Appendix A

QuarkNet Centers:
Status 2018-2019 Program Year

| Center | QuarkNet Status | Center | QuarkNet Status |
|---|---|---|---|
| Black Hills State University | Active | University at Buffalo – SUNY | Active |
| Brown & Northeastern University | Active | University of California - Riverside | Active |
| Brookhaven National Laboratory and Stony Brook University | Active | University of California - Santa Cruz | On Sabbatical |
| Catholic University of America | Active | University of Cincinnati | Active |
| Chicago State University (with University of Illinois) | Active | University of Florida | Active |
| Colorado State University | Active | University of Hawaii | Active |
| Fermilab & University Chicago | Active | University of Houston (with Rice University) | Active |
| Florida Institute of Technology | On Sabbatical | University of Illinois Chicago (with Chicago State University) | Active |
| Florida International University | Active | University of Iowa/Iowa State | Active |
| Florida State University | Active | University of Kansas | Active |
| Hampton, George Mason, William & Mary Universities | Active | University of Minnesota | Active |
| Idaho State University | Active | University of Mississippi | Active |
| Johns Hopkins University | Active | University of New Mexico | Active |
| Kansas State University | Active | University of Notre Dame | Active |
| Lawrence Berkeley National Laboratory | Active | University of Oklahoma | Active |
| Northern Illinois University | Active | University of Oregon | Active |
| Oklahoma State | Active | University of Pennsylvania | On Sabbatical |
| Purdue University | Active | University of Puerto Rico-Mayaguez | Active |
| Purdue University Northwest | Active | University of Rochester | Active |
| Queensborough Community College | Active | University of Tennessee | Active |
| Rice University (with University of Houston) | Active | University of Washington | Active |
| Rutgers University | Active | University of Wisconsin-Madison | Active |
| Southern Methodist University | Active | | |
| Syracuse University | Active | | |
| Texas Tech University | Active | | |
| Vanderbilt University | Active | | |
| Virginia Tech University | Active | | |
| Virtual Center | Active | | |
| Wayne State University | On Sabbatical | | |

Note. Information compiled by S. Wood, K. Cecire and M. Bardeen June 2019. There were 55 centers -- 50 (year 3+ centers); 1 virtual center; and 4 centers on sabbatical.

# *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?

Key Stakeholders: Initial Interviews

| Name | Affiliation | Email Address | Email Sent | Phone Number | Scheduled Date | Completed |
|---|---|---|---|---|---|---|
| Wayne Mitchell | Lead PI Professor, Dept. of Physics University of Notre Dame | mwayne@nd.edu | 9/17/2018 | 574-631-8475 | 9/25/2018 1:30 p.m. 10/11/2018 Noon | 9/25/2018 1:30 p.m. 10/11/2018 12:15 p.m. |
| Morris Swartz | Co-PI, Johns Hopkins University | morris@jhu.edu | 9/17/2018 9/25/2018 | 410-516-5159 | 10/1/2018 1:00 p.m. | 10/1/2018 1:00 p.m. |
| Marge Bardeen | Co-PI Fermilab/retired | mbardeen@me.com | 9/17/2018 | 630-399-9609 | 9/18/2018 2:00 p.m. | 9/18/2018 2:00 p.m. |
| Deborah Roudenbush | Education Advisor Oakton HS, Fairfax VA Public Schools (retired) | droudebush@cox.net | 9/17/2018 9/25/2018 | 703-302-0059 | 10/2/2018 Noon | 10/2/2018 12:30 p.m. |
| Jeremy B. Smith | QuarkNet Educational Specialist, Balitmore County Public Schools | jsmith10@bcps.org | 9/17/2018 9/25/2018 | 443-834-9406 | 9/29/2018 2:00 p.m. | 9/29/2018 2:00 p.m. |
| Ken Cecire | Staff Teacher University of Notre Dame | Kenneth.W.Cecire.1@nd.edu | 9/17/2018 | 574-631-4736 | 9/19/2018 3:00 p.m. 9/25/2018 2:00 p.m. | 9/19/2018 3:00 p.m. |
| Shane Wood | Staff Teacher University of Notre Dame | swood5@nd.edu | 9/17/2018 9/25/2018 | 612-242-7386 | 9/28/2018 1:00 p.m. | 9/28/2018 1:00 p.m. |
| Mark R. Adams | Cosmic Ray Coordinator Fermilab | adams@fnal.gov | 9/17/2018 | 630-508-7459 | 9/27/2018 1:00 p.m. | 9/27/2018 1:00 p.m. |
| Spencer Pasero | Fermilab, Manager of Office of Education and Public Outreach | spasero@fnal.gov | 9/17/2018 | 630-840-3076 | 9/24/2018 2:00 p.m. | 9/24/2018 2:00 p.m. |
| M. Jean Young | Past Evaluator | jyoung@dakotacom.net | 9/17/2018 | 520-271-3679 | 9/26/2018 11:30 p.m. | 9/26/2018 11:30 p.m. |
| Ginny Beal | Past Evaluator | yoginny@cox.net | 9/17/2018 | 520-325-0354 | 9/21/2018 Noon | 9/21/2018 Noon |

Email to Stakeholders

Hi

As I mentioned during the QuarkNet leadership meeting in August, I am interested in conducting a structured interview with you. The purpose of this interview is to gain your ai perspective on various components of the QuarkNet program. I estimate that this conversation will take between 1 to 1 ½ hours to complete. I will be digitally recording our conversation for note taking purposes only; and will gladly turn off the recording at any time if you request this. Your individual responses will remain anonymous but collectively used to develop the Program Theory Model of QuarkNet.

Please suggest a few dates and times (please indicate your time zone, I am in central time) when you are available. If evenings are best, please let me know. I will try and accommodate your suggested times as best as my schedule will permit. Also, please suggest the best phone number to reach you that day/time. Once we have a scheduled date and time, I will send you a written protocol that will be used to guide our conversation.

Thank you in advance for your participation. Gathering information from those who know QuarkNet best will help insure that the Program Theory Model is representative of the program and aid in its utility to guide program modifications and inform evaluation efforts.

Best,
Kathy

# QuarkNet Partners

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

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

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

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

QuarkNet: The QuarkNet Collaboration is a long-term, national program that *partners high school science teachers with particle physicists* working in experiments at the scientific frontier. A professional development program, QuarkNet immerses teachers in authentic physics research and seeks to engage them in the development of instructional strategies and best practices that facilitate the implementation of these principles in their classrooms.

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

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

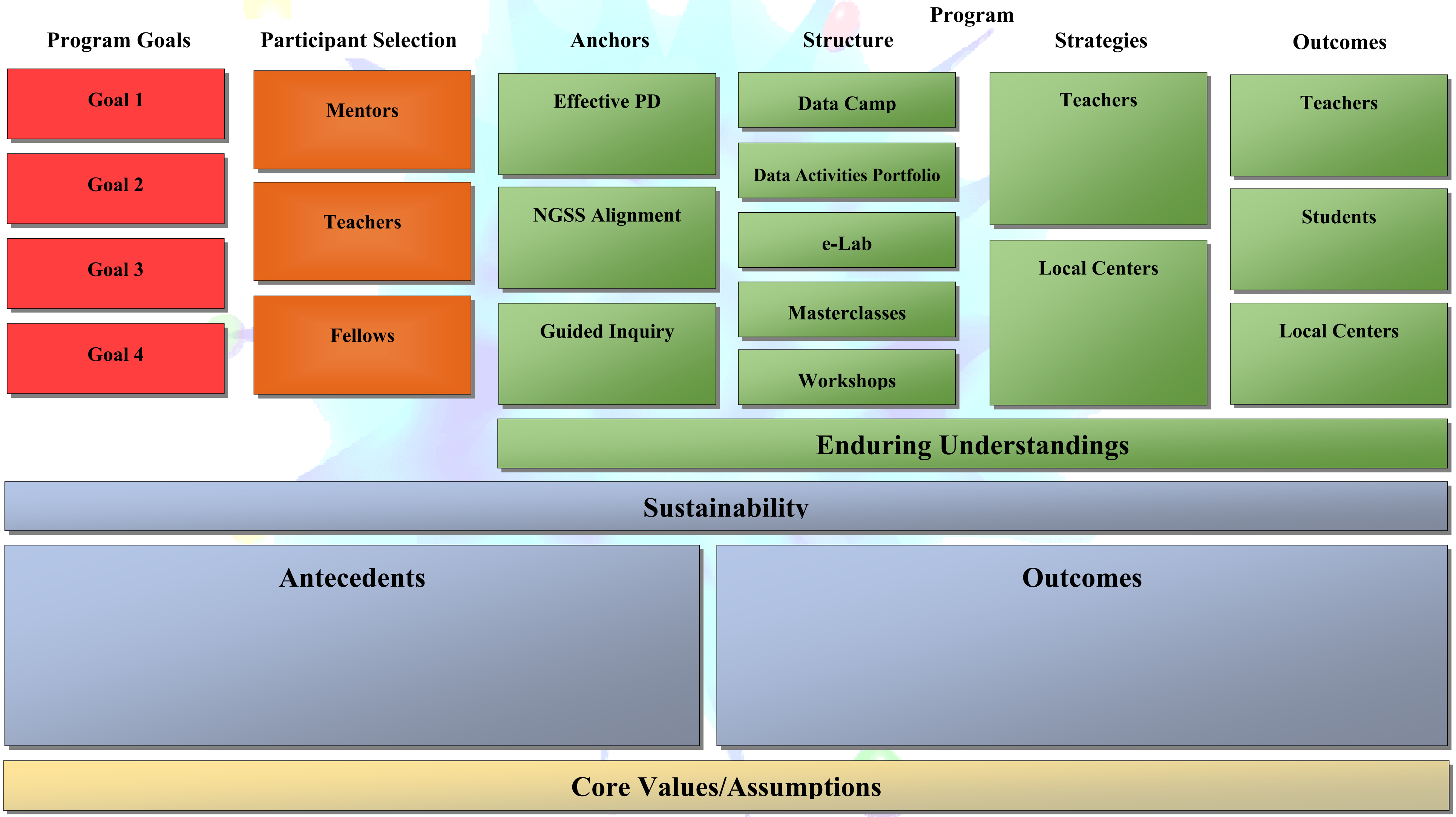
**U.S. CMS:** A collaboration of more than 900 scientists from 50 U.S. institutions who make significant contributions to the Compact Muon Solenoid (CMS) detector. Discoveries from the CMS experiment are revolutionizing our understanding of the universe. USCMS is a co-sponsor of QuarkNet.

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

# QuarkNet Program Theory Model

**Program Statement:** The QuarkNet Collaboration is a long-term, national program that partners high school science teachers with particle physicists working in experiments at the scientific frontier. A professional development program, QuarkNet immerses teachers in authentic physics research and seeks to engage them in the development of instructional strategies and best practices that facilitate the implementation of these principles in their classrooms.

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



# QuarkNet Program Theory Model

**Program Statement:** The QuarkNet Collaboration is a long-term, national program that partners high school science teachers with particle physicists working in experiments at the scientific frontier. A professional development program, QuarkNet immerses teachers in authentic physics research and seeks to engage them in the development of instructional strategies and best practices that facilitate the implementation of these principles in their classroom.

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

## Program Goals

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

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

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

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

## Participant Selection

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

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

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

## Program Anchors

**Characteristics of Effective Professional Development**[1]

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

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

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

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

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

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

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

# Program Structure

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

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

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

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

[2]Conseil Européen pour la Recherche Nucléaire

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

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

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

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

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

## Program Strategies

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

**Teachers**

*Provide opportunities for teachers to be exposed to:*

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

*Provide opportunities for teachers to:*

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

**Local Centers**

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

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

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

## Program Outcomes

**Teachers**

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

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

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[4] College Board Advanced Placement science standards and practice; and AP Physics; International Baccalaureate Science standards and practices.

[5] To the extent possible in their school setting.

**(And their) Students will be able to:**

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

**Local Centers**

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

*Through engagement in local centers*

***Teachers as Leaders:***

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

***Mentors:***

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

***Teachers and Mentors:***

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

## Enduring Understandings (See last page.)

# Sustainability[a]

## Antecedents

**Characteristics of the Specific Program**

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

**Organizational Setting at the Center-level Program**[c]

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

**Specific Factors Related to the Center-level Program**

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

## Outcomes

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

## Core Values/Assumptions

*QuarkNet provides opportunities:*

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

*The program is based on the premise that:*

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

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

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

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

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

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

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

## Enduring Understandings of Particle Physics

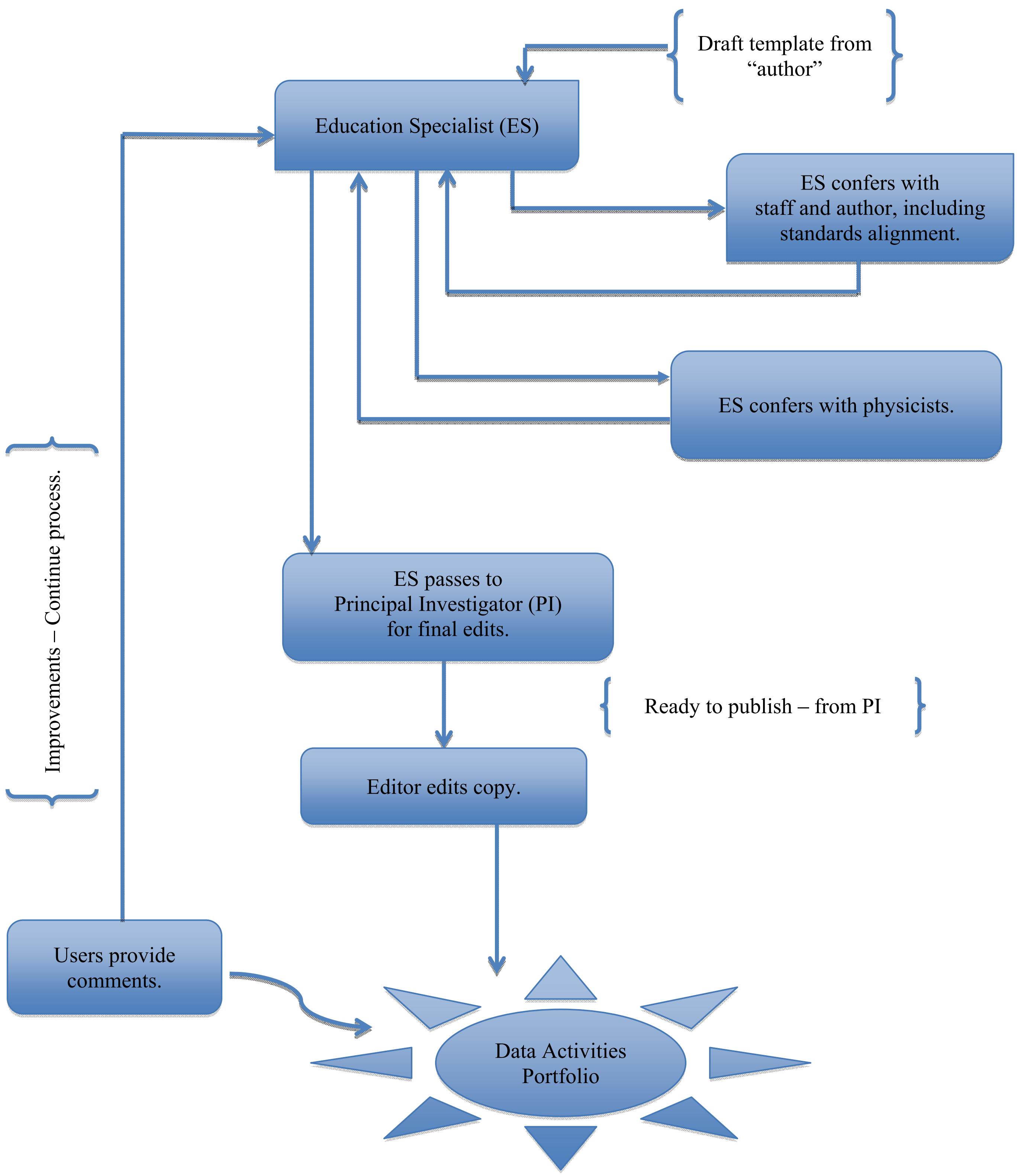
1. Scientists make a claim based on data that comprise the evidence for the claim.
2. Scientists use models to make predictions about and explain natural phenomena.
3. Scientists can use data to develop models based on patterns in the data.
4. Indirect evidence provides data to study phenomena that cannot 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 datasets.
6. Scientists form and refine research questions, experiments and models using observed patterns in large data sets.
7. The Standard Model[6] 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.

Developed by Young, Roudebush, Smith & Wayne, 2019

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

# Instructional Design Pathway and Templates for Data Activities Portfolio

**<u>PROCESS</u>:** To ensure what we publish is of highest quality.



**<u>CRITERIA USED AT INSTRUCTIONAL DESIGN STAGE – ANNOTATED</u>**

***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 build background skills and knowledge needed to do a Level 1 activity. Students analyze one variable or they determine patterns, organize data into a table or graphical representation and draw qualitative conclusions based on the representation of these data.

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

Level 2 Students use skills from Level 1but must apply a greater level of interpretaion. The analysis tasks are directed toward specific investigations. Datasets are large enough that hand calculation is not practical, and the use of statistics becomes central to understanding the physics. They perform many of the same analysis tasks but must apply a greater level of interpretation.

Level 3 Students use the skills from Level 2. They develop and implement a research plan utilizing large datasets. They have choices about which analyses they do and which data they use; they plan on their own investigations.

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

**Micro Design**

1. There are behavioral objectives.

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

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

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

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

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

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

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

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

# TITLE (TIMES NEW ROMAN, 18)
## TEACHER NOTES (TIMES NEW ROMAN, 16)

*(TIMES NEW ROMAN, 12)*

**DESCRIPTION (THIS TYPE OF STYLE CAN BE FOUND UNDER *FORMAT, FONT, SMALL CAPS*.)**

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

**STANDARDS ADDRESSED (FILL IN AS APPROPRIATE. THIS LIST SHOWS FORMAT.)**

*Next Generation Science Standards*
- Science and Engineering Practices
  - 4. Analyzing and interpreting data
  - 5. Using mathematics and analytical thinking
- Crosscutting Concepts
  - 1. Observed patterns

*Common Core Literacy Standards*
- Reading
  - 9-12.4 Determine the meaning of symbols, key terms . . .
  - 9-12.7 Translate quantitative or technical information . . .

*Common Core Mathematics Standards*
- MP2. Reason abstractly and quantitatively.

*AP Physics 1 Standards*
- Exemplars

*AP Physics 2 Standards*
- Exemplars

*IB Physics Standards*
- Exemplars

**ENDURING UNDERSTANDINGS**

- One EU per activity

Choose from one of the following:

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

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

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

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

- xxx

### PRIOR KNOWLEDGE

What students should probably know before they engage in this activity

### BACKGROUND MATERIAL

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

### RESOURCES/MATERIALS

### IMPLEMENTATION

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

### ASSESSMENT

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

## NOTE: WE PROVIDE TWO TEMPLATES FOR STUDENT PAGES.

## GUIDELINES FOR WHICH TEMPLATE TO USE:

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

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

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

# TITLE (TEMPLATE FOR STUDENT PAGES)
## STUDENT PAGE

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

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

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

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

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

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

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

Assessment is a student report.

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

# TITLE (TEMPLATE FOR STUDENT REPORT SHEET)

## STUDENT REPORT

Research question: ________________________________________________

Reason: ________________________________________________

Physics principles: ________________________________________________

Hypothesis and reasoning: ________________________________________________

**Claim:**

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

**Evidence:**

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

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

**Reasoning:**

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

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.

**Sources of Uncertainty in Measurement:**

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

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

**Practical Applications:**

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

What is the value of what you learned?

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<br>(T, S, R) | 7/22/14 | 3/20/26 | | ✓ |
| Plotting LHC Discovery<br>(T and S pages) | 3/29/14 | 2/25/16 | ✓ 4/16 | ✓ |
| Calculate the Top Quark Mass<br>(T and S) | 3/21/14 | 3/20/16 | | ✓ |
| Quark Workbench | 3/20/14 | 3/15/16 | ✓ | ✓ |
| Mass of U.S. Pennies<br>(T notes, S handout) | 3/10/14 | 2/25/16 | ✓ | ✓ |
| Making it 'Round the Bend<br>(3 activities) | 7/25/14 | 3/18/16 | | ✓ |
| Rolling with Rutherford<br>(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<br>*(Shift Report 8/2/16)* | 7/21/14 | 3/15/16 | ✓ 4/16 | ✓ |
| Cosmic Rays and the Sun<br>(T notes) | 3/17/15 | 2/25/16 | ✓ | ✓ |
| TOTEM Data Express<br>(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<br>(a reworked Calculate Top Quark Mass) | |
| Special Relativity Holds the Answers | |