Evaluation of the QuarkNet Program: Evaluation Report 2023-2025

Appendices A-L

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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 (PTM)

In sync with the start of the award period (2019-2022), 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. 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.

We used 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. We included a framework that adds program sustainability strategies and outcomes into the mix.

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).

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).

Model Development

Key steps in the development of the PTM were a series of interviews with key program staff and a meeting with past evaluators.

Initial Interviews with Key Program Stakeholders

An important part of the information-gathering step in creating the PTM was the conduct of structured interviews 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 used for these interviews is presented 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. 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?

Program Theory Model: Components

PTM: Three Program Anchors

The PTM is anchored by:

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

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[a]	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[a]	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.

[a]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, Wood, 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 QuarkNet 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) (Herron, 1971; Jan-Marie Kellow, 2007).

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's Program Theory Model: Program Structure

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.

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 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.

The primary program components of the QuarkNet Program Theory Model are:

- Workshops
- Data Camp
- Coding Camp
- Data Activities Portfolio
- Masterclasses
- e-Labs (as well as cosmic ray studies, cosmic watches)

These program components and the program structure of QuarkNet is shown in the narrative of the evaluation report as Exhibit C.

QuarkNet Partners

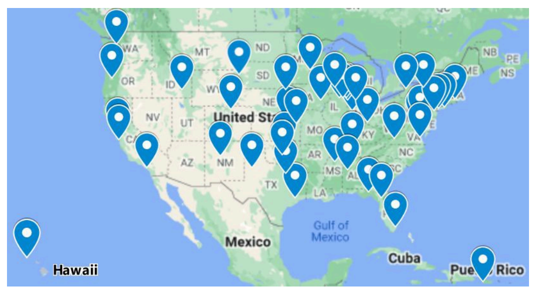
NSF: The National Science Foundation is an independent federal agency created by Congress in 1950 "to promote the progress of science; to advance the national health, prosperity, and welfare; to secure the national defense…" NSF supports basic research and people to create knowledge that transforms the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

Broadening Participation and Community Outreach: QuarkNet works on multiple fronts to help broaden participation beyond the existing community, including teachers and students who are underrepresented in physics. Examples include center needs assessment workshops that serve to identify ways to reach out to these communities. QuarkNet partners with other STEM organizations to reach more teachers and students. Recent partners are *STEP UP, STEMarts Lab, and i.am.Angel Foundation.* Many Data Activities Portfolio activities have been translated into Spanish. Often, participating teachers develop classroom implementation plans that integrate culturally sensitive content. Centers integrate QuarkNet in their community outreach efforts, partnering to reach beyond existing QuarkNet schools to students traditionally underrepresented in STEM.

Advisory Board: Typically, eight to ten 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+.

IRIS-HEP: A software institute funded by the National Science Foundation. It aims to develop the state-of-the-art software cyberinfrastructure required for the challenges of data intensive scientific research at the High Luminosity Large Hadron Collider (HL-LHC) at CERN, and other planned HEP experiments of the 2020's. In partnership with IRIS-HEP, QuarkNet offers professional development opportunities for teachers to improve coding skills to enhance classroom implementation of particle physics instructional materials.

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.

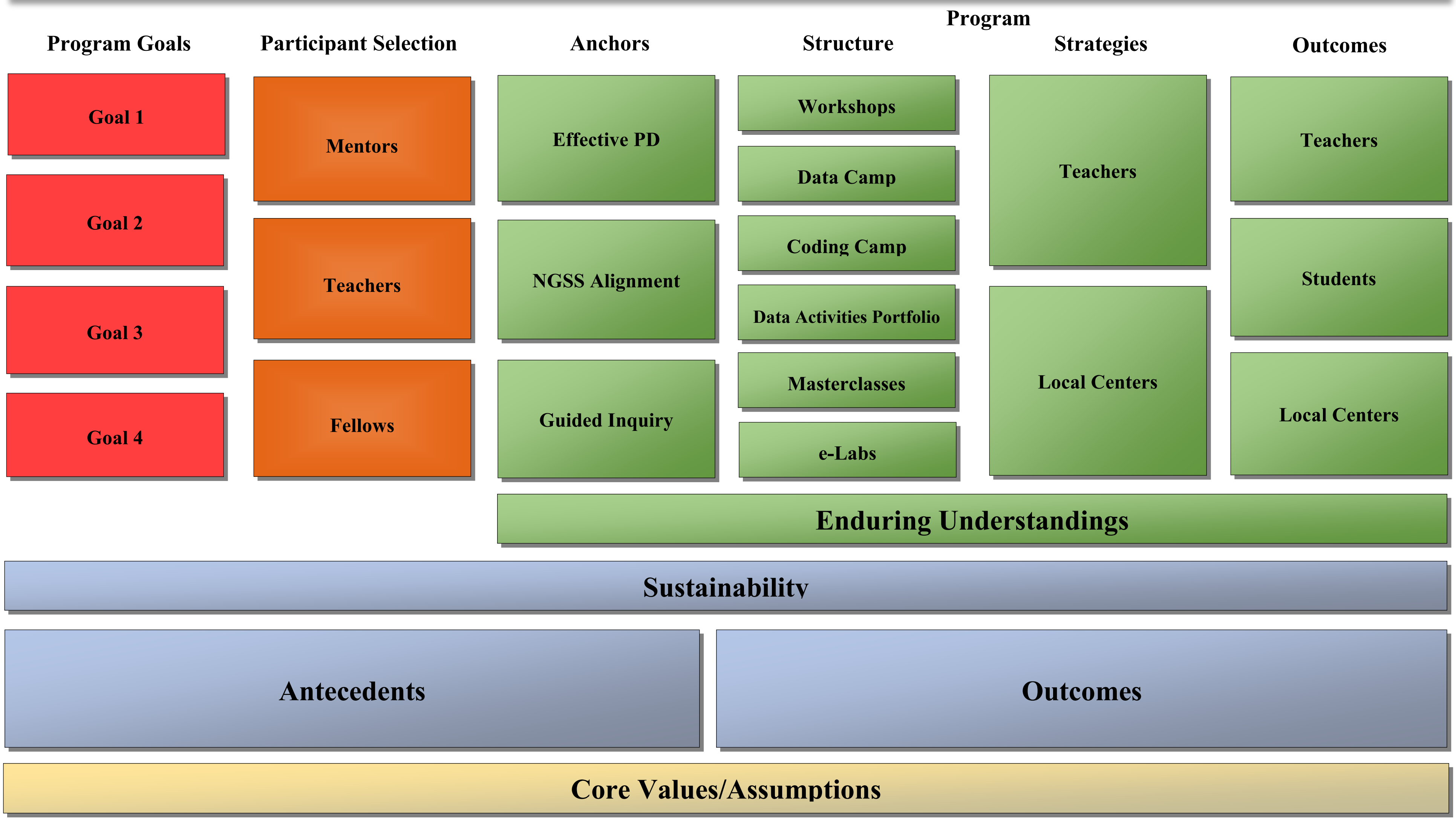
U.S. CMS: A collaboration of more than 900 scientists from 50 U.S. institutions who make significant contributions to the Compact Muon Solenoid (CMS) detector. Discoveries from the CMS experiment are revolutionizing our understanding of the universe. USCMS is a co-sponsor of QuarkNet.

Broader Impacts: QuarkNet has led in facilitating the public use of large particle physics datasets. Working within the International Particle Physics Outreach group (IPPOG), QuarkNet shares the overall central coordination of International Masterclasses (IMC). QuarkNet schedules and coordinates ATLAS, CMS, MINERvA and NOvA International Masterclasses with videoconferences based at Fermilab. Also, QuarkNet develops and coordinates World Wide Data Day, an IMC extension, and shares leadership in the global cosmic ray studies project. QuarkNet provides a wealth of information for IPPOG members to consider in their own education and outreach programs. QuarkNet staff and teachers attend and present at meetings of the American Association of Physics Teachers and the American Physical Society. These presentations have highlighted how QuarkNet works, e-Labs, the Data Activities Portfolio and scientific discovery for students.

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.



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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. Science and Engineering Practices

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: Offered annually at Fermilab, this 1-week summer program 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 teachers engage as active learners (as students) of a challenging topic they may have known very little about. In the beginning of the week, teachers receive an authentic CMS dataset and work in small groups 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 analyses. In the second half of the week, teachers explore various instructional materials in the Data Activities Portfolio that help incorporate particle physics concepts into their everyday lessons and propose an implementation plan for their classrooms. Throughout the week, teachers take tours and participate in seminars from theoretical and experimental physicists.

Coding Camp: A virtual 1-week program offered annually in the summer for teachers of physics and physical science with little-to-no experience in computer programming and/or incorporating computer science into their courses. The camp emphasizes an authentic data analysis experience in which teachers engage as active learners (as students) using common scientific programming software (e.g., Jupyter, Python, & SciPy) to analyze and visualize large datasets from various scientific disciplines, including particle physics, astronomy, and geology. Like Data Camp, during the first half of the week, teachers are learners of challenging content, In the second half, they use reformed pedagogy in planning how to integrate coding into their courses. Throughout the week, teachers participate in virtual seminars with scientists and programmers working in various fields.

Data Activities Portfolio: An online compendium of particle physics classroom instructional materials organized by data strand, level of student engagement, curriculum topics and NGSS Standards. Instructional materials conform to a specific instructional design and are aligned with NGSS and AP science standards (Physics 1 and Physics 2) as relevant. Materials are based on authentic experimental data used by teachers to give students an opportunity to learn how scientists make discoveries. Strands include LHC, Cosmic Ray Studies, and Neutrino. Level descriptions, 0 to 4, explain the data analysis skills that students apply at each level: tasks in Level 0 are simpler than those in Levels 1 and 2. While each level can be explored individually, students who start in one level and progress to more complex levels experience increasingly engaging and challenging tasks.

Each curriculum topic provides connections between topics routinely covered in physics class and particle physics content and methods. The drop-down menus identify activities related to desired content and student skill sets. Teacher, student resources and data sets are available for each activity. In the Curriculum Topic drop-down menu, Spanish Language versions are available for some activities. Also, coding activities are available.

Masterclass, QuarkNet Model: A one-day event in which students become "particle physicists for a day." Teachers and mentors participate in an orientation, either remote or in person, by QuarkNet staff or fellows. Teachers implement up to 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 teachers explain the measurements they will make using authentic particle physics data. Working in pairs, students analyze data from visual event displays, characterize the events, pool their data with peers, and draw conclusions. Students are helped by and discuss interpretation of data with one or more particle physicists and their peers and teachers. 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, CERN, or another high energy physics facility. Some masterclasses take place at school with teachers providing the particle physics and measurement information. QuarkNet Masterclasses are part of a larger program, International Masterclasses.

Workshops: The primary vehicle through which participating QuarkNet teachers receive professional development. Teachers engage in QuarkNet workshops when new to the program and often over multiple years.

Workshops are in-person events held at a center. (A virtual center accommodates teachers from a dispersed area.) QuarkNet staff work with individual centers to build this experience with considerable flexibility to organize workshops that meet local needs and interests. Workshops vary in length, from 1-to-5 days, typically occur during the summer, but many centers may meet during the summer and school year. Workshops can be locally led or nationally led and are often a combination of the two, thus varying in content and structure. Nationally-led workshops, conducted by QuarkNet staff and/or fellows, cover content including, for example, cosmic ray studies, LHC or neutrino data, coding in support of particle physics, and related activities from the Data Activities Portfolio. Nationally-led workshops support opportunities for teachers to engage as active learners, as students, engage in activities from the Data Activities Portfolio, collect and analyze data, work in a learning-community environment, learn and share ideas related to content and pedagogy, and build collegial relationships with other teachers, fellows and mentors. Of importance, teachers have time to develop and discuss classroom implementation plans. Often locally- led workshops mirror these components and offer opportunities for teachers to tour local research labs, participate in unique events, and/or hear presentations by local physicists and students.

Staff encourage centers to post their agendas and annual reports on the QuarkNet website to share this engagement with other centers. Often, centers collaborate with other centers (e.g., rotating host responsibilities from one year to the next), join together through shared interests or content needs and other opportunities for multi-center engagement.

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

Cosmic Ray Studies: Across most centers, QuarkNet supports a high school long-term collaboration based on the High Energy Physics model using particle detectors provided in kit form. In this hands-on learning opportunity, students assemble the parts into a working scientific instrument based on the design used in the Collider Detector at Fermilab. Students and their teachers use the detectors for inquiry-based learning involving authentic research tasks and experiments such as muon flux, muon lifetime, and speed of muons, using data they collect themselves. Their data can be uploaded to the cosmic ray e-Lab for analysis, creating graphed plots to display results.

Cosmic Watches: Smaller more portable particle detectors, cosmic watches extend the reach of authentic research activity to all students, not just research groups, by moving cosmic ray studies into classrooms increasing the number of teachers using cosmic rays to teach about elementary particles and observing the invisible.

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[3,4] 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.

[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

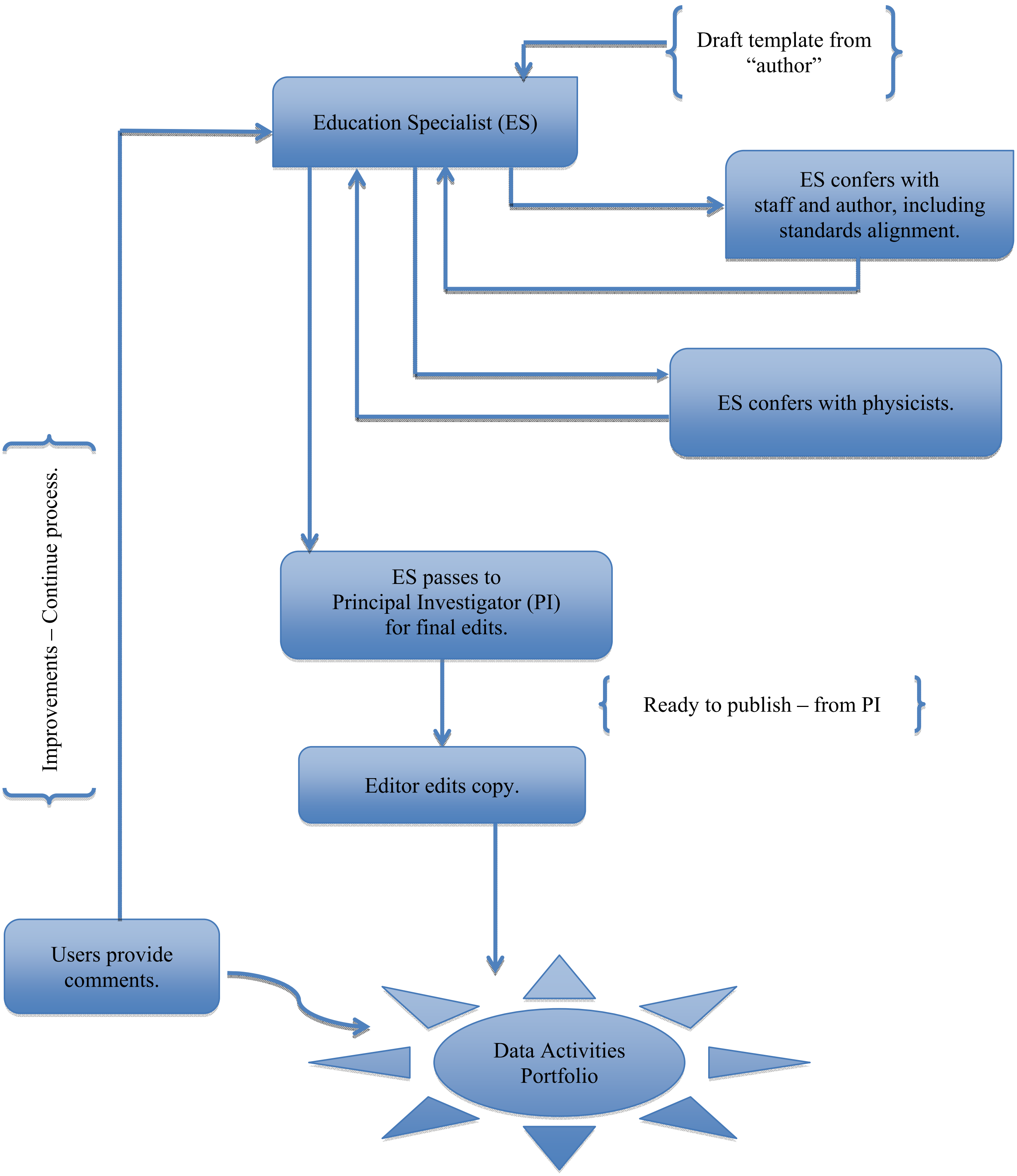
1. Scientists make a claim based on data that comprise the evidence for the claim.
2. Scientists use models to make predictions about and explain natural phenomena.
3. Scientists can use data to develop models based on patterns in the data.
4. Particle physicists use data to determine conversation rules.
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[5] 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.

Based on the work of: Darling-Hammond, L., et al. (2017, June) and Wiggins, G. J. & McTighe, J. (2005). Developed for QuarkNet by Young, Roudebush, Smith & Wayne, 2019, revised 2021.

[5] 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."

Instructional Design Pathway and Templates for Data Activities Portfolio

<u>PROCESS</u>: 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

**A Framework for K–12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, 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 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/or 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 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.

(Times New Roman, 12) Title (*Times New Roman, 18*)

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.

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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.

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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		

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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

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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.

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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.

Table F-6

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).

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Table F-6 (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 F-6 (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)

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Table F-6 (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 F-6 (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 F-6 (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 F-6 (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 F-6 (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.

Table F-7

2023 QuarkNet Workshops and Meetings: National- and Center-led (December 2022-October 2023)

Center	2023 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 5-8	**BHSU/SURF Workshop**	Introduction to Jupyter (0) Review from coding 1 Advanced applications for data analysis Creating a data activity for your classroom Dark Masterclass Cloud Chamber Radiation Shielding CRMD
	May 12	Science Day @Cheyenne-Eagle Butte School	Data Activities Portfolio: Particle Cards (0) Rolling with Rutherford (1) Building a Neutrino Detector
	May 13	Women in Science & Neutrino/ NOvA Masterclass	NOvA Analysis Near Detector Events – Using Coding Notebooks
Boston Area/Brown University/ Northeastern University[a]	December 8, 2022	Winter Meeting Projects in Physics Class	Various projects were highlighted including a constructed photoelectric apparatus; data to measure the Sgr A* supermassive black holes; a sound speed measurement; an egg crash project using a double pendulum to regulate speed; a Rube Golberg construction project to demonstration energy conversion; a constructed periscope to help under mirror reflections; particle quest project where student created an imaginative fact or fiction story involving the particle; project where construct parachutes from readily available materials to test Aristotle's theory that the speed of fall is proportional to weight.
	March 11	CMS Masterclass	Thirty-one high school students and five QuarkNet teachers from Massachusetts, Rhode Island, and Vermont participated; Agenda items included get-acquainted exercises; talk on particle physics; talk on analysis of CMS proton collision images; opportunity to talk with physics grad students at lunch; and a visit to lab where a small liquid argon time project chamber is being built. Students and teachers met via a video conference with students from Williamsburg VA, Mexico and Columbia and physicists and fellows at Fermilab.
	June 8	Spring Meeting	Teachers worked in pairs to calculate physical and angular measurements related to black holes and their shadow images engaged as active learners, as students.
	August 9-10	Summer Workshop Questions and Clues in Particle Physics	Standard Model of Particle Physics and its limitations; the importance of doubt 5 σ criterion in physics; muon g-2 experiments; σ and β decay; Dune and other neutrino adventures; and W bosons 2 mass.

Table F-7

2023 QuarkNet Workshops and Meetings: National- and Center-led (December 2022-October 2023)

Center	**2023 Dates (All dates except where noted)**	**Workshop/Meeting**	**Brief Summary of Activities and Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
Brookhaven National Laboratory – Stony Brook University[a]	June 26-29	**Summer Workshop Neutrinos**	Data Activities Portfolio Activities: What Heisenberg Knew (1) The Case of the Hidden Neutrino (1) Coding with Phyton Teachers prepared and shared implementation plans
	June 29	**NOvA Masterclass**	NoVA masterclass measurement
Catholic University of America	July 17-21	**Summer Workshop**	QuarkNet Data Activities Presentations (e/g/. Physics at JLab; Comic Ray Archaeology) Tour of National Accelerator Facility Presentations (e.g., CERN research) and Exploration (e.g., cosmic watches) Implementation Plans and Presentations
Colorado State University	March 4	**Masterclass**	Students interacted with the Data Activities Portfolio activities. Analyzed data from MINVERa experiment. Shared experience via videoconference with two other masterclasses.
	October 13-17	**Annual Workshop**	Four-day trip to Los Alamos, NM to align with solar eclipse; engaged in cosmic ray flux study with two telescopes with different filters. Tour of Los Alamos National Lab Share-a-thon presentations and discussion
Fermilab/University of Chicago/College of DuPage[a]	August 1-3	**QuarkNet Teachers Workshop**	Series of presentations by scientists, teachers and students; a number of activities working toward the introduction of statistical analysis of data while learning physics Data Activities Portfolio Activities: Particle Transformations (1) Energy Momentum and Mass (1) Coding Activity: Invariant Mass of the Muon Shuffling the Particle Deck (0) NOvA Masterclass Measurement Teachers developed plans toward integrating physics research data into their classrooms.

Table F-7 (con't.)
2023 QuarkNet Workshops and Meetings: National- and Center-led (December 2022-October 2023)

Center	**2023 Dates (All dates except where noted)**	**Workshop/Meeting**	**Brief Summary of Activities and Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
Florida International University	No activity		
Florida State University	July 26~~-28~~	**FSU Summer Workshop**	Shuffling the Particle Deck (0) Mapping the Poles (0) Totem 2 (2)
Idaho State University	July 24-27	Idaho State QuarkNet Summer Workshop	Shuffling the Particle Deck Measuring Z Calculating W-bosons 1,2 Muon g-2 experiment Implementation Plans
Johns Hopkins University	July 24-28	2023 JHU Workshop	Half-day Morning Coding Sessions Introduction to Jupyter Probability Position graphs Other notebooks Scaffolded Notebook Best Practices for Coding with Python Modifying an existing notebook Share out implementation plans
	March	LHC Masterclass	Teachers and about 35 students participated
Kansas State University	June 5-7	Workshop	Various tours and NREL workshop
	March 31	Masterclass	Six teachers and their students participated
	March 4	Masterclass Orientation	Eight teachers participated
	No date	Research Project	Twelve CRMD teacher worked with students to correlate muon rates with atmospheric temperature and pressure changes (from NASA data)

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]Combined QuarkNet center

Table F-7 (con't.)

2023 QuarkNet Workshops and Meetings: National- and Center-led (December 2022-October 2023)

Center	**2023 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 23 June 26	**Particle Physics Data Activities**	Particle Cards (0) Quark Workbench (0) Search for Higgs in CMS data Z Mass Measurement (1)
	June 20-30	Physics in and through the Cosmology Two Week Virtual Workshop (3 hours per weekday)	A total of 6 teachers and 49 students participated. Discussion on a variety of topics and students worked in groups for an Interview a Scientist Project. Presentation by Nobel Prize winner Saul Perlmutter
Northern Illinois University	No activity		
Oklahoma State University/University of Oklahoma[a]	July 24-26	**Summer Workshop**	The Case of the Missing Neutrino (1) What does the Muon g-2 experiment tell us NOvA masterclass measurement Share-a-thon Implementation Plans
	3 events (no dates)	**Atlas Masterclasses**	
Purdue University	July 28-29	Neutrino Workshop	Shuffling the Particle Deck (0) Mean Lifetime Dice (1) Mean Lifetime MINERvA (3) Neutrino Masterclass Measurement Coding Activities Implementation Plans
	February	Masterclass Orientation	1 teacher and 12 students participated
Purdue University Northwest	June27-30	Summer Workshop: Computation in the Classroom	Workshop topics: Solving problems computationally Python for beginners Using Python in the classroom with Jupyter Notebooks and Google Colab Introduction to Particle Physics QuarkNet DAP activities Use and analysis of cosmic ray data and LHC Data Introduction to Machine Learning

Table F-7 (con't.)

2023 QuarkNet Workshops and Meetings: National- and Center-led (December 2022-October 2023)

Center	2023 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	August 14-18	Testing and Characterizing Cosmic Ray Scintillating Courses	Individual projects presented on website Queensborough Community College QuarkNet Center | QuarkNet
Rice University/University of Houston[a]	June 22-23	**World Wide Data Day and New Questions Workshop**	Shuffling the Particle Deck (0) Making Tracks (0) New Questions
	June 19-21	**IRIS-HEP Coding Workshop**	Teachers created 13 coding activities that they can take back to their classrooms and their students
Rutgers University	2-weeks	Summer Program on Fundamental Physics	24 students analyzed data from MINERvA experiment and gave presentations to an audience of family, friends and the general public.
Southern Methodist University	June 26-28	**3-Day Coding Workshop**	Intro to Colab Intro to Coding Other Notebooks Explore and work through notebook examples Particle Physics CMS Particle Analysis Implementation Plans
	June 29-30	**Dark Matter** **New Questions in Particle Physics**	The physics of g-2 Dice activity
Syracuse University	August 14-16	Summer Workshop	Shuffling the Particle Deck (0) Rolling with Rutherford (1) Feynman Diagrams Making Tracks I (0) Mass of the Top Quark (1) World Wide Data Day measurement MINERvA Masterclass measurement
Texas Tech University	No activity		
University of Alabama	June 5-7	Coding Workshop (First year in QuarkNet)	Each participating teacher created a coding project for a total of five.

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]Combined QuarkNet center

Table F-7 (con't.)

2023 QuarkNet Workshops and Meetings: National- and Center-led (December 2022-October 2023)

Center	**2023 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	August 17-18	Summer Workshop	Presentations by mentors Demonstrations (e.g., Cloud Chamber, Cosmic Ray detector) Analysis of NOvA experiment data: Coding activity Shuffling the Particle Deck (0) Implementation plan discussions
University of California – Irvine	July 12-14	**Summer Workshop**	Intro to Colab Notebook Intro to Colab with Python Experience Explore and work through notebook examples Work on a notebook Bringing Coding into the Classroom Coding Share out Shuffling the Particle Deck (0) NOvA Video Cosmic Ray Muon Detector Phyton Near Event Analysis
	March 25	**Neutrino Masterclass**	NOvA masterclass measurement 1 NOvA masterclass measurement 2
University of California -Santa Cruz	March 4	Masterclass	61 registered students of which most attended in person; followed up with a classroom BAMA activity at a local school on May 22.
University of Cincinnati	June 20-22	Workshop	Shuffling the Particle Deck (0) Introduction to Coding/Probability and Histograms/Muon Mass STEP UP: Careers in Physics (Lesson 2) (1) STEP UP: Women in Physics (Lesson 3) (2) Calculate the Z mass (1) Implementation plan discussion

Table F-7 (con't.)
2023 QuarkNet Workshops and Meetings: National- and Center-led (December 2022-October 2023)

Center	**2023 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 21	CMS Masterclass	21 students participated Rolling with Rutherford (1) or Quark Puzzle Analyzed CMS multi-lepton data
University of Illinois at Chicago/Chicago State University[a]		Eight Half-day Meetings (Oct 30, 2022; Dec 4, Jan 8, Feb 12, Mar 19, Aug 23, Sept 3)	Analyses for the Moon Shadow experiment
	June 14-16	**Workshop**	Analyses for the Moon Shadow experiment (measure the shadow of the moon cats in muon at the earth's surface)
University of Iowa/Iowa State University[a]	July 25-29	Summer Teacher Institute	Shuffling the Particle Deck (0) Particle Adventure Quark Workbench (0) Rolling with Rutherford (1) Mass of the Z Boson (1) Mass of the Top Quark (1) Making Tracks 1 () Making Tracks 2 (1) Energy Momentum and Mass (1) Implementation Plans
University of Kansas	May 10, 2023 Apr 12, 2023 Nov 8, 2022 Oct 26, 2022	Cosmic Ray Zoom Series	Kansas flux/storm project
University of Minnesota	August 9-10	**Summer Workshop**	Shuffling the Particle Deck (0) QuarkNet Work Bench (0) Making Tracks (0) Rolling with Rutherford (1) Mass of Z (1)
	March 11	**NOvA Masterclass**	NOvA measurement Part 1 & 2

Table F-7 (con't.)
2023 QuarkNet Workshops and Meetings: National- and Center-led (December 2022-October 2023)

Center	2023 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	July 17	Belle II Data Workshop Pilot	Public workshop to test Belle II becoming an official QuarkNet Masterclass Shuffling the Particle Deck (0)
	March 24	Belle II Masterclass	
University of New Mexico	October 11-12	**Classroom Visit**	Shuffling the Particle Deck (0): Student Work Rolling with Rutherford (1)
	July 26-29	**Cosmic Ray Muon & STEAM Workshop**	Shuffling the Particle Deck (0) Mean Lifetime Part 1 Dice Mean Lifetime Part 2 Cosmic Muons Analyze Cosmic Ray Data Implementation discussion
University of Notre Dame		Summer	Cosmic Ray studies with CRMDs and Cosmic Watches and Project GRAND. Other projects included Astrophysics, magnetic phenomena, building and testing CO_2 sensors (with Indiana University South Bend), and CMS Data.
		Regular Monday Afternoon Hybrid Meetings	World Wide Data Day International Cosmic Day International Muon Day
	Feb 28	Masterclass	
University of Oregon	No activity		
University of Puerto Rico - Mayaguez	November 21	Neutrino Data Workshop	Sharing advanced work from NOvA masterclass
	March 25	MINERvA Masterclass	
	March 4	Masterclass Orientation	

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[a]Combined QuarkNet center

Table F-7 (con't.)
2023 QuarkNet Workshops and Meetings: National- and Center-led (December 2022-October 2023)

Center	2023 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 South Dakota	July 17-18	STEM Workshop	Mass of US Pennies (0) Quark Workbench (0) Rolling with Rutherford (1) LHC Masterclass measurement
University of Washington	July 10	IRIS-HEP Workshop	Very limited participation Attempting to re-energize center
University of Wisconsin – Madison	April 20	Five 2-hour sessions over the course of 6 weeks	Teachers work to develop an engaging activity for high school students on the IceCube Project; pilot tested during summer over a 2-week enrichment program with students.
Vanderbilt University	June 19-23	Workshop	Workshop focused on developing YouTube style videos to support imparting particle physics content with support from Python coding Implementation Plan development and discussion
Virginia Center (Hampton University, the William and Mary, and the George Mason University)[a]	October 28	Fall Workshop	Making Tracks II (1)
	August 2-4	Summer Workshop	Shuffling the Particle Deck (0) Making Tracks I (0) Rolling with Rutherford (1) Calculating the Z Mass (1)
	March 11	Masterclass	
Virginia Tech University	August 4	New Questions Workshop	Last day of workshop co-implemented with Virtual Center Particle Cards (0) Measuring the Z (1) The physics of g-2
	August 2-3	Workshop	Assembling, commissioning and collecting data from a muon 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.
aCounted as a double center.

Table F-7 (con't.)

2023 QuarkNet Workshops and Meetings: National- and Center-led (December 2022-October 2023)

Center	**2023 Dates (All dates except where noted)**	**Workshop/Meeting**	**Brief Summary of Activities and Data Activities Portfolio (Level)** [and/or classroom use/implementation plans]
Virtual Center	August 4	New Questions Workshop	Last day of workshop co-implemented with Virginia Tech Particle Cards (0) Measuring the Z (1) The physics of g-2
	August 2-3	Workshop	Diffraction data Z Mass spreadsheet (2)
Coding Camp 1	June 26-30	Five Day Coding Camp (Virtual Event)	24 participating teachers 22 coding projects created by participating teachers
Data Camp	July 9 – 14		Dice Histograms CMS Calibration Analysis Time to independently explore the Data Activities Portfolio

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

Linking Program Strategies to Outcomes

The principal intent of the PTM is to logically link core strategies to program outcomes. Tables 1 and 2 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 1). 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 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 2 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.*

Program outcomes directed toward teachers are measured by a Full Teacher Survey (followed by a short update) distributed on an annual basis. And program outcomes related to mentors and interactions between mentors and teachers have been 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.

Table 1. QuarkNet: Aligning Program Anchors and Core Strategies

Program Anchors: Effective Professional Development and Best Practices	Core Strategies: What Happens in QuarkNet?
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.	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.
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)]	

Table 2. 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.

Table 3
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.

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 56 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.

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 3 (previous page), 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).

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).

Development of Evaluation Measures and Evaluation Plan

The evaluation measures used to assess teacher-level, student-level and long-term outcomes were developed or adopted to align with the measurable outcomes listed in the PTM. Evaluation measures were supported by program operations data, annual reports submitted by participating centers, virtual site visits by the evaluator during implementation plan discussions at workshops, posted implementation plans, and examples of teacher and/or student work when available to help provide the context in which this assessment has occurred. (See Exhibit A in this appendix or Exhibit F in the full report.)

Sources of Outcomes Data

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

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

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

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

Exhibit A shows a summary of the sources of outcomes data and multiple sources of information that helps in the assessment of program fidelity (implemented vs. designed) as well as linking exposure to core strategies to program outcomes.

To this end, a Teacher Survey (in two versions full and in an abbreviated update) and a Center Feedback Template were developed; these evaluation efforts began in September 2018 to coincide with the 2018-2019 program year, where most QuarkNet workshops and meetings at participating centers occur over the summer (as already noted). The Teacher Survey (full version) was rolled out to coincide with summer 2019 activities. (This aligns with Goal 2: assess teacher-level outcomes as well as student and long-term outcomes).

A pilot test of the Center Feedback Template began in November 2019 and was rolled-out during the 2019-2020, 2020-2021 and 2021-2022 program years. This coincided with assess center-level outcomes (Goal 3) and served to provide a context for teacher-level responses. In anticipation of obtaining a renewal grant period, the full Teacher Survey was modified slightly to include additional QuarkNet options for teachers to select when querying past/current program engagement and a few skip functions for new teachers. This survey version was rolled out to coincide with the 2023 QuarkNet program.

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 has been strongly recommended for center-run workshops as well. And, to coincide with the 2020-2021 program year, a template was created to help teachers think through the components of these plans. Often these classroom implementation plans are posted on the QuarkNet's website or linked within the posted 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. The Update: Teacher Survey will again be rolled out, as an option for teachers, during the 2024 program year. Finally, workshop observations (most done remotely) have been incorporated into this process.

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 4). The full survey is shown in Appendix H (in a PDF format) for the original and modified versions; the update survey is shown in Appendix I.

There are six segments to the full 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.

The survey is a planned annual event; however, a given teacher is asked to complete the full survey only once during a 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 survey focuses 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.

Table 4
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>

Table 5
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 (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.</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 has been 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 (see Table 3).</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>

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 5); and gather information on success factors as a means to assess sustainability outcomes (see Table 6).

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); and Section IV is focused on the Success Factors listed in Table 6. Finally, there is an optional fifth page for Centers to add any additional comments, if desired. The protocol used to implement this approach is also described in Appendix J.

Table 6
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.

2023 QuarkNet Teacher Survey

QuarkNet Full 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. 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. **(If you participated in more than one QuarkNet workshop/program in 2023, please complete this survey only once.)**

1. Today's Date

2. Your Email Address (optional)

3. Your Name (optional)

4. Your Gender (optional)

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)

2023 QuarkNet Teacher Survey

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
- [ ] Coding Camp 1
- [ ] Coding Camp 2
- [ ] Other (please specify)

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

2023 QuarkNet Teacher Survey

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 ◯ Not yet, new to program

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 ◯ New to program have not used as yet

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

2023 QuarkNet Teacher Survey

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. **If you are new to the program, please base your responses on the workshop you just completed.**

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.

2023 QuarkNet Teacher Survey

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. **If you are new to the program, please skip to Question 34 (the last question in this survey).**

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.

2023 QuarkNet Teacher Survey

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.	◯	◯	◯	◯	◯	◯

2023 QuarkNet Teacher Survey

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.	◯	◯	◯	◯	◯

2023 QuarkNet Teacher Survey

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?

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 J-1); and gather information on success factors as a means to assess sustainability outcomes (see Table J-2).

The Center Feedback Template is a 4-page form divided into four sections (see end of this appendix). 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 J-1); and Section IV is focused on the Success Factors listed in Table J-2. 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.

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.

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.

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.

Table J-1
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: Engage Teachers as Active Learners, as Students			Individual Teacher-level Responses: QN provides opportunities for teacher to engage as an active learner, as a student					Center-level Assessment: QN's Influence on Teachers (on this behavior)	
	Almost All	Most	Some	Excellent	Good	Average	N/A	Total	Very High	High
Black Hills State University	✔			12	2	0	0	14	✔	
Boston Area/Brown University[a]		✔		14	3	0	0	17		✔
Brookhaven National Laboratory/Stony Brook[a]	✔			13	5	0	0	18	✔	
Catholic University of America	✔			12	4	0	0	16	✔	
Colorado State University	✔			13	1	0	0	14	✔	
Fermilab/University of Chicago[a]	✔			39	4	0	1	44		✔
Florida State University	✔			15	2	0	0	17		✔
Johns Hopkins University[a]	✔			15	3	0	0	18	✔	
Kansas State University	✔			13	2	0	1	16		✔
Oklahoma State/University of Oklahoma[a]	✔			29	3	0	0	32	✔	
Purdue Northwest	✔			4	1	0	0	5	✔	
Rice University/University of Houston[a]	✔			23	0	0	0	23		✔
Southern Methodist University	✔			18	4	0	0	23		✔
Syracuse University		✔		13	6	1	1	21		✔
Texas Tech University	✔			1	1	1	0	3		✔
University at Buffalo			✔	5	1	0	0	6		✔
University of Cincinnati			✔	17	5	1	0	23		✔
University of Illinois at Chicago[a]	✔			7	2	0	0	9		✔
University of Iowa/Iowa State University[a]	✔			13	7	0	0	20	✔	
University of Kansas	✔			4	1	0	0	5		✔
University of Minnesota	✔			14	2	0	0	16	✔	
University of Notre Dame	✔			16	3	0	0	19	✔	
University of Puerto Rico – Mayaguez		✔		21	2	0	0	23	✔	
Vanderbilt University	✔			9	2	2	0	13		✔
Virginia Center	✔			10	8	0	0	18		✔
Virtual Center	✔			11	2	0	0	13		✔
Total	20	3	2	361 (81.1%)	76 (17.1%)	5 (1.1%)	3 (0.7%)	445 (100%)	11	14

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 centers (34 total centers).

Table J-2
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	L
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	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, but[1]	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes/ Unsur e	Yes, but[1]
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]	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	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	Yes, but[1]
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]	Unsu re	Yes, but[1] /Yes	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	Yes, but[1]
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	Yes, but[1]
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	Un- sure	Yes	Yes/ Yes, but[1]	Yes	Yes, but[1]	Yes	No/ Yes	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	Yes, but[1]

[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. 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. L = University of Cincinnati.
Note. Not all centers reached consensus in their ratings; this is reflected by multiple responses for these centers.

Table J-2 (con't.)

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

Effective Practices/Success Factors[a]	**QuarkNet Centers**												
	M	N	O	P	Q	R	S	T	U	V	W	X	Y
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, but[1]	Yes	Yes	Yes	Yes	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	Yes	Yes	Yes	Yes	Yes	Yes	Yes, but[1]	Yes	Yes	Yes	Yes	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	Yes, but[1]	Yes	Yes	Yes, but[1]	Yes	Yes	Yes	Yes	Yes, but[1]	Yes, but[1]	Yes	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	Yes	Yes	Yes	No/ Not sure	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	Yes	Yes, but[1]	Yes	Yes, but[1]	Yes	Yes, but[1]	Yes, but[1]	Yes	Yes, but[1]
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	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes, but[1]	Yes	Yes, but[1]
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.)	No	Yes, but[1]	Yes	Yes	No	Yes, but[1]	No	Yes	Yes	No/ Not sure	Yes, but[1]	Yes, but[1]	No/ Not sure
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	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes, but[1]	Yes, but[1]	Yes, but[1]
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, but[1]	Yes	Yes	Yes	Yes	Yes	Yes, but[1]	Yes	No/ Not Sure	Yes	Yes	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	Yes, but[1]	Yes	Yes	Yes	Yes	Yes	Yes	Yes, but[1]	Yes

[a]This section of the protocol has been adapted from M.J. Young & Associates (2017, September). *QuarkNet: Matrix of Effective Practices.* 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. V = Black Hills State University. W = Texas Tech University. X = University at Buffalo. Y = University of Kansas.

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.*

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.												

Figure 5. Section III of the Center Feedback Template.

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

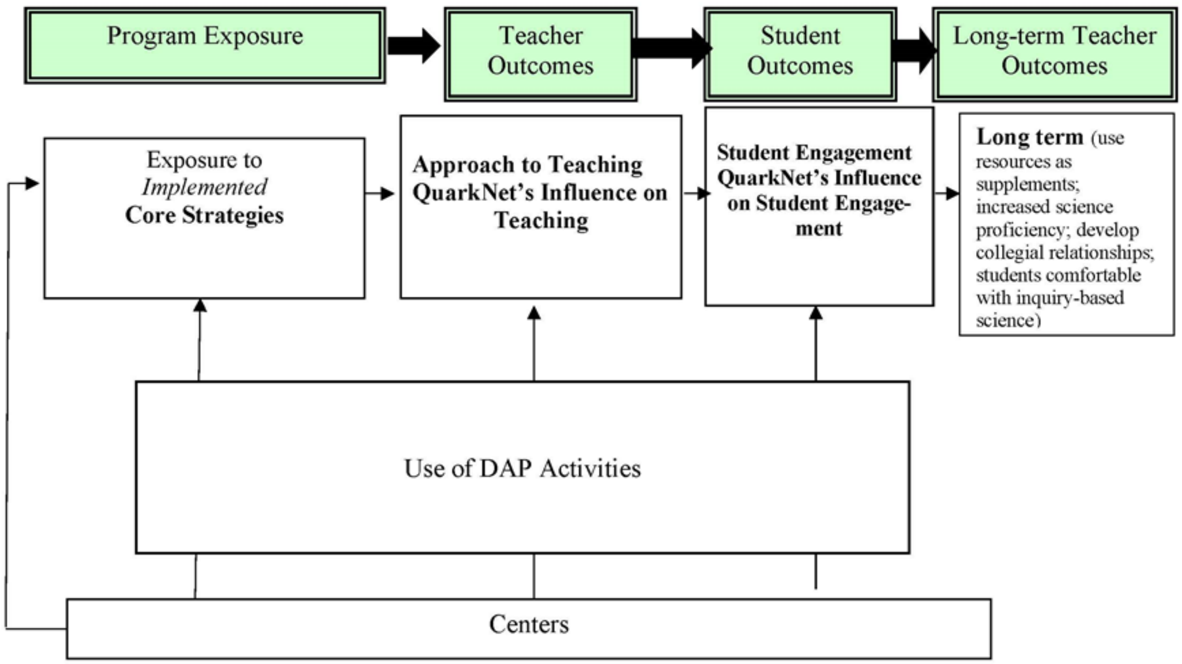

Figure 7. Teacher (and their Students) and Long-term Outcomes: Overview of Analyses

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, student engagement, and more recently long-term outcomes. And as stated in the full report, 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, the above figure (noted here and in the narrative of the report as Figure 8) 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=574, ranged from 12 to 60, with a Mean = 53.94 (Standard Deviation, SD = 6.96); and an alpha = 0.85 (reliability coefficient, Cronbach's alpha).

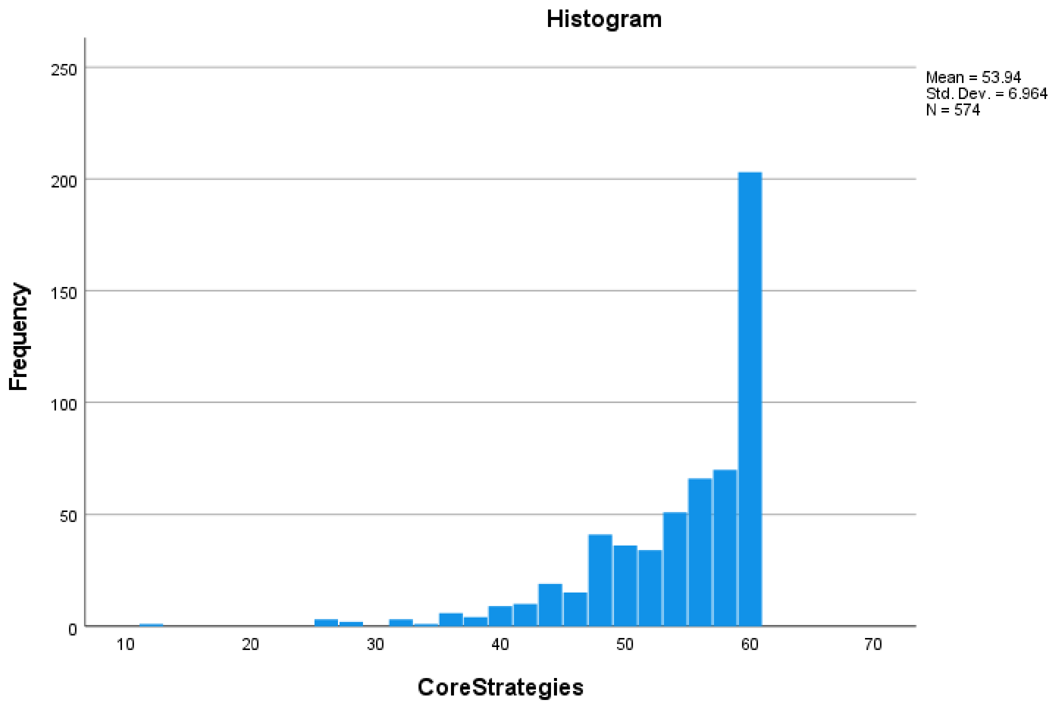

Figure K-1. Distribution of Core Program Strategies scale scores.

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=528, ranged from 14 to 60, with a Mean of 42.24 (SD = 8.66); 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

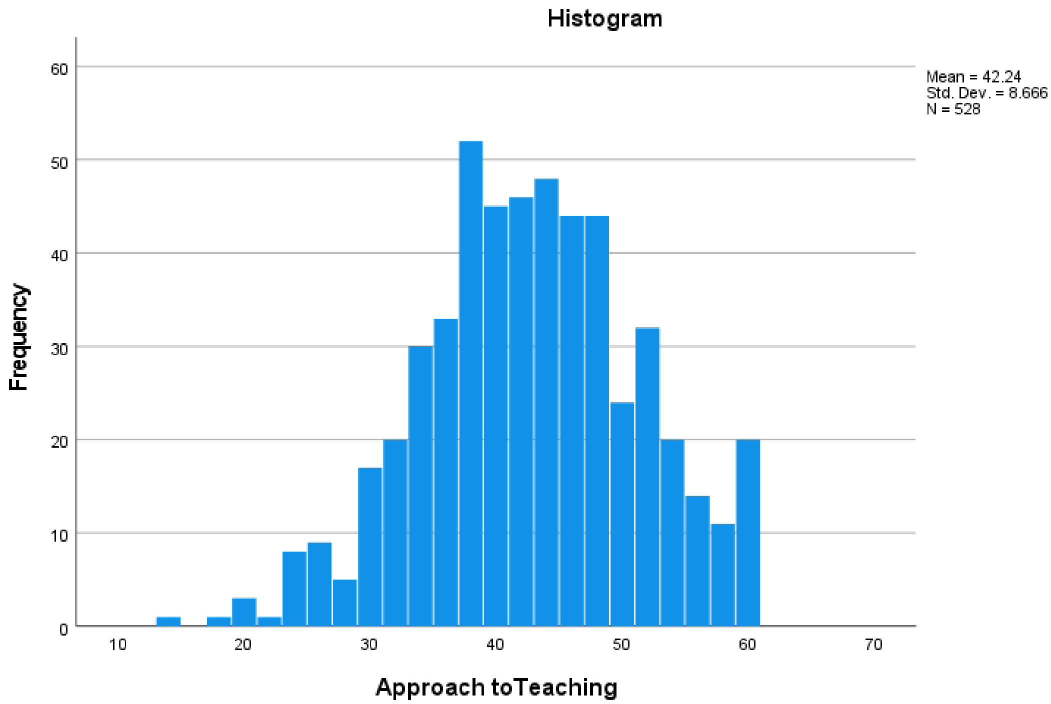

Figure K-2. Distribution of Approach to Teaching scale scores.

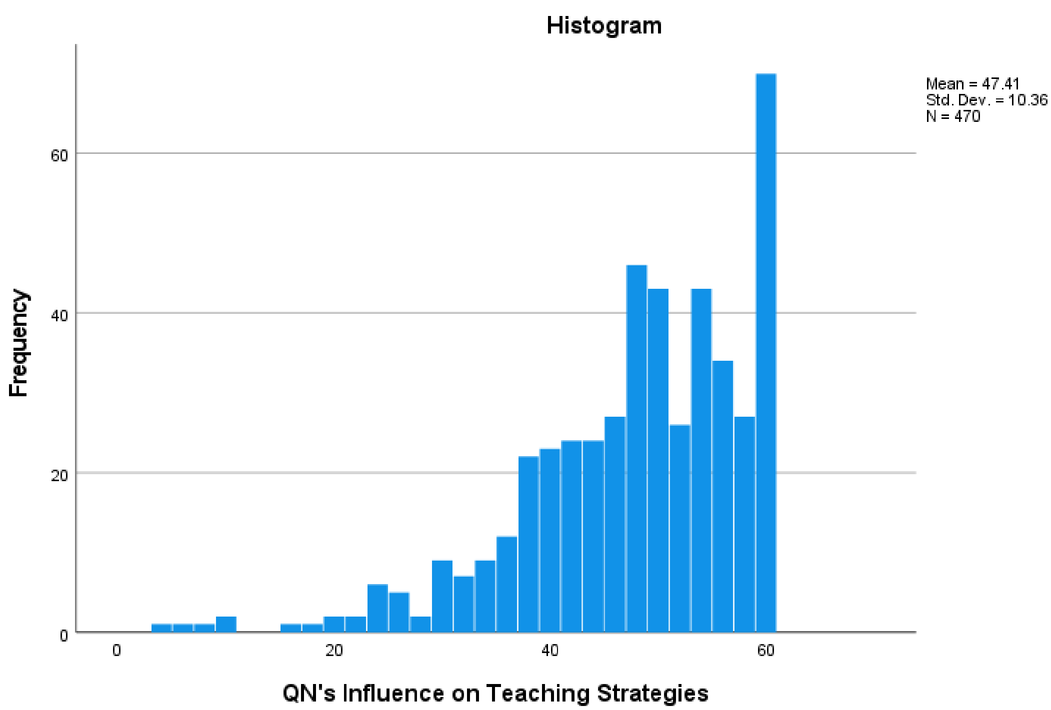

Figure K-3. Distribution of QuarkNet's Influence of Teaching scale scores.

this 12-item scale, based on an N= 470, ranged from 4 to 60, with a Mean of 47.41 (SD = 10.56); and an alpha of 0.93 (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=498, ranged from 2 to 25, with a Mean of 18.17 (SD = 3.72); and an alpha of 0.83(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= 415, ranged from 2 to 25, with a Mean of 18.98 (SD = 5.16); and an alpha of 0.94 (reliability coefficient). (See Figure K-5.)

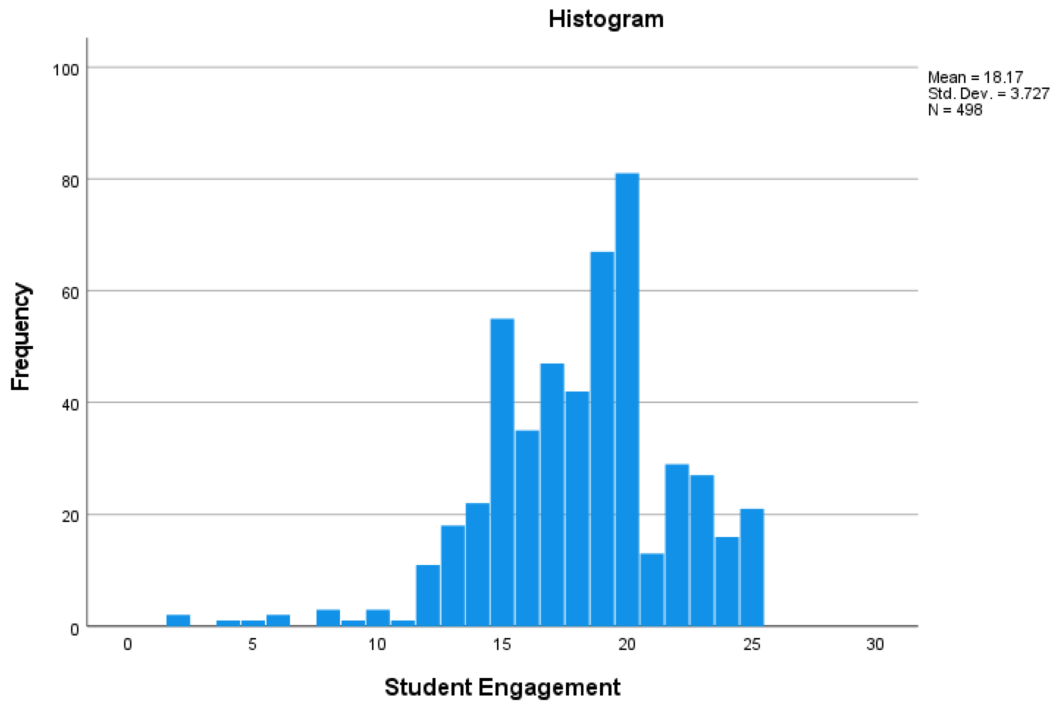

Figure K-4. Distribution of Student Engagement scale scores.

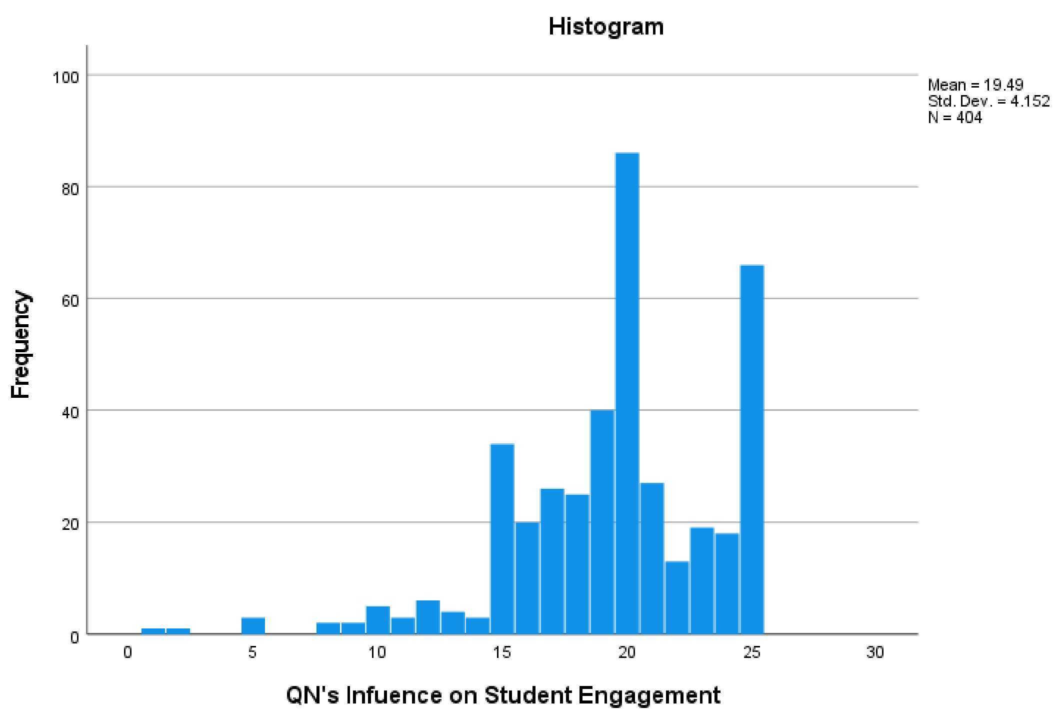

Figure K-5. Distribution of QuarkNet’s Influence on Student Engagement scale scores.

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=531, ranged from 6 to 20, with a Mean of 17.45 (SD = 2.49); and an alpha of 0.81 (reliability coefficient). See Figure K-6.

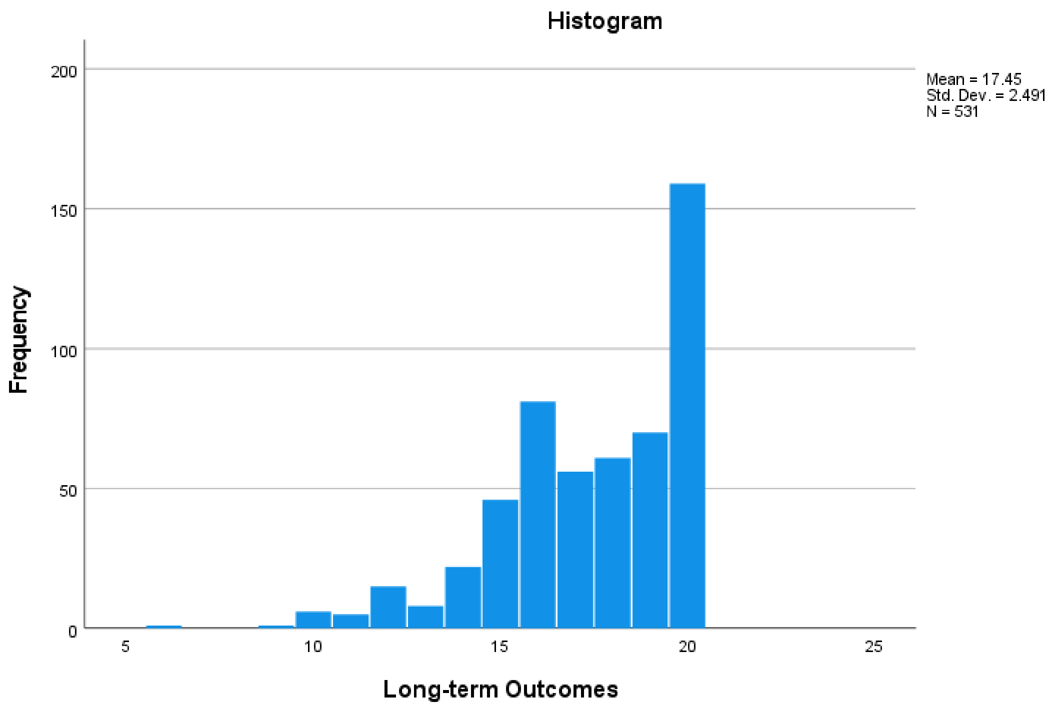

Figure K-6. Distribution of Long-term Outcomes: Teacher scale scores.

Supporting Tables: Exploration of NSF Suggested Analyses:
***New* Teacher Demographics and**
Unique Contribution of Select QuarkNet Programs

During a project and proposal review, NSF requested two additional sources of information about the implementation of the QuarkNet program. The first was related to the number and percent of participating teachers that are new to the program. Given the long-standing nature of this program, perhaps their concern which is notable, was whether the program has brought in or attracted a reasonable number of new teachers over the course of time helping to ensure that the program is reaching new audiences.

The second request was to explore the unique contributions to each of the major components of the program. Each of these requests is addressed in this appendix with summary information on these findings highlighted in the narrative of the final evaluation report.

Teachers *New* to QuarkNet

The following Table 1 represents a unique count of teachers who reported that they were new to the QuarkNet program during the 2019-2022 program years by center. And it includes a similar breakdown for the 2023 and 2024 program years, respectively. These counts are based on survey responses for a unique count total of 702. These data were based on a question, framed in an open-ended format, teachers were asked, *For how many years (approximately) have you participated in QuarkNet (including today or your most recent participation)?*

Most often, teachers new to the program either indicated that they were new; or had participated for one year or less in the program. When describing their participation as in and around one year, teachers frequently indicated that the workshop in question was their first. For this reason, the table includes both "new" and "1-year" responses as a representative number of new teachers. As indicated, these counts are broken down by QuarkNet center.

A total of 36% of teachers who participated in QuarkNet during the 2019-2022 program were new/1-year in the program. In the 2023 program year, 33% of participants were new/1-year in the program. Starting in the 2024 program year, a more complete profile of teachers new to QuarkNet based on registration/stipend information was available. Using this information a total of 96 out of the 302 teachers participating in 2024 were new to the program (or 32%). The full survey was able to gather data on 66 of these teachers out of a total of 199 matched surveys – this also represents about 33% of participating teachers.

Table 1
Unique Count of *New* Teachers at QuarkNet Centers: Across Several Program Years

Single or com-bined[a]	Summary from Previous Grant 2019-2022 Program Years				2023 Program Year			2024 Program Year		
	Center	Number of *New* Teachers		Total Number of Teachers	Number of *New* Teachers		Total Number of Teachers[c]	Number of *New* Teachers		Total Number of Teachers[c]
		New	1 year		New	1 year		New	1 year	
1	Black Hills State University	2	3	10	1	1	4	0	0	0
2	Boston/Brown University/ Northeastern University	0	4	15	3	0	3	0	0	4
2	Brookhaven National Laboratory/Stony Brook University	3	2	13	0	2	5	1	1	7
1	The Catholic University of America	0	6	11	0	1	5	1	0	6
1	Colorado State University	3	1	12	--	--	3	0	0	5
2	Fermilab/University of Chicago/College of DuPage	12	9	42	1	1	3	4	4	22
	~~Florida Institute of Technology~~ (Central Florida)	3	3	6	0	1	1	--	--	--
1	Florida International University	1	1	8	--	--	0	0	0	0
1	Florida State University	0	1	13	2	0	5	0	1	4
1	Idaho State University	2	4	13	--	--	0	0	0	2
2	Johns Hopkins University	0	0	15	4	2	7	0	0	6
1	Kansas State University	3	0	16	--	--	0	1	0	10
1	Lawrence Berkeley National Laboratory	1	7	20	0	1	2	0	0	4
1	Northern Illinois University	0	0	2	--	--	0	0	0	0
2	Oklahoma State University/Oklahoma State	1	0	17	3	9	15	1	0	7
1	Purdue University	0	0	0	1	2	3	0	0	1
1	Purdue University Northwest	0	1	5	--	--	0	0	0	0
1	Queensborough Community College	0	0	2	--	--	0	0	0	0
2	Rice University/ University of Houston	1	4	19	3	1	7	1	2	11
1	Rutgers University	0	0	3	--	--	0	0	0	0
1	Southern Methodist University	5	8	24	--	--	0	0	5	13
1	Syracuse University	3	4	22	3	2	6	2	0	5
1	Texas Tech University	1	1	3	--	--	0	0	0	1
1	University of Alabama[b]	0	0	0	0	1	1	0	0	0

Table 1 (con't.)
Unique Count of *New* Teachers at QuarkNet Centers: Across Several Program Years

Single or com-bined[a]	Summary from Previous Grant 2019-2022 Program Years				2023 Program Year			2024 Program Year		
	Center	Number of *New* Teachers		Total Number of Teachers	Number of *New* Teachers		Total Number of Teachers[c]	Number of *New* Teachers		Total Number of Teachers[c]
		New	1 year		New	1 year		New	1 year	
1	University at Buffalo -- SUNY	2	0	6	--	--	0	0	0	0
1	University of California – Irvine	6	1	8	6	3	9	0	1	1
	~~University of California – Riverside~~	0	0	0	--	--	--	--	--	--
1	University of California at Santa Cruz	0	0	1	--	--	1	0	0	0
1	University of Cincinnati	4	8	18	4	0	5	5	4	14
1	University of Florida	1	3	5	--	--	0	0	0	0
1	University of Hawai'i	2	2	6	0	1	1	0	0	0
2	University of Illinois at Chicago/ Chicago State University	0	3	10	--	--	0	0	0	1
2	University of Iowa/Iowa State University	1	3	14	0	5	7	0	0	0
1	University of Kansas	0	1	5	--	--	0	0	0	0
1	University of Minnesota	1	2	13	2	1	4	1	1	6
1	University of Mississippi	1	0	4	--	--	2	0	0	3
1	University of New Mexico	10	7	19	0	1	1	0	1	5
1	University of Notre Dame	0	1	19	1	0	2	0	0	5
1	University of Oregon	0	1	5	0	1	1	0	1	3
	~~University of Pennsylvania~~	0	0	0	--	--	--	--	--	--
1	University of Puerto Rico at Mayaguez	3	1	16	3	3	9	2	1	10
	~~University of Rochester~~	0	0	3	0	0	1	1	0	7
1	University of South Dakota[b]	0	0	0	1	0	1	0	1	11
	~~University of Tennessee~~			2						
1	University of Washington	0	0	0	1	2	3	1	0	4
1	University of Wisconsin - Madison	0	0	1	--	--	1	0	0	0

Table 1 (con't.)
Unique Count of *New* Teachers at QuarkNet Centers: Across Several Program Years

Single or com-bined[a]	Summary from Previous Grant 2019-2022 Program Years				2023 Program Year			2024 Program Year		
	Center	Number of *New* Teachers		Total Number of Teachers	Number of *New* Teachers		Total Number of Teachers[c]	Number of *New* Teachers		Total Number of Teachers[c]
		New	1 year		New	1 year		New	1 year	
1	Vanderbilt University	0	3	11	--	--	2	0	0	2
1	Virginia Center (Hampton, George Mason, William & Mary Universities)	0	2	11	2	4	8	2	2	12
1	Virginia Tech	1	1	9	--	--	0			10
1	Virtual Center	1	1	13	--	--	0			6
1	Louisiana Tech	--	--	--	--	--		1	0	1
	~~Wayne State University~~	0	0	0						
	Missing	0	0	2				3	0	6
56	Total	74 (15.3%)	99 (20.5%)	483	41 (15.9%)	45 (17.5%)	128[c] 257	35 (17.5%)	31 (15.5%)	199

Note. This table represents a unique count of teachers participating in QuarkNet's Teacher Survey over the program years presented in this table. The data in this table should **not** be used as a count of the number of teachers who have participated in QuarkNet in a given program year (e.g., 2023). In 2023, a total of 257 teachers completed their survey; of these teachers 128 (nearly 50%) were new to the survey process. Thus, an entry of "--" means a center did not have any new/1 year teachers for the 2023 program year. And similarly, an entry of "0" means that no teacher who participated in 2023 was new to the survey process.

[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).
[b]University of Alabama, and University of South Dakota are new centers.
[c]Represents a unique count of teachers. A total of 257 teachers participated in survey in 2023 many of whom had participated in QuarkNet and captured in the survey in previous years.

Unique Contribution of Major QuarkNet Program Components

At the suggestion of an NSF-based on project and proposal review, we have conducted a series of statistical analyses where each of the following QuarkNet program components, that is, Data Camp participation, Variety of Workshop engagement, and MasterClass participation, are analyzed simultaneously. In these analyses, each comprised of a 2x3x2 Analysis of Variance (ANOVA), the contribution of each QuarkNet component is simulatenoutsly assessed using the following as a dependent measure: Core Strategies (level of exposure to key instructional strategies), reported Approach to Teaching, the perceived influence QuarkNet has had on teaching in the classroom, reported Student Engagement of their students (as assessed by teachers), the influence of QuarkNet on this reported Student Engagement, and Long-term Outcomes.

The results of these analyses are summarized in Table 2 and statistical details including means, standard deviations, number of teachers included in each analysis and reported statistical significance levels are shown in Table 3.) *These analyses suggest that Data Camp and Variety of Workshops each contribute to teachers' reported engagement in Core Strategies, and that each major program component of QuarkNet contributes uniquely to at least one or more outcome measures: Approach to Teaching; QuarkNet's Influence on Teaching, Student Engagement (as reported by teachers), QuarkNet's Influence on Student Engagement; and Long-term Teacher Outcomes.* Thus, these analyses suggest that each of the major components of QuarkNet contribute *uniquely* to outcomes as measured.

These analyses, although encouraging, are limited in that each *does not* take into consideration that teachers are nested within their individual QuarkNet center. For the impact of centers to be included in this assessment of unique contributions, each center would have to include at least a unique count of 30 teachers (approximately 10 teachers who engaged in workshops, 10 engaged in masterclasses, and 10 who participated in Data Camp). The survey data collected over 2019-2024 does not support a unique count of this required high volume of data. Data from previous evaluations focused on the formative assessment of QuarkNet and did not collect data that are comparable to the outcomes data collected for the past several years.

As reflected in the outcomes analyses presented in the evaluation report narrative, centers contribute significantly to QuarkNet's reported impact. Later sections of both the report and appendices offers some insights to which QuarkNet components may have helped contributed to teachers' implementation of QuarkNet content and materials in their classrooms. In general, however, while these self-reported applications of QuarkNet suggest how materials and content are applied in the classroom, the unique contribution of a particular QuarkNet component is more difficult to discern from these responses. In large part, the value of responses to open-ended survey questions is the perceived cumulation of QuarkNet participation in toto as is also the case for the outcomes analyses suggested in the evaluation report. Arguing that the strength of QuarkNet participation is in its ability to offer a professional development over a sustained duration (i.e., Darling-Hammond, et al., 2017 characteristics of effective profession development) may ease the frustration and/or limitations of discerning the unique contributions of each of the major program components.

Table 2
Analyses Comparing Individual QuarkNet Components:
Unique Contributions of Each

QuarkNet Program Component	Statistical Results	Other Relationships	Long-term Teachers: Outcomes
Data Camp	Data Camp experience was shown to be statistically significantly related to higher **Core Strategies**[a] scores and **Approach to Teaching** scores (on average) by participating teachers.	Workshop experience was also statistically significantly related to higher **Approach to Teaching** scores (on average).	All QuarkNet components Data Camp, Variety of Workshops, and Masterclass participation were statistically significantly related to higher **Long-term Teacher Outcomes**[a] scores (on average).
Variety of Workshops	Participation in workshops (two or more) as reported by teachers was statistically significantly related to higher scores (on average) for **Core Strategies,**[a] **Approach to Teaching**, **QN's Influence on** Teaching,[a] and **Student Engagement.**	Higher **Student Engagement** scores (on average) were also statistically significantly related to teachers' participation in Masterclass.	
Masterclass	Participation in Masterclasses (one or more) as reported by teachers was statistically significantly related to **Student Engagement**, and **QN's Influence on Student Engagement** scores.	Higher **Student Engagement** scores were also statistically significantly related to reported workshop participation.	

Note: This table summarizes the results of a series of ANOVA analyses where each of the listed QuarkNet program components are treated simultaneously as independent variables, and where in separate analyses Core Strategies, Approach to Teaching; QN's Influence on Teaching, Student Engagement, QN's Influence on Student Engagement, and Long- term Teacher Outcomes scores each is treated as the dependent variable. Long-term outcomes include survey items that address: 1. Use resources as supplements. 2. Increased science proficiency; 3. Develop collegial relationships; and 4. Students are more comfortable with inquiry-based sciences. [a]Unequal variance was noted as well. Based on scale scores created from survey responses from 2019 through 2023 program years.

Table 3
Summary of Analyses: Unique Contribution of Each Major QuarkNet Program Component

	Program Exposure and Teacher and Student Outcomes																	
QN Program Component	Core Strategies[a] (A)			Approach to Teaching[b] (B)			QN's Influence on Teaching[c] (C)			Student Engagement[d] (D)			QN's Influence on Student Engagement[e] (E)			Long-term Oucomes[f] (F)		
	Score Range 12-60			Score Range 12-60			Score Range 12-60			Score Range 5-25			Score Range 5-25			Score Range 4-20		
Data Camp																		
	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD	N
No	**52.27**	**7.44**	**377**	**40.76**	**8.74**	**339**	46.54	10.98	284	17.65	3.77	311	19.16	4.30	228	**17.07**	**2.62**	**339**
Yes	**55.24**	**5.75**	**197**	**44.88**	**7.89**	**189**	48.74	9.20	186	19.03	3.49	187	19.93	3.92	176	**18.13**	**2.09**	**192**
Variety of Workshops																		
No	**52.27**	**8.09**	**257**	**40.45**	**8.60**	**231**	**45.19**	**11.70**	**195**	**17.56**	**3.53**	**212**	18.95	4.32	153	**16.99**	**2.77**	**231**
One Workshop	**54.70**	**5.88**	**162**	**41.80**	**9.09**	**147**	**47.80**	**10.20**	**126**	**17.57**	**4.25**	**136**	19.30	4.32	111	**17.37**	**2.50**	**146**
Two or More	**55.94**	**5.12**	**155**	**45.43**	**7.42**	**150**	**49.98**	**7.71**	**149**	**19.57**	**3.09**	**150**	20.24	3.73	140	**18.83**	**1.76**	**154**
Masterclasses																		
No	53.25	7.35	396	41.13	8.91	357	46.40	11.22	303	**17.59**	**3.79**	**330**	**18.86**	**4.37**	**244**	**17.03**	**2.59**	**356**
One or More	55.49	5.73	178	44.55	7.66	171	49.24	8.31	167	**19.30**	**3.33**	**168**	**20.45**	**3.60**	**160**	**18.31**	**2.03**	**175**

Note: This table summarizes the results of a series of ANOVA analyses where each of the listed QuarkNet program components are treated *simultaneously* as independent variables; where in separate analyses Core Strategies, Approach to Teaching; QN's Influence on Teaching, Student Engagement, QN's Influence on Student Engagement and Long-term Outcomes each is treated as the dependent variable. **Bold face comparisons (and shaded) reflect statistically significant findings**. Student Engagement/QN Influence on Student Engagement and Long-term Outcomes measured on a different scale. [For columns A-C, range of scores is 12 to 60; for columns D and E the range of scores is 5 to 25; and the range of possible scores for column F is 4 to 20.] Includes survey responses from 2019-2023.

[a]**Core Strategies**
When an Analysis of Variance (ANOVA) analysis was conducted with Data Camp, Variety of Workshops, and Masterclass simultaneously analyzed with Core Strategies as the dependent variable, with unequal variance based on Levene's Test [$F_{(11, 562)} = 5.15$, $p < .001$], Data Camp [$F_{(1, 562)} = 4.12$, $p < .05$] and the experience of two or more workshops was statistically related to higher Core Strategies scores [$F_{(2, 567)} = 4.75$, $p < .001$].

[b]**Approach to Teaching**
When an Analysis of Variance (ANOVA) analysis was conducted with Data Camp, Variety of Workshops, and Masterclass simultaneously analyzed with Approach to Teaching as the dependent variable, Data Camp [$F_{(1, 516)} = 11.19.47$, $p < .001$] and the experience of two or more workshops [$F_{(2, 516)} = 7.89$, $p < .0013$].were statistically related to higher Approach to Teaching scores.

[c]**QN's Influence on Teaching**
When an Analysis of Variance (ANOVA) analysis was conducted with Data Camp, Variety of Workshops, and Masterclass simultaneously analyzed with QN's Influence on Teaching as the dependent variable, with unequal variance based on Levene's Test [$F_{(11, 458)} = 3.50$, $p < .001$], the experience of two or more workshop was statistically related to higher QN's Influence on Teaching [$F_{(2, 458)} = 4.85$, $p < .01$].

[d]**Student Engagement**
When an Analysis of Variance (ANOVA) analysis was conducted with Data Camp, Variety of Workshops, and Masterclass simultaneously analyzed with Student Engagement as the dependent variable, the experience of two or more workshops [$F_{(2, 486)} = 7.81$, $p < .001$] , and the experience of Masterclass (one or more) [$F_{(1, 486)} = 7.91$, $p < .01$] were statistically related to higher Student Engagement scores.

[e]**QN's Influence on Student Engagement**
When an Analysis of Variance (ANOVA) analysis was conducted with Data Camp, Variety of Workshops, and Masterclass simultaneously analyzed with QN's Influence on Student Engagement as the dependent variable the experience of Masterclass (one or more) [$F_{(1, 392)} = 8.26$, $p < .01$] was statistically related to higher QN's Influence on Student Engagement scores.

[f]**Long-term Outcomes**
When an Analysis of Variance (ANOVA) analysis was conducted with Data Camp, Variety of Workshops, and Masterclass simultaneously analyzed with Long-term Outcomes as the dependent variable, with unequal variance based on Levene's Test [$F_{(11, 519)} = 4.53$, $p < .001$, Data Camp [$F_{(1, 519)} = 9.34$, $p < .01$], the experience of two or more workshops [$F_{(2, 519)} = 3.8$, $p < .03$], and the experience of Masterclass [$F_{(1, 519)} = 9.84$, $p < .01$] were statistically related to higher Long-term Outcome scores.