activities to introduce experimental design, resistive forces, and worked with LHC data to show the conservation laws. I will attend World Wide Data Day with my classes and offer Masterclass to my students. I have muon detectors to extend students access to particle physics. Examples: 1. I used my implementation plan for the “Mass of Z boson” and my work at data and coding camp to have students complete the activity in Google Colab. 2. I use “quark workbench” to introduce science practices or the E & M unit.</td></tr>
<tr><td>I love the dice rolling activities. I always use the dice rolling as an intro to the course because it gives them an intro to data but also problem solving. I plan to use all the lessons we looked at and the race discussions we talked about. Everything was extremely useful this year. I really enjoyed it. Examples: Dice rolling, Rutherford, Cosmic ray muons</td><td>I use the data activities portfolio activities pretty often. I also use the coding activities. Examples: Histograms, coin toss, quark workbench.</td><td></td></tr>
<tr><th>Program Year (Year of Full Survey)</th><th colspan="2">Subsequent Program Year</th></tr>
<tr><td>2021</td><td colspan="2">2022</td></tr>
<tr><td>I have used the top quark mass activity the most often, not only as an approachable way to teach detector physics but also as an example of 2D momentum conservation. I use the quark workbench fairly often with my AP class as an introduction to particle physics. With my new conceptual class, I plan to use the rolling with Rutherford activity to show the students how we develop a model for the atom. If I can get kids interested this year, I'd like to use several of the muon activities in there (except for signal and noise #1 because it's terrible, which I am allowed to say because I wrote parts of it and am not happy with it)</td><td colspan="2">QuarkNet shows up pretty much anywhere you want to put it. The top quark activity is a nice fit for not only vectors but also conservation of energy and momentum. Muon detectors are a cool way to test a constant velocity model and get a very surprising value for its speed. The use of histograms can help a 9th grade biology or physical science class understand that pennies have discreet mass. Examples: Top Quark, Pennies, Rolling with Rutherford, Dice Histograms Signal and Noise (once I fix that awful one I wrote). We are all partly-finished sculptures. I hope that QuarkNet continues to shape me into what a good science teacher looks like. .</td></tr>
</table>

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of a total of 15 teachers.)

Table C-8
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #8**

Center	Program Year (Year of Full Survey)
Center #8	2022
	My favorite is the Quark Workbench and Mass of Top Quark activities.
	Rolling with Rutherford, histogram dice roll, and meson/boson activity

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of a total of 15 teachers.)

Table C-9

Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #9**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #9	2019	2020	2021	2022
	None yet, but I am very excited to do so now that I know about them.			
	N/A	I plan to use the idea of probability to in radioactive decay. I am going to implement the Muon detector more in the class curriculum. Examples: dice part 1 and 2, mass of top quark		When teaching particle physics, I use some of the activities. Examples: Rolling with Rutherford, conservation of momentum.
	Rolling with Rutherford and calculating top mass. Good stuff to add to the modern physics unit in describing statistical analysis and how momentum works with quantum mechanics.	I want to use the muon decay lesson with histogram analysis to help students understand error analysis. Examples: Intro to histograms, Error analysis with histograms, Cosmic ray e-lab. Error analysis applications are great for students to understand how physics is done. I would like to have more direct content that uses histograms in my classroom.		
	Many of the Masterclass activities and a few others for measurement, etc.	Big Ideas in Physics - Include various QuarkNet activities to review of Conservation Laws, Measurement, Probability, etc at the beginning of the year. Examples: Used regularly: Mass of Penny, Quark Workbench, Mass of Top Quark, and Rolling with Rutherford	CRMD and Masterclass. Examples: Mass of top quark, Mass of z boson, quark workbench.	I would like to incorporate the following things into my physics classes and individual/small group projects the students would complete during the school year . CRMD and e-Lab, LHC and Neutrino Masterclasses. Examples: STEP UP Everyday Careers in Physics, and Women in Physics; Case of the Missing Neutrino; Mass of Top Quark; Mass of Z; Rolling with Rutherford; Mass of US Pennies; Quark Workbench.
	I've used several but can't think of their exact names.	I have retired from classroom teaching. But I am a private tutor in physics. I do incorporate ideas which I glean from the workshop. With one-on-one interaction with each student, I find this helps. While I no longer use actual labs, I do work with each student on interpretation of data for the lab.		
	My most used is the Top Quark Mass. I integrate this into my conservation of momentum unit.			Shuffling the Particle Deck is something I need to make a point of using. Examples: Rolling with Rutherford, Shuffling the Particle Deck, Top Quark Mass.

Table C-9
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #9**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #9	2019	2020	2021	2022
	Histograms: The Basics & Mass of Pennies *(planned to use)*	The overall plan is to use the Penny Mass to show small quantities before talking about atoms and subatomic particles. Understanding histograms is the other point I need to make with students. Examples: Mass of Pennies & Dice, Histograms, &Probability		
	Rolling with Rutherford and Quark Workbench			
	Quark Workbench, Mass of an Electron, Masterclass,			
	Quark Workbench, Rolling with Rutherford, Top Quark Mass, Z mass	Using a CRMD in my classroom to do research, We have used the data on the Cosmic Ray site to do research without our detector. I do Quark Workbench, Rolling with Rutherford, and Top Quark Mass. Examples: Quark workbench, Rolling With Rutherford, The case of the Hidden Neutrino	Totem activity- to bring out the wave particle duality in Chemistry. Examples: Rolling with Rutherford, Quark workbench, Making Tracks.	Conservation of momentum ties in with the mass of top quark, mass of Z. Will be teaching coding in my Chemistry and physics classes, do use Rolling with Rutherford, a Cosmic Ray muon detector, cosmic ray research, other data activities. Examples: Quark workbench, Rolling with Rutherford, Top Quark Mass, Mass of Z.
	I have used the Quark Workbench most often, but next year I plan to incorporate the Calculate the Z Mass/Top Quark mass activities when teaching vectors.	In the 2019-2020 school year, I had a student work independently on CRMD research. This student graduated, but I have another student scheduled to work independent study during the 2020-2021 school year. Examples: Rolling With Rutherford Quark Workbench Cosmic Ray e-lab.	I plan to use the following activities with my APP2 class. Some will also be used with a general physics class. Totem Data Express CMS Masterclass Human Tricks Mean Lifetime: Dice Rolling With Rutherford.	I have a Cosmic Ray detector in my classroom, and interested students have used the CRMD e-Labs to pursue independent study projects. Hopefully if the dates work out, my General Physics Class will participate in the Masterclass this spring. I am working to improve my AP Physics 2 modern physics unit with some QuarkNet materials this spring. Examples: I have used the QuarkNet Workbench and the Rolling with Rutherford activities previously in my classes. I plan to make use of the Making it Round the Bend (Quantitative) activity this year.
	Mass of Top Quark to use high energy physics concepts to practice vector addition.		Mass of Z to practice vector addition	Nature of Science and experiment. This involves most of the basic concepts of classical and modern physics. Examples: Mass of Z, Top Quark, Around the Bend.

Table C-9

Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #9**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year
Center #9	2020	2021	2022
	I use Indirect Measurement Lab to have students calculate pi.		
	Planning to implement Histograms: The Basics, Rolling with Rutherford in fall 2020.		
	Program Year (Year of Full Survey)		
	2022		
	Rolling with Rutherford		

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of a total of 16 teachers.)

Table C-10

Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #10**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #10	2019	2020	2021	2022
	With the advent of Next-Generation Science Standards (NGSS), school curriculum is in flux--and topics of study have not yet been firmly established at this time.	QuarkNet materials were implemented into my General Physics classes in two areas: 1) study of forces, and 2) applications of Conservation of Energy/ Momentum. The LHC was the primary tool. My current school Physics program has a fairly set lab schedule which makes it challenging.	I integrate the fundamental force carriers/The Standard Model when we introduce the forces unit. E-labs will be integrated on a case-by-case basis depending on the topics. Internet connectivity at my school is unreliable--so any access to websites or the 'Cloud' is on a hit-or-miss basis--which limits access to portals like QuarkNet's DAP	
	I have not used these activities yet (this workshop was my first introduction to them) but I will do so!			
	Program Year (Year of Full Survey)		Subsequent Program Year	Subsequent Program Year
	2020		2021	2022
	I have not been introduced to the Data Activities Portfolio.			
	This is my first BAMA workshop and I'm planning on using what I'm learning here in my teachings of chemistry			
	Mean Lifetime, Part 1: I actually developed a lab that was similar to this and used it for several years in conjunction with our Muon Rest Life Experiment. So I can't comment on the specifics of the version in the Data Portfolio, but the idea of rolling dice to build a histogram of particle lifetimes, and then using this to study mean-life and half-life, and to build conceptual understanding of how distributions of particle lifetimes are very different from lifetimes of people or pets, for example... that's a really valuable exercise for students. Rolling with Rutherford is another good one. Again, I didn't use this exact version, but something similar from an old edition of the Conceptual Physics lab book. Students were guided to develop their own formula to calculate the size of objects they couldn't see using only the statistics from collisions with marbles. Another powerful scientific exercise with direct application to particle physics.			
	have not had a chance yet.			
	Program Year (Year of Full Survey)		Subsequent Program Year	
	2021		2022	
	N/A so far. Maybe in the future as I'm able to explore the activities more.		I'm building a Cloud Chamber for my Astro students to observe subatomic particles. I'm using that to talk cosmic rays and aurorae. I'm using histograms to collate data on labs. I'm hoping to use some of the e-labs but I haven't had a chance to decide on which/how yet. My Astro class is a survey class so I don't get a lot of chances to dive deeply as many of the QuarkNet resources.	
	Program Year (Year of Full Survey)			
	2022			
	Rutherford, Mass of the Higgs			

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Table C-11
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #11**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #11	2019	2020	2021	2022
	I think engaging with the data would be the most helpful to students. They will learn to discover how to interpret data from different perspectives		I plan to use QuarkNet activities at the beginning of the year with careers in physics. I plan to use the particle cards to introduce modern physics to students. We can use the mass of z with the conservation unit. Examples: Mass of pennies, particle cards	
	Mass of the US penny		I plan on getting my cosmic ray detector working and try doing some e-labs and masterclass. Examples: Mass of Pennies Shuffling the particle deck Making tracks 1. I am really excited to use CMS data and the cosmic ray detectors	This year I plan on incorporating histograms and coding into my classes. I plan on using simple coding with matching potion time graphs to have students graph motion. I will be also using the standard model and have a much better background for teaching it. Examples: I have used the shuffling the particle deck and Rolling with Rutherford. I plan on using mean lifetime part 2 this next year for a more original way of doing half life representation.
	Shuffling the Particle Deck - It is a GREAT introduction to the standard model for students who have never seen it or are just learning about it. It also allows them to use pattern recognition and critical thinking to help students gain better understanding. I do like and use several others for similar reasons. I also like the teacher notes and organization of the activities, it makes using them much easier.		District Workshops sharing information, Careers in Physics, Detector Studies, analyzing data, scientific method, Mass of Z, histograms, Current Events. Examples: Mass of Z Particle Cards W2D2	
	I used the data from CMS e-lab where my students do their own research and provide their outcome in form of research paper as a project.		I am going to create lesson plan where students learn about quark particles while they do research about various colliders while searching latest news. Examples: 1. Rolling with Rutherford. 2. Mass of Z 3. Particle cards while printing sets for each group.	Data Activities, Content Knowledge using the Standard Model, STEP Up activities, Professional Development for Teachers. Examples: Plan to use: -Intro to coding -Energy, Momentum, and Mass -Step up -Changing the Culture.
	The activities give real world examples of advance physics concepts that can be used to teach physics fundamentals. CMS data can be used to teach conservation of energy, momentum as well as dimensional analysis application, concepts and even where and why it might be discounted.			

Table C-11
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #11**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #11	2019	2020	2021	2022
	"Mass of US Pennies" makes a great introductory lab exercise. "Calculate Top Quark Mass" is my most frequently used exercise.		I use the Data Activities at various times in the year especially when studying momentum and energy conservation. Examples: Mass of U.S. Pennies, Calculate the Z Mass Calculate the Top Quark Mass. M	Case of the Missing Neutrino Energy, Momentum, and Mass Shuffling the Particle Deck. Examples: Mass of U.S. Pennies Shuffling thee Particle Deck Intro to Coding Using Jupyter Calculate the Top Quark Mass The Case of the Hidden Neutrino
	I teach both biology and physics but was primarily a biology teacher when I first learned about the e-lab. Having taught a year of IB physics I see a lot of opportunities to integrate the data activities in the classroom. In particular, the lessons that encourage students to derive relationships using graphical analysis prior to teaching the specific laws. This also provides a great resource for students looking to incorporate accessible and professional databases into their senior research projects in IB physics.			
	So far, I have not had time to do a complete activity, but I have pulled out portions of LIGO e-Lab, Quark Workbench and CMS Data Express.	I teach the conservation laws as part of the required state curriculum. I give my students a Standard Model lecture during the 4th quarter each year and I have them explore the Particle Adventure online. Examples: I used Rolling for Rutherford when I taught Chemistry. I would like to use Mass of Top Quark.	I plan to use the Step Up Careers Activity and Masterclass prep: Standard Model, Conservation Laws, Mass of Z activity. I have also taught about Gravitational Waves. Examples: Mass of Pennies, Particle Cards, Mass of Z Calculation.	Have done Rolling with Rutherford, Masterclass and Standard Model presentation. Plan to do Shuffling the Particle Deck, and Coding Activities. Examples: Use Rolling with Rutherford already, Plan to use Shuffling the Particle Deck and more STEP UP activities like Careers in Physics.
	Rolling with Rutherford and the Penny Lab			Personally I am using the coding skills I have gained to get students into coding with auxiliary lessons and tasks. I am currently being used as a biology teacher, so I have not been able to implement many of the activities in my classroom yet. However, I am able to provide better insight to students into what people in physics fields do.

Table C-11

Self-reported Use of Data Activities Portfolio Activities: Based on Reponses from the Full Survey and then Responses from the Update Survey in Subsequent Years **Center #11**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #11	2019	2020	2021	2022
	I have utilized several of the Data Analysis activities contained in the portfolio within my physics classroom. Rolling with Rutherford is an activity that provides students with the opportunity to use data they have generated for themselves, take measurements, and perform relevant calculations. The activity also provides students with the opportunity to learn firsthand how Rutherford made his influential discovery which resulted in our modern view of the composition of the atom.			
	Mass of the Penny, Quark Workbench, Shuffling the Deck, Rolling with Rutherford, Mass of Top Quark	I intend to use coding in the jupyter notebooks for both my engineering classes as well as my physics classes as a way to deal with large data sets as well as some basic coding skills. Examples: Penny Mass, Quark Workbench, Dice Histograms		I will be using short coding activities throughout my courses. I use data activities as year starters (Shuffling the Particle Deck and Quark Workbench). I also use particle physics and momentum conservation. Examples: Shuffling the Particle Deck, Quark Workbench, Calculating the Z Mass.

Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year
2020	2021	2022
I used the Rutherford model of finding subatomic particles in an atom and implemented Bohr model too.		Coding activities, neutrino activities etc. implemented python programing to calculate kinetics rate.

Program Year (Year of Full Survey)	Subsequent Program Year
2021	2022
Rolling with Rutherford and mass of pennies.	I have incorporated Rolling with Rutherford with my chemistry students, particle deck, mean ½ life. Examples: Rolling with Rutherford, half life, particle deck.
Haven't had a class to use it in yet.	Will be using Shuffling the Particle Deck, Particle Transformation, Calculate the Top Quark and Mapping Poles this year. The opportunity to work with other teachers in great.
Just introduced to them in this workshop so have not had a chance to implement.	
Input data into spreadsheet for calculation and graphing.	

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Table C-12
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #12**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Year
Center #12	2019	2020	2021	2022
		e-Labs, especially for remote students. Did not use because of Covid	Puzzles for sorting python programming (puzzles for sorting and programming for skills)	
	Not a chance yet.			
	Dice/histograms *(plan to use)*			
	New to program			
	I have not had a chance to apply these in the classroom but look forward to looking through all the activities and seeing what I can do with them.			
	The activities related to histograms will have great use in my lab class. I plan to use them early this year. Also, I am planning to use the activities related to E&M. *(first year in QuarkNet)*			
		I will incorporate materials periodically throughout the year when time permits. Examples: Shuffling the Particle Deck, Dice, Histograms & Probability and QuarkNet: Changing the Culture		
			I plan on using the coding information we used this week to have students create motion graphs. Dice, Histograms, and Probability Rolling with Rutherford I've used both of these to discuss how data is collected, shared, and how to interpret it.	Collection and analysis of data is critical to my students, especially after COVID, so many activities are useful. Example: Mass of Pennies, and Rolling with Rutherford.
	CMS			
	I use data camp activities at the beginning of the year and after the AP testing. the dice histogram which I make use of for a number of things like data analysis and even answering that age old student lab question of how many data points do I need, to which I answer you need as many as you need.			
	Histogram Rolling with Rutherford and conservation	I am planning on using the Step Up information on careers and diversity in the classroom. I am going to have students use the cosmic ray detector for gathering data and analysis. I cannot remember which ones I have used.	I have an advisory period every day for students to learn anything and relearn. I am planning on implementing this during the advisory period as learn some cutting edge science. Examples: mass of a penny; momentum, shuffling the particle deck, coding, Cosmic Ray detector	I am planning on using these activities to explain graphing and understanding data. I am planning on using the cosmic ray information, Rolling with Rutherford, and masterclass information. Also, comparing the interaction for conservation of momentum and energy. Examples: Rolling with Rutherford, Shuffling the Particle Deck, missing neutron.

Table C-12
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #12**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Year
Center #12	2019	2020	2021	2022
	Cosmic Ray Data, Particle Analysis, and LHC lab experiments			

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year
Center #12	2020	2021	2022
	Not yet, but am looking forward to it.		
	Provides context and enrichment to my curriculum.	Classifying particles, intro to SM. Examples: Rolling with Rutherford, Quark Workbench.	The Half Life activity will have many uses in my classroom. In Algebra, the strands of data of representation, probability, and exponential decay. In earth science, the idea of half-life as a measure of geographic time, as well as radioactive decay with implications for long term nuclear waste storage. Examples: Too early to tell at this time.
		As a 6th grade teacher, I will be able to use of couple of the activities such as Rolling with Rutherford as I introduce students to the concept of the atom for the first time. Examples: Mass of US Pennies, Rolling with Rutherford, Dice, Histogram and Probability.	I will be using Rolling with Rutherford when introducing the nature of atoms. Though I have taught high school physics in the past, I am currently teaching 6th grade science. I will implement many of the philosophical strategies even if I don't use any of these specific activities. Since I am teaching 6th grade, these are beyond the scope of my students.
	Rolling with Rutherford and Making it Round the Bend have been relevant to state standards and easily worked into the time allotted to teach the prescribed curriculum.		

Center	Program Year (Year of Full Survey)	Subsequent Program Year
Center #12	2021	2022
	Coding Program	I will be incorporating this information with conservation and momentum. I plan to use Mass of Pennies, Dice Histograms & Probability, Shuffling the Particle Deck, Rolling with Rutherford.
	Have not used content.	
	I will use the probabilities program/activity for my classes.	Due to my teaching assignment, I have not used (teaching forensic science not physics/astronomy or earth and space). Examples Rolling with Rutherford can be adapted to teaching bias. Having students aim at the objects will skew the calculated size of the objects in a way that can approximate bias in law environment.

Center	Program Year (Year of Full Survey)
Center #12	2022
	I like using the Penny lab for data collection and analysis.

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of a total of 24 teachers.)

Table C-13
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #13**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #13	2019	2020	2021	2022
			I will use the case of the missing neutrinos to show how particles are discovered from indirect evidence as well as the conservation of momentum. Examples: Shuffling the particle deck, the case of the missing neutrinos	I intend to incorporate the mapping of the poles activity as well as the data analysis techniques used in the workshop. Examples: Mapping of the Poles.
		I'm not going to have enough time this year to cover all the topics that I usually do so I'm going to take that as an opportunity to try more of the activities in the QuarkNet experience. Examples: Particle Cards, Rutherford Marble Activity, BAMC.		
	Rolling with Rutherford			
	Rolling with Rutherford *(planned)*	I used the Cosmic Ray detector as an extension two years ago and have implemented Rolling with Rutherford and ideas of collecting whole-class data, histogram use, and sprinkling Standard Model facts. Examples: I don't plan on using them. They are too complex, and we are currently overwhelmed with lack of tech.	Conservation of momentum, standard model vocabulary, STEP-UP resources. Examples: Shuffling of Particle deck, the case of the missing neutrino	
	Indicated that (s)he used DAP activities but gave no examples.	I have had a group of students work with my cosmic ray detector. I have also taken those students to do a masterclass. I have done the rolling with Rutherford activity with my students. Examples: Rolling with Rutherford, Quark Workbench, Calculate the Z Mass.	I have done quite a few activities on the QuarkNet website. Every year I do the quark workbench. I have done Rolling with Rutherford and conservation of momentum and other as well in the past. Examples: Quark workbench, rolling with Rutherford, dice histograms and probability	I will use data from CERN to talk about particle physics. I would like to try to use the activities from QuarkNet for circular motion and conservation of energy/ momentum. I will also use quark workbench. Examples: Quark Workbench, Rolling with Rutherford, STEP UP, Cosmic Ray.
	Rolling with Rutherford as well as the Hadron workbench.		Cosmic Ray Detector, Masterclass, more particle physics especially at the beginning of the year. Examples: Case of the missing neutrino, particle deck, hadron workbench, cosmic ray detector	

Table C-13
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #13**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year
Center #13	2020	2021	2022
	QuarkNet Workbench *(planned)* - Invaluable in letting students "discover" many aspects of The Standard Model on their own, and in getting them invested in exploring the topic further. I plan to use several others this year, too!	The summer workshop helped guide me toward asking questions to help students think through particle physics research procedures. (The lead modelled this extremely well.) Also, it was great to learn about ways that "standard topics" like momentum could be taught via particle physics, all the while creating a sense of wonder in the process. Examples: Shuffling the Particle, Workbench 2D, The Case of the Missing Neutrino.	This program definitely clarified several details which I was fuzzy or about which I was incorrect in my understanding. I have used Google forms to collect labs, but I have never used them to create classroom/ daily collections of data, which I really liked. One classmate suggested posting student reports in the hallway, which creates an authentic audience for student work (and likely will increase the effort students put into their posters). Examples: Quark Workbench 2D, CMS Masterclass J/PSIs (for those who participated) Cosmic Ray e-Lab.
	I honestly did not know these activities were openly available on the site until this workshop. I will look through them and use some this coming year.		
	Program Year (Year of Full Survey)	Subsequent Program Year	
	2021	2022	
		I like using the LHC examples to show the real-life applications of conservation laws. I also like how the Data Activities Portfolio Activities are tied to standards. Examples: Ill use Dice, Histograms & Probability, Mass of U.S. Pennies, and Shuffling the Particle Deck.	
	I have not used any yet but will be soon.	I totally plan on using Shuffling the Particle Deck, with my class as an introduction to the particle physics of the standard model. Examples: Shuffling the Particle Deck, Rolling with Rutherford, mass of penny.	
	Rolling with Rutherford		
	Program Year (Year of Full Survey)		
	2022		
	Rolling with Rutherford, the Quark Workbench		
	I haven't had a chance to use the DAP yet, but expect to use a version of the Rolling with Rutherford one next year.		

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of a total of 16 teachers.)

Table C-14
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #14**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year
Center #14	2019	2020	2021
	Not as yet, but plan to when school resumes. Provides in-depth information. Provides more "college ready" physics applications and topics of study, other than the traditional kinematics.		
	Have not had a chance to implement this into my teaching. I think after this year if I can use this in my classroom I would recommend it, but I would like to see the material have more of a storyline in how one thing leads to another.		
	None yet - just took the class. It's an area I haven't studied before, so it's useful from that perspective.		
	I have used Rolling with Rutherford to show the idea of indirect measurement and histograms. The materials are well thought out and often use data analysis techniques that the students are are not familiar with.		
	I have used Rolling with Rutherford (to practice with histograms) and the Top Quark activity.		
	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year
	2020	2021	2022
	I'm new to QuarkNet and haven't had a chance yet, If it's as good as what I've seen so far in the Workshop, then it's going to be useful both for me and for my colleagues.		
	I plan to use this year. I think this can be very helpful to teachers to help motivate the students and excite them more about learning physics.		
	I have yet to have had the opportunity to use these activities in my classroom, but perhaps I will this Fall. The portfolio has unique activities that may be difficult to find/create and will likely engage students in a manner that is unique and intriguing.		
	N/A I just haven't tried it yet due to time constraints in my curriculum.		
			Currently using Python activities learned in coding camp, data activities from QuarkNet, World Wide Data Day. Plan to use the cosmic ray detector and explore the idea of doing a Masterclass. I incorporate materials into the units, coding for lab data analysis, coding to explore physics concepts (kinematics, momentum, etc.) Examples:

Table C-14

Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #14**

Center #14	Program Year (Year of Full Survey)	Subsequent Program Year
	2021	2022
		After attending a workshop at another center and Data Camp this year, I plan to bring students to a Masterclass and have and work with them on e-Labs. I also want to implement one of the advanced activities in my class, the mass of the top quarks activity. I plan for them to understand better and work more on conservation laws and Einstein's formula. Even though the curriculum does not have Modern Physics, I plan to implement the standard model. Examples: The mass of top quarks, Rolling with Rutherford.
		I use some of the particle games in the activities in my physics class last year and they really enjoyed them. Examples: We use the marble demonstration to describe the Rutherford experiment.
	Program Year (Year of Full Survey)	
	2022	
	Round the bend.	

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program years. Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of a total of 18 teachers.)

Table C-15
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #15**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #15	2019	2020	2021	2022
	Hard to tell there is so much there and I have so little time to do anything after 1870.			Python training, individual mentor visits for trouble shooting hardware. Rolling with Rutherford.
	I use the portfolios for students to use as tutorials to learn about possible data collection experiments.		I use it as an independent study class to study cosmic rays. Examples: Depends on where the student questions go. Sometimes they fit and other times not so much.	
	I often use the penny histogram activity in my regular level class because it gives students a way to think about data representation. It also forces them to attempt to draw conclusions from their results. I have also, in more advanced settings such as my research club, used the particle playing cards and quark puzzles to help students understand the particles we discuss.			
	Histograms (penny, dice, Rolling with Rutherford), particle cards of standard model, cosmic ray e-Lab, quark workbench, mean lifetime, top quark.			

Center	Program Year (Year of Full Survey)	Subsequent Program Year
Center #15	2021	2022
	Rolling with Rutherford, golden flies, Mass of pennies, histograms.	We do a unit on modern physics. We will use the classroom cosmic ray detector as an introduction into subatomic particle physics, getting to an understanding of the Standard Model.
	School has not started yet.	
	Rutherford	
	I have not yet but plan to this upcoming fall.	

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of a total of 10 teachers.)

Table C-16
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #16**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year
Center #16	2019	2020	2021
	No		
	I have tried to use the muon detectors and do cosmic ray labs with mixed results over the years.		
	I no longer teach the atomic structure aspect of physical science.		

Center	Program Year (Year of Full Survey)	Subsequent Program Year
Center #16	2021	2022
	I have used modified versions taken from the listed activities.	
	Mass of a Penny helps to show practices in graphing. Rolling with Rutherford - Interesting to use data to estimate size of objects without actually taking a measurement.	
	I have used the Dice Decay and the Cosmic Ray e-labs. The basic decay labs were quite useful. I found the cosmic ray lab challenging mostly because of the hardware interface. We wasted most of our available time attempting to get the detectors to work and trigger rather than looking at what it all meant.	
	I have not had the opportunity to use them yet as I have only taught for one year.	
		I'm trying to understand the standard model enough that I can incorporate it into some lessons in my 9th grade science and physics classes. Examples: I don't know the names. I am so sorry. I looked at them 60+ days ago and don't plan on writing my lessons until after January. It's far from my mind at the moment!
	Rolling with Rutherford is great for atomic structure.	
	I don't teach physics, and a lot of the activities from previous courses were too in depth for my students. However, I am incorporating Python code from this coding camp.	

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of a total of 14 teachers.)

Table C-17
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #17**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #17	2019	2020	2021	2022
	Calculating the mass of the Z boson is probably the most used activity. It is easy to incorporate into the momentum unit. I've also used the quark workbench, rolling with Rutherford, and a few others.	I began by incorporating individual lessons into my regular and advanced physics classes (data activities mainly). I also have had student interest in a "particle physics group." Examples: Quark Workbench Rolling with Rutherford, Making it 'Round the Bend	Preparing an Introduction of Particle Physics based on Data Activities Portfolio activities.	I have consistently incorporated QuarkNet materials in my classroom. I have used about 10-12 of the activities from the data activities portfolio with my students. Beyond the curriculum I have learned several teaching methods by working with QuarkNet staff. From how to create exceptional group work and cooperation to how to engage students and catch their interest. I have consistently been bettered through my interactions with QuarkNet staff and other teachers. Examples: Making it Round the Bend, Quark Workbench, Rolling with Rutherford.
	Penny Histograms, Rolling for Rutherford, That's How We Roll (Dice Histograms) - good hands on ways to show how Histogram data is useful		Rolling with Rutherford	
	Quark Workbench and others. These are valuable resources because I know that have been vetted for accuracy and correct. They also have wonderful directions and teacher notes.	I'm interested in doing a masterclass now that I'm teaching upper-level science courses. I also intend to continue using the lesson examples in the resources that are in QuarkNet. Examples: Quark Workbench Rolling with Rutherford.		I have used a lot of the content of in various ways. Primarily with introducing the basic ideas of particle physics with students and then giving them resources to continue exploration on their own. I also have the resources for activities in various ways to have students collaborate in full blown lessons focused on particle physics. Examples: Quark Workbench, Rolling with Rutherford.
	Rolling for Rutherford Pennies Dice Histogram	Conservation of Momentum, Vector Addition - The Case of the Hidden Neutrino and The Mass of the Top Quark Calculate the Z-Mass. The use of Real Data and 'discovery' is what really engages the students. They like to work with data they can read about with real applications. Examples: Quark Workbench 2D/3D Z-Mass Top Quark Hidden Neutrino		
	Quark Work Bench, Mass of US Pennies, Cosmic Rays and the Sun, Cosmic Ray e-Lab	I try to sprinkle in as many activities as I can in my various classes. I also lead the Particle Physics Club at our school. I do plan on adding the Careers in Physics activity this year as well as. Examples: -Step Up: Careers in Physics -Quark Workbench -Rolling with Rutherford.		Quark Workbench, Histograms: The Basics. QuarkNet Changing the Culture, Rolling with Rutherford, Careers in Physics, CMS e-Lab.

Table C-17
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #17**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #17	2019	2020	2021	2022
	Masses of a Penny QuarkNet Workbench Dice, Histogram, & Probability Calculate the Mass of the Z CMS Masterclass Cosmic Ray e-Lab	Using the e-lab the deal with conservation momentum and vector analysis; along with using the Cosmic Ray detector with students to analyze data and have then choose what they want to explore. Examples: Mass of U.S. Penny, Quark Workbench 2D/3D, Histograms: The Basics, Calculate the Z Mass.		
	Rolling w/Rutherford, Top Quark, Cosmic Ray Experiments of Time of Flight and Lifetime	Introduction content - Use Rolling with Rutherford. Planning to use Careers in Physics and Changing the Culture this coming year as well. End of intro kinematics/constant velocity use Cosmic Rays. Examples: Rolling with Rutherford Top Quark Speed of Cosmic Ray Muons	Rolling with Rutherford for data collection (and achieving an indirect measurement result), Time of Flight cosmic ray experiment for constant velocity, Muon lifetime cosmic ray experiment for relativity. Examples: Rolling with Rutherford, Making Round the Bend, Top Quark.	I use many QuarkNet activities for data analysis. Showing how data can be collected, working with (in spreadsheets and python notebooks) and with outcome results presented. Also, when they tie in to the current topic being covered (time of flight of cosmic ray muons in the constant velocity unit as an example). I try to use QuarkNet activities as I’m able to. Examples: Python notebooks, cosmic ray detector time of flight and muon lifetime experiments, top quark vector analysis, Rolling with Rutherford, Making it Round the Bend.
	Rolling with Rutherford	Use CMS & Cosmic Ray e-Labs, Masterclass, W2D2, Data Activities Portfolio, and neutrinos extensively in Particle Physics Research Hybrid course. Use these resources to a small degree in AP Physics 1. Examples: Mass of U.S. Pennies, Quark Workbench 2D/3D, QuarkNet: Changing the Culture, Rolling with Rutherford	e-Labs for several activities; to explore conservation laws and standard model; use CMS detectors and CMS data. Examples: Rolling with Rutherford Calculating the Z Mass Cosmic Ray e-Lab.	Cosmic Ray detector studies, Cosmic Ray e-Lab, CMS e-Lab. All used in physics classes. Examples: Rolling with Rutherford, Calculate the Z Mass, Cosmic Ray e-Lab. Examples: Rolling with Rutherford, Calculate the Z Mass, Cosmic Ray e-Lab.

Table C-17

Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #17**

Center #17	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year
	2020	2021	2022
	Rolling with Rutherford, CMS e-Lab. I plan on using the Neutrino oscillation material.		
	Women in Physics - Career Profiles, and follow up data slides	Using Python notebooks to analyze large data sets and to perform numerical modeling of phenomena. Examples: Dice, Histograms, Probabilities Histograms: The Basics QuarkNet STEP UP: Careers in Physics	Last month I used the Standard Model cards, and the Quark Workbench lessons with my physics class, and I plan to do so even earlier next year. I hope to get rolling on the CRD earlier in the year as well – not sure if we'll run a club, or I'll just get some enterprising students to take care of it during class. Examples: Standard Model Card Sort, Quark Workbench, STEP UP lessons.
		Using Python notebooks to analyze large data sets and to perform numerical modeling of phenomena. Examples: Dice, Histograms; Histograms: The Basics, QuarkNet STEP UP: Careers in Physics.	

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of a total of 13 teachers.)

Table C-18
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: Center **#18**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #18	2019	2020	2021	2022
	WILL USE, since this is my first experience with them... Penny Histogram, Spectroscopy (which I have used for years but emphasized identifying chemicals, not particle differences)			
	N/A - just learned about them this summer.	In my middle school "Super Science" elective class, I did use several of the introductory particle physics lessons from summer 2019. Mostly introduction to the standard model. Examples: QuarkNet Workbench, Shuffling the Particle Deck, Rolling with Rutherford.		
	Program Year (Year of Full Survey)		Program Year (Year of Full Survey)	
	2021		2022	
	I will use the method of collecting data and making a table with post its--I'm sure it will come up, I like how intuitive it is and visual too.		Use of more/real data in the lessons (including histograms and analysis), some of the activities with students, stay in contact with other science teachers to share ideas/experiments arrange a presentation with real scientists or a virtual lab tour. Examples: Dice, Histograms, and Probability Histograms: Uncertainty, STEP-UP Careers in Physics.	
	I do not know what the Data Activities Portfolio is, but I would be interested in finding out. At the professional development that I attended I gained great ideas for teaching physics content in the classroom and increased my own particle physics pedagogy.			
	The marble/Probability activity.			
	Marbles			
	None – too advanced		I teach 6th graders so cognitively; these topics are difficult to work with for this level of student. However, I will use Rolling with Rutherford and card sorting activity as inquiry activities. Examples: Mass of U.S. Pennies, Shuffling the Particle Deck, Histograms, Making Tracks, Rolling with Rutherford, Mean Lifetime Decay Part 1.	
	Program Year (Year of Full Survey)			
	2022			
	Rolling with Rutherford			
	I have used the Rolling with Rutherford activity in my chemistry class. It was a fun and insightful activity to do with my students and I can see doing it more.			
	Histogram creation and bin sizing Use of spreadsheets for analyzing data sets			
	Particle shuffle, Rolling Rutherford, Step Up, and Z-boson activities.			
	I plan on using the penny mass activity and Rolling with Rutherford. I'll let you know in the future which one ends up being used more and how.			
	Rolling with Rutherford for model design and experimental set up.			
	I think I will use Mass of US Penny, Step-Up program, Rolling with Rutherford			
	Not yet applicable			

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of a total of 19 teachers.)

Table C-19
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years**: Center #19**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #19	2019	2020	2021	2022
		I have used some of the e-Labs and data from the LHC in my particle physics unit in my high school physics class. I haven't used them as of yet, since our school has moved to virtual classes and I have not yet decided.		
	No experience with them.			
	I have not reviewed those materials yet.	My Physics II class will be collecting data with the Classroom Cosmic Ray Detector and uploading the data. They may also be doing an e-lab or analyzing some LHC data. Examples: None yet - this is the first year for Physics II.	Physics II students will use the classroom cosmic ray detector to study cosmic ray events, and indirectly relativity and the standard model. I have not used the activities. Most of our time in Physics I is classical physics and thus we don't have a lot of time to get to modern/particle physics.	We do a unit on modern physics. We will use the classroom cosmic ray detector as an introduction into subatomic particle physics, getting to an understanding of the Standard Model. I was planning to do several activities in the past three years, but because of schedule disruptions due to COVID, we ran out of time and I had to drop these activities.
	Rolling for Rutherford (I actually teach chemistry)	Teaching freshman biology how to use python to make simple graphs.	N/A because I am not a physics teacher.	
	I use the Particle Adventure Internet site with my ICP students. I have also used the "Mass of US Pennies" lab, and participated with Rolling for Rutherford at some of our public science outreach events.	I plan to use PhyPhot with my physics students. Examples: Particle Zoo, Exoplanet Masterclass, labs such as mass of pennies	I have used a cloud chamber and muon detector with my students. I have also used the Particle Adventure site with students. Examples: Particle Adventure, Exoplanet Masterclass	I have used a cosmic ray detector and cloud chamber with my students. I have also participated in an exoplanet masterclass and world wide data day. I have used particle adventure site with my students.
	Penny Mass Rolling with Rutherford			
	Rolling with Rutherford	Analyzing J/Psi data with students. Example: J/Psi Data		
	Mass of the Top			
	I used the mass of a penny activity and the top-Quark activity both after going to Data camp last year.		I use Cosmic Rays and the LHC talk about uncertainty and statistics. Examples: Mass of Pennies, Dice, Histogram, and Rolling with Rutherford.	I talk to students about our ability to create matter at the LHC when we talk about conservation of matter. I also include that there are more subatomic particles than Protons, Neutrons, and electrons. One of the biggest things I include is the nature of science research. Examples: I use Penny Mass and Rolling with Rutherford.

Table C-19
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #19**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #19	2019	2020	2021	2022
	Rolling for Rutherford - in Integrated Chemistry/Physics to introduce models of the atom. I use histograms (and a Masterclass) in my Advanced Research Class. Showing uncertainty and data spikes and all the wonderful things you can see with this activity really helps students understand large groups of data.	I have done Masterclasses (2 different ones) after school for interested students, had an Advanced Research class student work with me over the summer doing QN research at Notre Dame, done a STEP UP program. Examples: Mass of Pennies, Rolling with Rutherford, Dice Histograms, STEP Up, CMS Masterclass, Atlas Masterclass.	I have a masterclass after school in the spring, add in some of the build up for it in the energy/momentum unit, and use QN activities like Rolling for Rutherford. Examples: Rolling with Rutherford, Mass of US Pennies, Calculate the Z mass.	Conservation laws and momentum units in AP Physics we helped by particle physics modeling. Examples: Rolling with Rutherford, calculating the z mass, cams data express, neutrino masterclass.
	Quark Puzzle, rolling w/Rutherford, top quark, z-mass, penny mass.	I use the Cosmic Ray muon lifetime lab using the detectors in my classroom, attend masterclasses, several data activities including dice, quark puzzle, rolling with Rutherford, top quark, z-mass. Examples: Dice and histograms, quark puzzle, top quark, z-mass, rolling with Rutherford.	I use QuarkNet activities from the Activity Portfolio, specifically: Z-Mass(Conservation of Momentum, Energy, Mass and Charge), D-Zero(Conservation of Momentum, Energy. Examples: Quark Puzzle Z-Mass D-Zero Rolling w/Rutherford Dice Half-Life.	I use my cosmic ray detector to introduce the standard model, time dilation, and exponential decay. I use the following QuarkNet activities from the data activities portfolio to reinforce concepts of momentum and energy and the standard model; z-mass; Rolling with Rutherford, quark puzzle. I also participate in World Wide Data Day, Cosmic Week, and international Masterclass. I have recently begun incorporating coding activities using CERN open data and Space-X rocket data. Examples: Rolling with Rutherford, Quark Puzzle, Z Mass, Mean Lifetime 1 and 2.
	Collision exercises and the hadron cards			
	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	
	2020	2021	2022	
	I plan on using these activities more. With going virtual, we have to be more creative.	When covering the conservation laws, I bring up LHC and how it applies to modern day physics discoveries. Examples: CMS Masterclass, Energy Momentum and Mass, Rolling with Rutherford.	The conservation laws such as Conservation of Momentum and Energy. I use these laws to explain how some of the subatomic physics are observed. Examples: I have not had time to use these activities in my classroom. I am hoping to make time this year to incorporate more of these activities.	

Table C-19

Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #19**

Center #19	Program Year (Year of Full Survey)	Subsequent Program Year
	2021	2022
		Students learn about the elementary particles form in the early universe. Examples: We cover a full semester every quarter, so there is not sufficient time.
	Program Year (Year of Full Survey)	
	2022	
	Rutherford experiment is very helpful to study the way of abysis.	
	Penny activity Rolling with Rutherford Mass/Energy activity Z Mass etc.	
	Data gathering, data comparisons, and identifying various variables based on the data collected.	

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of a total of 19 teachers.)

Table C-20

Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #20**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #20	2019	2020	2021	2022
	I have really only pulled information to help/work with individual students.			
	I have not used the Data Activities yet, but would like to learn more about how to integrate them into my classroom.			
				I will definitely bring students to the Masterclass. I like the Polar Bear activity and the Rolling with Rutherford activity.
	None	I use many QuarkNet activities already in my classroom. I will certainly use the Step Up activities this coming year. Examples: Card Game, Rolling with Rutherford, Calculating z particles		
	Dice, Histograms, and Probability Mass of US Pennies			
	I have taken students to a master class at Oklahoma state university	I plan on using Step Up plans as a new item to work with as we move forward. I have used other lessons for years from the QuarkNet program.		
	Quark workbench, Rolling with Rutherford, Isotopes of Pentium, various games with dice	Use cosmic ray detector as example of real time data gathering and large data sets. Used top quark mass to introduce particle accelerator and reinforce vectors as an analysis tool. Use quark work. Examples: Quark workbench Penny mass Top Quark mass		
	Quark workbench, particle deck, calculating top quark mass, particle adventure website, z-path, phyching out the system			
	I have used these for chemistry not physics class. I think that QuarkNet needs to expand their thinking about just wanting physics teachers. It has helped me go deeper into my lessons with chemistry students when talking about the atom. Before, it was so superficial. I have a better understanding and therefore I think my kids will too. This can be the first step toward a better physics class that students take the following year. I have used the marbles and dice, mass of pennies, and particle deck.			

Table C-20

Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #20**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #20	2019	2020	2021	2022
	Quark Workbench Determining the mass of the top quark Determining the mass of the Z boson Deck of Particle Cards Rolling with Rutherford			I use the quark workbench, particle physics deck, Rolling with Rutherford experiment, particle adventure website, and determining the mass of the Z boson, and top quark activities. I have gone to Masterclasses in the spring and I plan to go again. I also have done World Wide Data Day with students in the fall, and I was able to go to Fermilab for Data Camp. From this year I would like to begin introducing some coding to my students, but as of now my district has refused to allow Google Colab to be used on the district computers. So, I need to iron out issues with the district before I know what I will be able to do in the future in the classroom. Examples: I use the quark workbench, particle physics deck, Rutherford experiment, particle adventure website, and determining the mass of the Z boson and top quark activities. I have gone to masterclasses in the spring, and I plan to go again. I also have done the day of data with students in the fall, and I was able to go to Fermilab for the data camp. From this year I would like to begin introducing some coding to my students, but as of now my district has refused to allow Google Colab to be used on the district computers. So, I need to iron out issues with the district before I know what I will be able to do in the future in the classroom.
	Program Year (Year of Full Survey)			
	2020			
	Rolling with Rutherford			
	Rolling with Rutherford.			
	Data activities: Histograms, Quark WorkBench 2D/3D. Rolling with Rutherford.			
	I have used the Cosmic Ray activities in a school club setting			
	Program Year (Year of Full Survey)			
	2022			
	I plan to use the panda game and the Rutherford boards with my 5th grade science classes this year			

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of a total of 17 teachers.)

Table C-21
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #21**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #21	2019	2020	2021	2022
	Compared a cosmic ray received in the different climate zone.			
	In astronomy theme			
	Rolling with Rutherford			
	This year we used the muon detector with my students.		Explaining conservation and atomic particulars. Examples: Rolling with Rutherford and detectors	
	Conference information		Adrons and mesons puzzles; Rolling with Rutherford	
	Is part of my conference in atomic theory			
	Rolling with Rutherford			
	Rolling with Rutherford as an example to make histograms	He incorporado ejemplos de fisica de particulas en temas como conservacion de momentum, energia y fuerzas fundamentales. Pienso crear mas ejemplos y ejercicios utilizando codigos de python que aprendi Examples: He utilizado Rolling with Rutherford y Histogram the basics. Planifico utilizar otros.		
	Quark Puzzle	I will incorporate the activity of Particle Conservation (DAP) in the discussion of conservation and energy. Examples: A year ago I was able to identify a group of students interested in particle physics.		
	Presentation on atomic theory and Rutherford with Rutherford	Actualmente ofrezco el curso de Química y el la unidad 2 de mi curso incorporo todo lo aprendido en QuarkNet cuando ofrezco el tema de la Estructura Atómica, entonces actualizo mi curso integrado. Examples: La actividad de Roderford y programa de rayos cósmicos	I plan to incorporate the theme of Cosmic Rays in a Scientific fair project. Examples: Rolling with Rutherford, and cosmic ray information	He incorporado ejemplos de fisica de particulas en temas como conservacion de momentum, energia y fuerzas fundamentales. Pienso crear mas ejemplos y ejercicios utilizando codigos de python que aprendi. Examples: 1. Actividad de Rutherford. 2. Experimento de MINVERvA.
	Rolling with Rutherford, puzzle and card game	I incorporate QuarkNet informacion en todo el curso de Fisica. Exampes: Histograms, Rolling with Rutherford, jpsi decay, Mass of penny and STEP UP presentation.	Use QuarkNet for energy and momentum and nuclear fission. Examples: Rolling with Rutherford; making histograms.	All, I use all information Rolling with Rutherford, Coding, STEP UP.

Table C-21
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #21**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #21	2020	2020	2021	2022
	Dice histogram and probabilities			
	Transformaciones de particulas			
	First year in QuarkNet. Plan to use activities.	Conservation of momentum, standard model vocabulary, STEP-UP resources. Examples: Shuffling of Particle deck, the case of the missing neutrino		

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of a total of 16 teachers.)

Table C-22
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years**: Center #22**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year
Center #22	2019	2020	2021
	This will be my first year to implement activities.	I would like to support and assist teachers during the school year. I became a Dean of Students after the workshop. My teachers were not exposed to the program last year; assist teacher during this process. I want to use this program to encourage students to review and or select career paths in science.	Muon Absorption Rates. Examples: Coding CMS Data Analysis Python/Jupyter notebooks
	We researched the correlation between lightning strikes and Muon count.		
	My students have participated in International Muon Week. They completed most of the steps of the online map; however, we ran out of time and could not complete the entire activity. I had been developing a rigorous and developmentally-appropriate curriculum, using materials from QuarkNet, CERN, the Perimeter Institute, and other sources, for a semester-long Physics 2 class. Topics included Basic Electric Circuits; Physics of Waves; Introduction to Quantum Mechanics (including a little Bra-Ket Algebra); Introduction to Particle Physics, and Introduction to Special Relativity. The Commonwealth of Kentucky has made the regrettable decision to remove Physics 2 from the high school science curriculum. On a "block schedule," only a few days are allotted to topics in modern physics in the Physics 1 curriculum.		
	We researched the correlation between lightning strikes and Muon count.		
	My students have participated in International Muon Week. They completed most of the steps of the online map; however, we ran out of time and could not complete the entire activity.		
	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year
	2020	2021	2022
	The Quark Workbench activity: my Physics 2 students really enjoyed it!	I would like to try incorporating coding in a Google Notebook into my Honors Physics curriculum. I would use the data from this year's QuarkNet workshop and provide a brief introduction to Particle Physics. DAP Examples: None. Opportunities to teach modern physics topics in any meaningful way are extremely limited to nonexistent.	I have incorporated CRMD activities into the Physics 2 course. Students practice the skills of taking data, analyzing data, and interpreting the physical meaning of the analysis. This is especially challenging for high school students because there is physical to see: numbers appeared on the computer screen but there was no other indication that anything was happening as muons were being counted. Examples: Quark Workbench 2D/3D, Particle Transformation, Cosmic Ray e-Lab
	Showing how to collect data and its importance		
		Exploring hardware design and implementation within both small classroom detectors and larger research detectors. I have transitioned over to teaching an engineering focused curriculum.	
	I have not used them yet, but I plan to in the future.		
	I haven't had the opportunity to use them yet but look forward to it in the coming school year.		

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms. (Out of a total of 11 teachers.)

Table C-23
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #23**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #23	2019	2020	2021	2022
	Z Boson Activity		I teach a "unit" of four class days to my AP Physics 1 students. Covering Standard Model, bubble chambers, and masterclass activities. Examples: Bubble chamber, Z Boson, J/psi masterclass	Use some of the activities in a mini-unit on particle physics in my AP physics 1 class. Attend Masterclass with students. Examples: Z Boson, Making Tracks, CMS e-Lab.
	Calculate Mass of Z, Calculate the Top Quark Mass, Penny Lab, Dice Histogram	I will be using z mass, top quark, rolling with Rutherford, and standard model, and quark bench as part of the curriculum. Examples: Mass of Pennies, Histogram Basics.		
	The particle Workbench, Rolling with Rutherford, particularly for masterclass prep and IB Physics	While I am not teaching in the 20-21 school year, I'll be back after 1 year. I did the masterclass with some students and used the Making it Round the Bend data portfolio activities. Examples: Making it Round the Bend, Totem Express.	I've taken students to masterclass, both virtually and in person, used many of the data activities, including StepUp, Making it Round the Bend, etc. Examples: StepUp careers in physics Making it round the bend.	I will try using coding in my particle physics unit to get a feeling for how we know about particles and in the magnetism unit with a phone app to collect magnetometer data and explore magnetic fields caused by currents. Examples: Makin' it Round the Bend, Quark Workbench, Step Up
	Rolling with Rutherford: the students thoroughly enjoyed the activity, and it covered a broad range of laboratory skills (plotting data, importance of multiple trials, mathematical modeling, indirect measurements, etc.).	I use QuarkNet resources in class whenever I can. Our class has a "Physics Fun Friday" every few weeks, in which we explore a topic in modern physics. I often use QuarkNet data activities. Examples: Z mass activity, Rolling with Rutherford, Particle Deck		
	Mass of US Pennies, because it made the students think of different descriptors to measure, and as a great intro to histograms	I'd like to use the Calculate the Top Quark Mass particle activity to show applications of vectors and vector addition and introduce basic idea of momentum. Examples: I have used the Mass of US pennies activity, Mapping the Poles, and Making it Round the Bend activities.	I prefer to sprinkle in modern physics where I can. For example, when I talk about sig figs tomorrow, I plan on mentioning/ doing a quick explanation of LIGO. I'd like to use some of the activities	I just wrote up a Python-based lab activity where we use data from Earth's satellite to figure out what affects satellite period. I'd have also used activities from the Data Activities Portfolio like Penny Mass, Making it Round the Bend, and some of the STEP UP topics. Examples: Mass of U.S. Pennies, Making it Round the Bend, STEP UP Careers.

Table C-23
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #23**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year
Center #23	2020	2021	2022
	Group analysis of data used to identify an unknown.	I use these concepts to unite topics in physics and to expand the understanding and depth of the understanding of these topics.	I have used cosmic ray data and particle interaction explanations. I have used LHC data to help students understand the Higgs boson was detected and explained why it was searched for, I have used statistical exercises to help students grasp how students grasp how testing results. And many other lessons. Examples: Much the activities from the Data Activities Portfolio was developed after I retired from teaching but I was using cosmic ray data with my students.
	Calculating the Z-mass. It's a great activity because it can be a competitive thing. It also reinforces some major math concepts.		
	Z-mass activity, Masterclass	I teach a “unit” of four class days to my AP Physics 1 students. Covering Standard Model, bubble chambers, and masterclass activities. Examples: Bubble chamber, Z boson, J/psi masterclass.	
	The DA portfolio activities currently are not quite user-friendly for Honors level courses and the AP curricula are packed. I do use the DA a bit for Masterclass preparation as the students are already motivated and interested in the content and usually are better equipped to use the activities. Examples: Masterclass and coding	Rolling w/ Rutherford, TQ etc. as Masterclass preparation.	AP Physics 2 – following or concurrent with Fluids and Thermo units or if hurricane affects the region. Examples: Rolling with Rutherford, Top Q, Hidden Neutrino – probably others but cannot think of titles right now.
	Program Year (Year of Full Survey)	Subsequent Program Year	
	2021	2022	
	Mass of pennies, dice-histograms-probabilities, histograms - the basics, rolling with Rutherford, mean lifetime, cosmic ray e-lab.	I used the Comic Ray detectors quite a bit. I’ve included many of the activities from the QuarkNet resources, specifically Rolling with Rutherford, Mass of U.S. Pennies, Dice Histograms and Probabilities, Mean Lifetime, Cosmic Ray, e-Lab, and some Jupyter Notebook Coding. Examples: Rolling with Rutherford, Mass of U.S. Pennies, Histograms.	

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Table C-24
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #24**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #24	2019	2020	2021	2022
	Have not used yet.			After learning more about the Cosmic Ray detector and some ideas on how to use it, I want to incorporate data collection and data analysis in my computational physics course. This is a new course for me to teach so I have a lot of open opportunities and I want to try to incorporate a variety of QuarkNet activities. One of my colleagues in the group set a great goal that I want to copy. Having really only done level 0 and 1 activities in the past, my goal will be to add in at least level 2 activity into my course.
	No response	Modify “sequim science.com	When discussing “the world” with students, friends and family (retired)	
	Rolling with Rutherford			
	Rolling with Rutherford and Quark Workbench have been used consistently in introducing statistics and the structure of matter.	I've already incorporated the Cosmic Ray and e-lab activities as well as Masterclasses, and will add in what I've learned and developed in the Data Camp. These included lessons on CERN, conservation. Examples: Shuffling the Particle Deck Rolling with Rutherford Quark Workbench.	I'll use particle collision materials for Conservation on Momentum and Energy. Examples: Shuffling the Particle Deck, STEPUP Lessons	I use the Data Activities Portfolio regularly for areas such as histograms (Mass of Pennies) to Conservation Laws and vectors products (Calculate the Top Quark). I also provide a masterclass. Examples: Mass of Pennies, Calculate the Top Quark Mass, Shuffling the Particle Deck (and more).
	No response.		I have incorporated a variety of activities when teaching conservation laws. Examples: StepUp, Rolling for Rutherford, Particle Cards.	I will use many of the activities from the data portfolio as after school projects. Some of which will be used through while teaching conservation and quantum mechanics. Examples: Neutrino masterclass, Z mass, the case of the hidden neutrino.
	No response	Rolling with Rutherford, and dice decay		
	While I haven't used any yet, I love the activities like Workbench that make abstract concepts concrete and manipulative for the students, these really help deep understanding.	Being a part of Virtual QuarkNet has been one of the very best professional development opportunities I have experienced in my 10 years of teaching. The cohort is amazingly supportive and knowledgeable.	I will offer a Coding with Python enrichment for students, and I will mentor a STEM student's OSEF Science Fair Project using the Cosmic Ray Detector. Example: Cosmic Ray E-lab will be an introduction used in STEM class to build student knowledge and engagement to develop the science fair project; using all coding activities will be offering a coding workshop	

Table C-24
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years: **Center #24**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Center #24	2019	2020	2021	2022
	I do not believe that I am familiar with the 'Data Activities Portfolio' so I am unable to answer this question with any certainty.		I use the Heisenberg Uncertainly lab when I introduce graphing and the concept of uncertainty. I use both WWDD and the CMS Masterclass when discussing Energy and Momentum conservation and as an intro. Examples: What Heisenberg knew, Quark Workbench, Rolling with Rutherford	I've used them for conservation of energy and momentum as well as special relativity. I just moved to a new school with a new curriculum, and I need to find places to use them this year.
	I used Rolling with Rutherford, Quark Workbench, and Calculate Mass of the Z when doing Masterclass for the past 8 years or so. All seemed to be helpful in teaching various aspects of physics.	I've used CRMD for learning, also for Science Fair and Illinois Junior Science and Humanities Symposium presentations, I have had students participate in International Physics Masterclass. Examples: Rolling with Rutherford; Quark workbench; Calculating the mass of the Z particle. (*retired)*		
	Program Year (Year of Full Survey)	**Subsequent Program Year**	**Subsequent Program Year**	
	2020	**2021**	**2022**	
	Rolling with Rutherford.			
	N/A: to be used this year!			
	rolling for Rutherford, quark workbench, both great for explaining basic particle physics and collecting data			
		I incorporated neutrino activities in my Cosmology class. I used the top quark activity for conservation laws and an introduction to vector addition. I plan to get my cosmic ray detector working. Examples: mass of Z mass of top quark signal and noise rolling with Rutherford step up particle transformations MINERvA.	Cosmic Ray detectors are used for special projects, neutrino and CMS masterclass for conservation laws, uncertainty and intro to particle physics, colab notebooks for teaching a variety of topics. Examples: Z mass, cosmic ray, rolling with Rutherford and more.	

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