**Evaluation Section: NSF Annual Report**

**September 2013**

This Annual Evaluation Report provides information about the QuarkNet program as it transitions to the current grant. This year’s (2012-2013) evaluation is also a transition between the previous Evaluation Matrix (see NSF Annual Report, Evaluation Section, September 2012) and a new matrix that matches the Strategic Plan for the current grant. The new Matrix focuses on evaluation of QuarkNet centers and data portfolios. While the evaluation of centers has not substantively changed, data portfolios are new and under development. Since this report addresses this transition, there were no data available to answer several study questions related to data portfolios, and, the report includes a *Transition Section* for which data were collected related to the previous Matrix. Questions from the new Evaluation Matrix are addressed below, preceded by a summary of findings and data collection and analysis for centers, then for data portfolios.

The evaluation data were collected between September 2012 and September 2013.

**Summary of Findings**

Below, is a summary of findings for the effectiveness of several program components, including those for which data were collected in this transition to the new Matrix.

**Centers**

Data on QuarkNet Centers were gathered by leadership fellows during their visits to institutes summer 2013, and spring telephone interviews and classroom visits to teachers from centers whose institutes they visited in summer 2012. Each year centers “considered to not be operating effectively” are suggested by QuarkNet staff to be evaluated. A teacher survey was conducted in the spring to a random selection of QuarkNet teachers. Findings indicate that, in general, the centers that were visited are operating as effectively as many others and the teachers are typical of those participating at other centers, therefore these data provide further information about centers in general.

***Institute Visits:*** During the summer of 2013, leadership fellows visited institutes at four QuarkNet centers. One center had a teacher institute and a student program. The centers were viewed by staff as struggling prior to the visits.

* The activities/projects offered at the four institutes gave the teachers an opportunity to explore research, inquiry practices and classroom implementation.
* The leaders at the centers appeared to be making great efforts to keep the programs going and increase the numbers of participants.
* The centers appeared to face obstacles that are common to many QuarkNet centers, in terms of mentors’ time and access to supplemental funds.
* Concerns expressed by the fellows about the centers have to do with the needs of the teachers in terms of technology and equipment; also funding and maintaining communities.

***Teacher Interviews:*** During 2013 teachers were interviewed by leadership fellows during a classroom visit and during institute visits and by telephone. Twenty-five teachers were interviewed. Of those only two did not teach physics; 17 reported participating in QuarkNet activities such as summer institutes and masterclasss.

* Teachers reported they engaged in activities that supported QuarkNet goals of increasing their knowledge of particle physics and involving their students in working with data and with research projects. They said the types of activities provided at institutes included: building/ maintaining Cosmic Ray detectors or other equipment, lectures, tours, introductory particle physics, implementing particle physics in the classroom, planning and sharing teaching ideas, Cosmic Ray e-labs and ongoing student research projects. Participation in national QuarkNet was: Cosmic Ray e-lab, Masterclass, Boot Camp, CMS e-lab, LIGO e-lab, Teaching & Learning Fellows, LHC Fellows, CMS Fellow and trip to CERN.
* Direct connections for how to implement QuarkNet in their classrooms varied from making lesson plans and games as a group to learning information on fundamental particles, conducting independent research projects, data analysis with detectors, inquiry-based instruction, modern physics topics, videoconferences, using detectors, demonstrations by professors for classroom transfer.
* Supports to centers include mentors and teacher leaders at the centers and staff teachers at the national level. Leadership at the centers is mostly done by the mentors. Of the 17 responses related to leadership, 10 were mentors, four were mentors and teachers and three were teacher leaders. There were seven responses about center mentors’ activities and interactions with the teachers. The support they offer is in the form of organizing workshops, setting up detectors, contacting participants, instructing on how to implement QuarkNet and running a student research program. Twenty teachers commented that QuarkNet Staff teacher support included: detector support, moral support, Friday Flyer, Emails/Calls/Support, runs masterclass and presents at QuarkNet “meeting.” Most of the teachers could identify the staff teacher assigned to their center; three could not.
* There were 42 total instances of teachers implementing QuarkNet activities at lower duration of one-to-two or three-to-five lessons compared to 29 instances of longer durations of one to two weeks, or long-term projects. Other topics included scientific inquiry, cloud chambers and engineering design. QuarkNet teachers who teach grades 10-12, and higher-level classes tended to engage students in lessons or projects of longer duration. Those teaching lower grades implemented topics such as *Particle Adventure* and the Standard Model in one or two lessons rather than long-term projects, and tended not to be involved in professional activities as much as those who teach higher grades.
* Based on past data, teachers who are more experienced in QuarkNet usually participate in activities that indicate a high degree of professionalism, which is known to contribute to successful QuarkNet centers. This year 12 (40%) have given workshops that include local and district physics gatherings, mini-workshops, professional development, State STA, AAPT, LIGO and particle physics workshops. Twenty-two (88%) of the teachers have attended meetings of professional organizations such as AAPT (One helped host an AAPT session), NSTA, State STA, State APT, School & university meetings. Twenty-one have been involved in leadership at their schools in the following capacities: department chair, technology mentor/committees, curriculum/science task force, policy review/site council or recruiting QuarkNet teachers and students.

*Classroom Visits:* Fellows visited nine teachers’ classrooms.

* All of the teachers appeared to be dedicated to introducing particle physics content or current topics in science and research in their classrooms, barring equipment and technology challenges. While in most cases, the topics introduced were not related to particle physics, the teachers exhibited several “best practice” strategies, especially inquiry and research-based projects, which are advocated by QuarkNet
* Based on the ratings of their students’ classroom habits and class activities, five to seven of the teachers included inquiry. All nine of the teachers engaged in instructional strategies, and seven of the nine focused on instructional emphases that reflected inquiry-based teaching and learning. Seven of the teachers had students work in groups or pairs, indicating collaborative efforts. About half (4 - 6) involved inquiry in their discussions and hands-on work.

***Teacher Survey:*** The survey was placed online by QuarkNet staff in early spring of 2013. The overall response rate this year was 54 per cent after exhaustive efforts to achieve a greater number of responses, therefore could not be said to represent QuarkNet teachers. These data, however, did indicate that results are similar to past results, when there was a random sample. In addition, findings corroborated much of the data collected by fellows during interviews and site visits.

* Survey responses revealed that both the practices that support inquiry-based learning, collaboration and research and those that do not support were used at high frequencies. This year’s data show more frequent use of those practices that are not considered to be best practice, according to national standards, by more experienced QuarkNet teachers, possibly indicating a decline over time.
* Teachers participate in programs and activities that support learning communities and professional development as evidenced by the numbers of teachers who have made QuarkNet-related presentations (10 or 17%), shared information with colleagues (48 or 82%), developed new materials for courses (45 or 60%) and held leadership roles in their schools and districts (14 or 23%).
* As in past years, teachers have attended a high number (116) of QuarkNet programs other than their local summer institute: Cosmic Ray e-lab and Teaching and Learning workshops, masterclass and Boot Camp. Therefore, programs offered nationally and not only center-related, are being attended at high rate.
* Responses indicated that teachers used resources and topics in the classroom that included Cosmic Ray Detector, Cosmic Ray e-lab, *Particle Adventure*, Standard Model, LHC Web Site, CMS e-lab and LIGO e-lab. Teachers widely used particle physics examples such as Conservation Laws, Momentum, Vectors, Energy, Nuclear physics/energy and Energy–Mass conversion (E=mc2).

**Data Portfolios**

Data Portfolios are being developed to address three levels of student engagement with data: 1) Introductory Activities; 2) in-class and national/international CMS/ATLAS masterclass; 3) CMS, Cosmic Ray, LIGO e-labs. This year data portfolios were under development, therefore data on support structures, feedback from participants were not available.

***CMS masterclass workshops:*** There were several Data Workshops conducted this summer that were the precursor to CMS masterclass workshops, levels 1 and 2 of data portfolios. One workshop was observed for formative evaluation purposes. Following are “best practices” that were observed:

* A lot was covered but did not feel rushed. Relevant and appropriate information was provided then teachers were referred to resources to access; not too much (more is less) was addressed nor was anything substantive left unaddressed.
* Scientists’ talks were at an appropriate level. Teachers‘ questions were answered at their level of understanding. The atmosphere encouraged an easy exchange between mentors and teachers, teachers and facilitators.
* Activities were done in groups so that teachers could experience them as would a student, then discussed as adults and as teachers, i.e., classroom implementation. Teachers had plenty of opportunity to interact with the data and engage in activities in pairs or groups. The workshop was an excellent model for how to organize and conduct the activities and data analyses with their students.
* Implementation was discussed throughout and focused on each day and at the end of the workshop. Teachers were left with multiple ways to engage students with particle physics and specifically with CMS data.

***Student e-Lab Posters*:** In several teachers’ classes and/or clubs, students who conducted an e-lab (level 3) were asked to complete a poster. The expectations in general were that the students achieve a layman’s understanding of the particle physics and scientific process included in the e-lab. There were three kinds of e-lab posters: LIGO, CMS and cosmic ray. The posters assessed were selected at random therefore *represent* the posters submitted overall.

* Overall, the LIGO and cosmic ray student posters did not meet expectations using the new (2011) rubric; the CMS posters exceeded expectations to a small extent using the 2010 rubric. Most missing are students providing evidence to support their claims and critically analyzing the results such as for validity.
* There were few discernible patterns to what works and what does not in conducting an e-lab. Whether honors or college or just regular physics, the duration, resources used and the extent the teacher reflects that the e-lab was effective, appears to depend more on what the teacher expects. If the expectation is just to complete a research project, the teacher appears to be satisfied.
* Two significant patterns in the contextual data were: 1) long-term projects using e-labs that focus on research and include the science are effective in achieving expectations as described in the rubric; 2) e-labs appear to fulfill the objectives and standards for conducting research to a great extent. In some contexts, the e-lab uniquely addresses some standards, especially those related to scientific research.

***CMS e-Lab Workshops:*** CMS e-lab workshop participant surveys were collected from 50 respondents from four centers, between June and August, 2013. E-lab workshops prepare teachers to implement level 3 of data portfolios.

* Positive responses to survey items such as “My understanding of the material increased.” appeared to contribute to preparing the participants to implement having their students work with data at levels 3.
* Comments from teachers indicate that the workshops were not consistent in terms of the participants being at the same level for understanding the content, and that the facilitators varied in their presentation of the material. For example, when asked “What related topics would you like to know more about, their comments ranged from, “Are there any teacher guides? I'm still making sense of it myself” to “Pseudorapidity improving analysis techniques.” Comments also indicated some of the workshops provided broader content and others basic information about analyzing CMS data.

**Transition**

The purpose was to gather data to confirm findings from three-to-four years of evaluation that shows the student research program and national/international CMS/ATLAS masterclasses are mature programs and effective; effective practices for each are included in the body of the *Metrics* section of this annual report.

***Student Research Programs****:* The data largely represent students participating in research programs; data from 71 percent of centers providing student research programs and 64 percent of students participating in the programs were used in the analyses. There is actually not one student research program since each site conducts the program somewhat differently and with different research. It is the program overall that has been shown to be effective in increasing scientific literacy.

* A T-test analysis indicated that the difference in pre- and post-test scores was statistically significant. This year there was only a slightly statistically significant difference between pre- and post-tests (P = .03). In previous years the differences were <.01 and even <.001. The smaller significance this year may have been due to a larger response rate in which students who may not have completed tests, especially post-tests, in the past were completing tests.
* This year, as in the past, qualitative data from pre- and post-tests indicate a more in-depth understanding of scientific methodology. Chains of thought indicated a better idea of how scientists engage in actual research, as opposed to a linear, “The” scientific method. Since the ‘pre’ indicates what students learn in school, it is clear that this research experience leads to a more complete understanding of how scientific research is actually carried out.

***National CMS/ATLAS Masterclass:***It is unclear the extent to which the data *represent* QuarkNet national CMS/ATLAS masterclasses overall since surveys were provided from 13 of 19 sites (65% response rate). However of the data collected, there was a 93 percent response rate for students and an estimated 92 percent response rate for teachers. Again, masterclass is not one program but several in that each site has different facilitators, presenters and slightly different processes, such as some have tours a few do not. Overall, the students matched the demographic shown to have the more positive experiences and outcomes from attending masterclass (MC) with regard to grade level (96%) and being enrolled in a physics class (82%). Over the years, masterclass data show it is effective in increasing students understanding of particle physics as well as the instruments used to collect data, authentic data analysis and nature of scientific research.

* All but five of the 36 teachers who completed surveys used topics, activities, resources with their students to prepare them for MC. Several teachers who reported not using or using few resources, commented that in the future they would prepare their students better next year. Teachers reported that the resources and support for MC were “very good” at means of 4.4 to 4.7 out of ‘5’.
* Students were asked how much they know the several particle physics-related terms before MC, then they were asked the extent to which they had learned something new about the terms through MC. For each, there were statistically-significant differences (<.001) between pre-and post-survey responses. After attending MC, 68 percent of students reported they were more interested in physics.
* Students rated all aspects of MC more toward “interesting,” “easy to understand” and “good” (means of 3.1 to 3.8 out of 5). Videoconferencing at some sites continued to have technical issues, mostly related to quality of sound. Teachers rated the aspects higher than students at means of 3.9 to 4.7. When students were asked the extent to which they liked the masterclass they attended the overall mean was a 4.1 out of 5 with a low standard deviation of 0.8. The majority (65%) also reported that the level was “exactly right.” Overall, student and teacher opinions of MC were positive.

**Data Collection and Analysis: Centers**

Data collected to address center Evaluation Matrix questions:

1. How effective are centers at creating and supporting opportunities for teachers to learn particle physics content and research? How effective are they in providing ideas for and ways to implement what they are learning in the classroom?
2. To what extent do teachers provide workshops, presentations to their colleagues; share ideas with colleagues and provide services in their schools with a goal toward becoming more professional including contributing to the quality and practice of colleagues in the field of science education?
3. To what extent does QuarkNet provide support for centers, especially those that have been identified as not operating effectively?

The instruments are available upon request. All instruments, described below, address all three Matrix questions regarding centers.

**Center Programs:**

Data were obtained using protocols for the following: Institute Site Visit, Classroom Visit Observation and Telephone Interview. The cadre of leadership fellows trained to gather data by evaluators between 2009-2012 obtained these data for the following: spring 2013 visits to nine classrooms of teachers and telephone interviews with four teachers from four 2012 summer institutes, and summer 2013 institute visits to four centers.

From February to September 2013, QuarkNet teachers were asked to complete the online survey. Twenty per cent of the active teachers were picked, for a total of 112 teachers. Sixty (54%) teachers responded.

***Institute Visit Protocol:***

The institute visit protocol was adapted from the *Template for Site Visits* that has been in use to assess QuarkNet center programs for 13 years. The Template was originally developed for Department of Energy teacher enhancement programs (National Center for Improving Science Education, 1995). The current Protocol was specifically designed for ease of use by leadership fellows and to identify effective practices that could be disseminated to other centers, and issues and challenges to be addressed by the centers. The Protocol is in nine sections: evaluation/observer activities, demographics, geographic and other contexts, mission and/or focus of the center, leadership at the center, observation of activities, implementation, comments and issues/concerns. Data collection to complete the Site Visit Protocol includes mentor and teacher leader interview protocols and a participant interview guide. The findings are summarized as “success factors” (see DOE Metrics section) and, for the leadership fellows to develop with the staff teachers assigned to the centers, a *Success Factors Toolkit* that addresses the issues and concerns.

The mentor interview protocol includes nine questions such as follow-up, recruitment and the center focus or mission. The teacher interview protocol is the same as the telephone interview protocol (see below), and is used for interviewing teachers in a leadership role at the institute. For interviewing teacher participants, an interview guide was developed for focused interviews to obtain critical information on participants, such as their reasons for participating and plans for implementation. In 2013, four centers were visited by leadership fellows.

*Analysis of Data:* Data are analyzed qualitatively (content analysis) and summarized into the annotated “success factors.”

***Classroom Visit Protocol:***

The classroom visit protocol was adapted from one developed for the DOE Teacher Enhancement Programs. It was adapted to address specific implementation goals and practices advocated by QuarkNet and for which professional development is provided. The Protocol is in three sections: 1) Basic demographics and information such as what were some of the activities teachers engaged students in, what were some assessment strategies and what were the emphases of the lesson, 2) A *Typology* characterizing the teacher role, classroom activities and instructional strategies including discussions and investigations. 3) Reflections and interpretations including characterizing students and their attitudes toward the subject matter and the teacher and extent of inquiry-based teaching and learning.

*Analysis of Data:* qualitative (content analysis) and quantitative (frequency distribution).

***Telephone Interviews:***

The interview protocol includes ten questions including demographics, classroom implementation, perceptions of the center teacher programs, and support from QuarkNet staff. The interview protocol is used by leadership fellows during telephone interviews as follow up during the spring. When possible, teachers are chosen randomly from a database provided by QuarkNet staff, and interviews are conducted with teachers who (1) can be reached using the database contact information and (2) are willing to be interviewed. The proposed number of teachers from each center is four for a total of 20.

*Analysis of Data:* qualitative (content analysis)

***Teacher Survey:***

The survey was placed online by QuarkNet staff in early spring of 2013. One hundred and twelve teachers were selected to complete the survey with the expectation of a 70% minimum response rate, or 78 responses.

The survey was adapted from one that was used for several years to assess classroom implementation of a lead teacher summer workshop (currently changed to Boot Camp) conducted by QuarkNet for twelve years. It was developed to collect data related to the QuarkNet goals and objectives to corroborate and supplement data gathered using other instruments. The survey is in three parts: demographics, classroom implementation and perceptions and use of the QuarkNet program. The purpose of the survey is to collect classroom data, information about how QuarkNet may have influenced teacher professionalism, and satisfaction with QuarkNet.

For the 2012-2013 school year, from February to September 2013, QuarkNet teachers were asked to complete the online survey. The database was said to have information on 574 “active” teachers. This number included retired teachers and those with no email addresses. With those subtracted the total was 561. Initially twenty per cent of the teachers were picked, for a total of 112 teachers.

Emails were sent to a total of 112 teachers requesting that they respond to the online survey. Evaluators were notified by five teachers that they were inactive or not participating, which resulted in the number of “active” teachers being 556.

Emails were sent on seven separate occasions, once to the whole group and then to subgroups who had not responded. Other individual and small group emails were sent. Participants were reminded that “Providing Information for Program Evaluation” is one of the participant expectations as stated on the web site: <http://quarknet.fnal.gov/tchr_respons.shtml>

As an incentive for submitting a survey, teachers were told that their names would be entered into a lottery; one teacher received $100 for being the first to submit the survey and six other teachers received $50.00 for completed surveys.

When emails were returned as undeliverable in six cases, other teachers were chosen from the database. Valid responses were received from 60 teachers. The overall response rate is 54 per cent after exhaustive efforts to achieve a greater number of responses. The selection could not be considered random and fewer than the expected 70% responded, therefore the data cannot be said to *represent* QuarkNet. These data indicate that results are similar to past results, when there was a random sample.

*Analysis of Data:* Quantitative (frequency distributions) and qualitative (content analysis).

**Data Collection and Analysis: Data Portfolios**

Data collected to address data portfolio Evaluation Matrix questions:

1. To what extent do CMS/Cosmic Ray Masterclass workshops provide content and skills (including implementation) for facilitating masterclasses in classrooms and/or at their centers? To what extent do teachers report satisfaction with the content and organization of the workshops?
2. To what extent do CMS/Cosmic Ray e-lab workshops provide content and skills (including implementation) for facilitating student research in classrooms? To what extent do teachers report satisfaction with the content and organization of the workshops
3. To what extent do QuarkNet teachers create environments (opportunities) for students to interpret, evaluate and provide explanations for phenomena in the natural world with a goal towardincreasing students’ awareness and knowledge?
4. To what extent are the support structures and resources effective in reaching data portfolio questions 1 through 3 (above)?

The instruments are available upon request.

**Q1 - *Data/Masterclass Workshop*:**

This year there were several “data workshops” that appeared to be the precursor to masterclass workshops in that they covered the same basic information as will the masterclass workshops. This year one data workshop was observed using a protocol developed for the Interactions in Understanding the Universe (I2U2) program. Besides dates of the workshop, location, number of teachers, mentor(s), facilitator(s), data are collected on the subject areas, grades and levels for each teacher, learning objectives including “big ideas” for the overall kind of workshop, and workshop objectives that may be specific to the site. Then, for each day, there is an introduction and major activities and their duration, which is described in detail and where possible and relevant, direct quotes from the facilitators, mentors and teachers. The time is recorded for change in activity or at regular intervals when the activity does not change, e.g., 12:30, 12:50, 1:30… At the end of the protocol is a Comments/Reflections section addressing the following:

1. Characterize the interactions between participants and the facilitator.
2. In what ways did the workshop reflect “effective” or best practices?
3. In what ways did the workshop reflect ineffective practices?
4. What are your suggestions for improvement?

The last part is Closing Thoughts, which gives the observer a chance to reflect on the workshop overall.

*Analysis of Data:* The report is provided to QuarkNet staff as transcribed and summarized for external reports, then the Comments/Reflections section is summarized for this report.

**Q1, Q2**

***Workshops - CMS e–lab and dataworkshops:***

Workshop facilitators (LHC fellows for CMS e-lab and data workshops) are asked to distribute and have teachers complete a brief survey at the end of each workshop. There is also a cover sheet facilitators complete that provides contextual information about the workshop and information about the participants such as number and how they were recruited. The teacher-participant survey asks what subjects they teach and students’ achievement levels, then asks them to rate several aspects of the workshop including: how well the session was organized, if they feel the workshop provided time to consider ways to use what they learned in the classroom, if their understanding was increased. They were finally asked to respond to four open-ended questions: either “Comments;” “What were the 2-4 most important things you learned from this workshop?;” “List specific strengths and weaknesses you would like the facilitator and/or QuarkNet to know about;” and “What related topic(s) would you like to know more about?”

*Analysis of Data:* Quantitative analysis of the items including frequency distribution, means and standard deviations; qualitative analysis of the open-ended questions.

**Q3**

***Student*** ***E-lab Posters:***

As part of engaging in an e-lab, several teachers have their students complete a poster to share results with others. Students write an abstract, methods and materials, results with figures pertinent to the results and finally discussion and conclusion. There is also a section for a bibliography. A rubric to assess the posters was developed by staff and evaluators. The rubric has a three-point scale with “does not meet expectations, meets expectations and exceeds expectations.”

The 2011Annual Report provides detailed information about a new rubric that was developed based on findings from the 2010 poster assessment. Because of miscommunication, the 2010 rubric was used to assess the CMS posters and the 2011 revised rubric, was used to assess LIGO and cosmic ray posters. Both rubrics address assessment of investigation, content and literacy. The revised rubric used weighted scores for those aspects that were considered to best reflect a student’s understanding of research, communicating clearly and providing evidence to support claims. Each aspect was rated separately and equally in the 2010 rubric. Each used “exceeds” “meets” and “does not meet” expectations scoring system. Both had a total of 30 possible points for exceeds and 20 possible points for meets.

Because there were issues with using the pre- and post-test for program evaluation, directly related to the contextual variables, posters were changed to focus more on gathering data for assessing the project objectives. While the new rubric is truncated, it reflects emphasis on the project objectives, reduces the need for contextual information since it focuses on the extent students (in any context) achieve the objectives, and includes weighted scores to eliminate bias.

On 21 and 22 April 2011, an internal and an external evaluator met to revise the rubric to meet the needs of the project, and conduct inter-rater reliability. Three cosmic ray e-labs, three CMS e-lab posters and two LIGO posters were rated. The standard of greater than 80% agreement was met. Evaluators agreed that the overall goal of poster assessment is to determine if the students have achieved a layman’s understanding of the particle physics and scientific process included in the e-lab. There were three types of e-lab posters assessed: cosmic ray, LIGO and CMS.

For the 2011 rubric, poster categories for “meets expectations” and their weights were: completed all aspects of poster appropriately (x1), introduction articulates a reasonable understanding of subject and scientific research (x2), procedure may need some adjustment; variable described and defined (x1), accurate charts, graphs, etc. provide insight into patterns in the data (x1), evidence supports claims made from the data; articulated a reasonable understanding of the investigation and its ramifications (x3), communicates information clearly (and logically) using appropriate terminology to convey ideas (x2).

During the 2012-2013 school year, 223 posters were submitted from students of 21 teachers. From the 202 posters submitted from students of teachers with six or more posters (11 teachers), 42 posters (about 21%) were selected. The three kinds of posters available and then selected were: LIGO – 10 posters from one teacher, three selected for assessment; CMS – 81 posters from three teachers, 16 selected for assessment; Cosmic Ray – 111 posters from seven teachers, 23 selected for assessment.

*Analysis of Data*: Posters were scored using tone of the two rubrics. Totals were added then means were calculated to determine the degree to which the posters met expectations.

**Q4** – Data collection and analysis are yet to be determined.

**Data Collection and Analysis: Transition Elements**

**Questions from previous matrix regarding student research programs and masterclass:**

**Question 3:** To what extent do QuarkNet teachers create environments (opportunities) for students to interpret, evaluate and provide explanations for phenomena in the natural world with a goal toward increasing students’ awareness and knowledge?

**Question 4:** To what extent do students learn particle physics content and research, and, more particularly LHC physics and research with a goal toward increasing students’ awareness and knowledge? (Do the opportunities provided by QuarkNet show evidence of being effective [see Question #3]).

**Q3**

**Student Research Programs:**

Student programs are assessed using pre- and post-tests to assess gains in understanding of scientific inquiry (science research methodology). Pre - and post-tests were conducted using the concept map format found to most reliably assess student achievement based on the 2009-2010 pilot test.

***Pre- and post-tests:*** Pre- and post-tests were conducted using concept maps on *Scientific Methodology*. The directions for constructing the tests included brief, simple instructions on how to create a concept map and a list of nine concepts to include in the map (equipment/instruments, library/reference materials, data, hypothesis, experiment, results, journal/notebook, laboratory, conclusions). The terms were adapted from concept maps created for Department of Energy student programs by the National Center for Improving Science Education. Students were instructed that they could add concepts to the nine provided.

During the summer 2013 (from 6/3 to 8/27), 14 QuarkNet centers conducted longer-term student programs. Of these, ten submitted two or more (two to 14) pre and post concept maps on “Scientific Methodology.” Overall, the 10 centers that provided data were 71 percent of centers providing long-term programs. Therefore, the data mostly *represent* QuarkNet student research programs. Of the sites that provided data 64 percent of pre- and post-test matches were used in the analysis. That is, a majority of tests that were submitted fit the criteria of being of equal effort pre and post. These tests therefore represent QuarkNet student participants to some extent.

*Analysis of Data:* First, pre and post concept maps were reviewed to see if students made equal effort on the pre- and post-tests indicating that they took the post-test as seriously as the pre-test. Unequal effort included: not writing propositional statements between concept on the post-tests whereas they had on the pre-test; and/or a sloppy or incomplete post-tests such as using all the nine terms pre and not post.

Second, the concept maps were graded using an adaptation of the scheme developed by Novak and Gowin. (in, *Learning How to Learn*, 1984). The scoring was: Hierarchy or layers of complexity were counted (one point each); cross-links or meaningful connections were counted (two points each); number of appropriate concepts (one point each); and significant propositional statements that link the terms (one point each). The propositional statements were most significant in that, for many students, a more sophisticated idea of scientific methodology was expressed post than pre. Once the total score was counted, data were analyzed both quantitatively (means, range, frequency distribution; T-test) and qualitatively.

**Q4**

***Masterclass Questionnaire.*** The survey was modeled after the European masterclass (MC) survey and adapted for use with the 2008 MC and subsequently the 2009 through 2013 masterclasses, with a few editing changes along the way.

The survey is in three parts. The first part asked students to respond to several basic demographic questions and asked them about their current experience with topics and terms they would encounter through MC. Part II asked them about several aspects of MC such rating the four parts of the MC program (videoconference, lectures, exercises, tours), rating specific aspects of the videoconference, then choosing which of the four parts of MC they liked best. For each aspect, the students were given a space to write comments. A final question asked students to provide their opinions on several aspects of MC. Finally, students were given a spec to add anything they would like to express about masterclass.

There were 204 student surveys from the 13 sites. Number of respondents at each site ranged from 40 to one. There were two ninth graders, six (3%) tenth graders, 69 (34%) eleventh graders, and 127 (62%) twelfth graders. The majority of students, 82 percent, reported currently being enrolled in physics.

*Analysis of Data:* qualitative and quantitative. Quantitative included frequency distribution, means and standard deviations and T-tests. Qualitative included content analysis of student comments.

***Masterclass Teacher Survey:*** The teacher survey was in three sections: student demographics, classroom instruction, resources and materials (preparation for MC and topics/resources used prior to masterclass, orientation and an open-ended question asking if there was anything else they used to prepare their student for MC.); perception of MC including rating elements of masterclass and degree different factors contributed to student learning (and an open-ended question). The survey was a truncated version of the *Form and Transmittal Sheet* developed for the Masterclass Study.

*Analysis of Data:* qualitative and quantitative. Quantitative included frequency distribution and means and standard deviations. Qualitative included content analysis of comments.

**Formative Evaluation Reports**

Following are formative evaluation reports, previously sent to QuarkNet:

* QuarkNet, Data Workshop, U. of Minnesota 13-14 August 2013; 19 August 2013
* Masterclass 2013: Survey Results; September 2013
* QuarkNet Teacher Survey Report; 25 September 2013
* QuarkNet Student Research Programs; September 2013
* I2U2 E-Lab Poster Assessment; September 2013
* QuarkNet Telephone Interview Report; 23 September 2013
* QuarkNet Summer Site Visit Report; 23 September 2013
* Help Desk; 26 September 2013

**Evaluation Matrix Questions: Centers**

**Question C1:** *How effective are centers at creating and supporting opportunities for teachers to learn particle physics content and research? How effective are they in providing ideas for and ways to implement what they are learning in the classroom?*

***Criterion C1-1a:*** Survey shows at least 80% report an increase in content knowledge.

***Introduction:*** Workshop survey data were collected June – August 2013, using the QuarkNet Participant Workshop Survey form for CMS e-lab and data workshops. Survey items (h) and (i) address the effect of the workshop on participants’ content knowledge: (h) “The workshop helped me feel more comfortable with the topic(s)” and (i) “My understanding of the material increased.”

***Findings: CMS E-Lab Surveys:*** The criterion, survey shows at least 80% report an increase in content knowledge was met. Fifty Surveys from CMS e-lab workshops representing four QuarkNet centers were reviewed. Responses for items (h) and (i) indicated greater than 80% increase in content knowledge. For item (h) and (i), all 50 (100%) respondents chose (1) “strongly agree” or (2) “agree.” For both items none chose (3) “disagree” or (4) “strongly disagree.” The mean for item (h) was 1.4 and for item (i) it was 1.3, both of which fall between (1) “strongly agree” or (2) “agree.”

***CMS Data Surveys:*** This criterion was met. Surveys from 17 respondents who participated in a CMS data workshop representing three QuarkNet centers were reviewed. For both items (h) and (i), all 17 (100%) respondents chose (1) “strongly agree” or (2) “agree,” indicating an increase in content knowledge. For both items none chose (3) “disagree” or (4) “strongly disagree.” The mean for item (h) was 1.2 and for item (i) it was 1.4, both of which fall between (1) “strongly agree” or (2) “agree.”

***Criterion C1-1b:*** Center programs include opportunities to learn particle physics. Fellows and evaluators use “effective practices” as a measure. (Staff gets data to correct ineffectiveness). Centers show an increase in effective practices.

***Criterion C1-1c:*** Teachers describe ways they are implementing what they learned.

*Introduction:* Evaluators have data to address these questions from several sources. During the summer of 2013, leadership fellows visited institutes at four QuarkNet centers. Nine teachers were interviewed using questions from what is called a “Participant Interview Guide” that includes a focused form of the interview protocol. In-depth interviews were conducted with five mentors and three teachers who hold leadership roles at the centers. During spring 2013, visits were made to nine teachers’ classrooms from centers visited in summer 2012, and telephone interviews were conducted with a total of four teachers. Interviews were conducted using separate Teacher and Mentor Interview Protocols.

***Findings:*** The criterion center programs include opportunities to learn particle physics was met to varying degrees as evidenced by the extent to which teachers use what they learn and experience through QuarkNet:

* All 12 (100%) teachers interviewed at summer institutes indicated that their participation in QuarkNet helped them implement particle physics in their classrooms at frequencies from 1-2 lessons to long-term projects. Seven (58%) used e-labs; nine (75%) had students do research with a detector; six (50%) *Particle Adventure*; four (33%) masterclass. All 12 taught the Standard Model and nine (75%) “sprinkled” topics such as conservation of momentum and energy throughout their curriculum. All mentioned that they were implementing QuarkNet to some extent.
* Of the four teachers interviewed by phone, three mentioned that through QuarkNet they found it easier to integrate topics into their classrooms. One teacher did not complete the year teaching. The three responses included: discovered how easy it is to sprinkle HEP ideas throughout the year; get a very good audience when I talk about HEP; frequently reference the detector. All are “sprinkling examples” and doing research with a detector at frequencies of 1-2 lessons or 3-5 lessons. One is using e-lab, another *Particle Adventure* and two say they introduce the Standard Model. Direct connections for using what was included at the workshop in their classes included: made lesson plans and interactive games for students as a group, and used the detector with an after school club.
* Classroom visits were made to nine teachers from four centers whose institutes were visited in 2012. When leadership fellows visited the classrooms, the topics were not related to particle physics but observations show that their intended outcomes were related to particle physics (2), physics (5) and research projects (2). Five out of the nine closed the class with a summary of the day’s lesson, and four related the lesson to what comes next. Seven of the teachers had students work in groups or pairs, indicating collaborative efforts. According to the leadership fellows’ observations and rating of the teachers’ practices, all nine of the teachers engaged in instructional strategies, and seven of the nine focused on instructional emphases that reflected inquiry-based teaching and learning. Based on the ratings of their students’ classroom habits and class activities, five to seven of the teachers included inquiry. About half (4-6) involved inquiry in their discussions and hands-on work. All nine had students who did long-term projects that included e-labs, Particle Adventure, and research with a detector, and “sprinkling” examples. All teach Standard Model, for 1-2 lessons or 3-5 lessons. Others teach 1-2 lessons or 3-5 lessons on topics related to QuarkNet and particle physics. Teachers’ comments about the QuarkNet experience included: giving them confidence to introduce particle physics and use the CRMD in their classrooms, helping them find resources to help design curriculum around particle physics and increasing inquiry based instruction.

**Question C2:** *To what extent do teachers provide workshops, presentations to their colleagues; share ideas with colleagues and provide services in their schools with a goal toward becoming more professional including contributing to the quality and practice of colleagues in the field of science education?*

***Criterion C2-1a and 1 b:*** At least 50% of teachers indicate they have provided workshops, presentations or other forms of leadership with their colleagues. Most (at least 75%) report sharing ideas with colleagues. Data show an overall increase over time in QuarkNet.

***Criterion C2-2a and b:*** Note any increases in professionalism.

***Introduction:*** From February to August, 2013 an online teacher survey was done to gather data on teachers’ experience with the QuarkNet program. Professionalism data were gathered from 60 teachers.

***Findings:*** Teachers responding to the online survey met this criterion to some extent. Of the 60 QuarkNet participants who responded to the online survey, 48 (80%) shared what they learned in QuarkNet with colleagues; 10 (17%) have given a workshop or presentation at a local or national meeting of a professional organization (e.g., AAPT); 45 (60%) have developed new materials for courses; 19 (42%) have been involved in reform efforts at the school or district level; 14 (23%) are mentor teachers and/or department chairs at their school. High numbers (47%) of teachers were new (one to three years) to QuarkNet, and therefore would be expected to increase their participation in giving workshops and presentations in future years.

Teachers responding to telephone interview questions did not meet this criterion. Of the four teachers who were interviewed, one reported being involved in giving workshops to other teachers, and one has given a presentation; two have attended meetings of professional organizations and have been involved in leadership at the school or district level. These results show much lower involvement in activities that indicate professionalism than in years past.

*Introduction:* Evaluators have these data from site visits to institutes and classrooms, and telephone interviews for four years. During the summer of 2013, leadership fellows visited institutes at four QuarkNet centers where nine participant teachers and three teachers who hold leadership roles were interviewed. During spring 2013 they visited classrooms of nine teachers and conducted telephone interviews with four teachers. Data for these are combined.

***Findings:*** Twelve (40%) have given workshops that include local and district physics gatherings, mini-workshops, professional development, State STA, AAPT, LIGO and particle physics workshops. There were 13 (43%) teachers who said they have not been involved in giving workshops to other teachers or given presentations.

Twenty-two (88%) of the teachers have attended meetings of professional organizations such as AAPT (One helped host an AAPT session), NSTA, State STA, State APT, School & university meetings. And four have not attended such meetings. Twenty-one have been involved in leadership at the school in the following capacities: department chair, technology mentor/committees, curriculum/science task force, policy review/site council or recruiting QuarkNet teachers and students. Four have not been involved in leadership at their school or district level.

This year’s data indicate that teachers new to QuarkNet and those who have been with the program longer are involved in activities that contribute to professionalism at about the same level. Those who have been with QuarkNet longer (6-12 years) and are in leadership roles appear to be more involved with professional activities such as QuarkNet national programs, giving workshops to other teachers, giving presentations at meetings and attending meetings.

**Question C3**: *To what extent does QuarkNet provide support for centers, especially those that have been identified as not operating effectively?*

***Criterion C3-1:*** Monthly report shows contacts and visits to centers especially those that are not operating effectively.

***Introduction:*** Each month staff prepares reports about their work including contacts with and visits to centers. The spokesman summarizes the reports and sends the summary to the Advisory Group, staff and evaluators. We expect that there is regular contact between staff and mentors, e-mails, phone calls, etc. to make sure mentors are informed about opportunities, deliverables, deadlines etc. However, these are too numerous to document. Staff writes up special contacts when they or fellows have more substantive interaction with a center.

***Findings:*** Staff reports 91 instances when a representative of QuarkNet—staff or fellow—interacted with 44 active centers and 1 sabbatical center. Activities ranged from helping set up the center Drupal membership, helping a new mentor with the annual proposal process or discussing how to restart a center after a sabbatical, to holding masterclass orientation and videoconferences, troubleshooting detectors, offering workshops, meeting with students who have held summer research internships, and more. All eight centers on the leadership fellow assist list had at least one visit. Visits ranged from one to ten for these centers, depending on staff/fellow availability. The mode was 3 or 4 visits.

***Criterion C3-2:*** Leadership fellows working with staff to determine strategies for supporting centers; centers that are not operating effectively are supported using the strategies.

***Introduction:*** Prior to the current program year, leadership fellows’ work consisted primarily of observing center institutes and QuarkNet teacher classrooms, and interviewing teachers. Based on these experiences, they worked with the staff teachers to develop general strategies related to each success factor. In October 2012, staff teachers and leadership fellows compiled success factor data on the centers and used it to identify seven centers that could benefit from additional support. A leadership fellow was assigned to each center and then worked with a staff teacher to develop a plan for helping the center. These plans were informed by the general strategies that had previously been developed, but customized to each success factor.

In April, one of these seven centers went “on sabbatical” due to other obligations of the mentor. Also in April, two more centers were identified as likely to benefit from additional support, so there are currently eight centers with leadership fellows assigned to them.

***Findings:*** The criterion was met for all nine centers that had leadership fellows assigned to them for support at any point during the period from October 2012 to September 2013.

The leadership fellows’ coordinator held phone conferences approximately every eight weeks with the staff teacher and leadership fellow to monitor progress. Leadership fellow activity was primarily in the area of supporting design and planning for summer institutes, weekend workshops, or masterclasses. Improving intra-center communication, primarily between the mentor and teacher leader(s) was another area of emphasis. While most leadership fellow contacts were by telephone, fellows made site visits to six of the nine centers.

**Evaluation Matrix Questions: Data Portfolios**

**Question DP1:** *To what extent do CMS/Cosmic Ray Masterclass workshops provide content and skills (including implementation) for facilitating masterclasses in classrooms and/or at their centers? To what extent do teachers report satisfaction with the content and organization of the workshops?*

***Criterion DP1-1a:*** Evaluators provide formative feedback; workshops incorporate “best practice” strategies.

***Introduction:*** QuarkNet is currently developing the data portfolios. The purpose is to have teachers, and their students, work with actual data at one or more of three levels. As a precursor to the CMS masterclass workshops, a staff teacher developed the Data Workshop that included aspects of the data portfolio, specifically Introductory Activities (level 1), working with LHC data (level 2), and a brief introduction to e-labs (level 3). The workshop included relevant talks from scientists, working through the activities as would a student then discussing as teachers, working with CMS data as would a student then discussing as teachers, and a review of resources available.

***Findings:*** This workshop incorporated many “best practice” strategies. The following summarizes the last four questions on the observation protocol

1. Characterize the interactions between participants and the facilitator: The main facilitator was excellent at time management. It is difficult to believe how much was accomplished in so short a time without it feeling rushed. Ample time was left for questions both from facilitators and mentors. Working lunches, in which food was provided, were well-received by the participants, which made more time for e.g., discussions with scientists. Perhaps most importantly, time was always left for discussing activities. Also for responses to teacher questions and facilitator prompts at the end of the day, then if not finished, the beginning of the next day. The participants got the information they needed, questions were addressed at their level of understanding and without feeling rushed through any of the activities.

The mentors were a big part of the workshop; being there to address questions and give short talks appropriate to what the teachers were learning. Since this was a group new to particle physics (with the exception of one teacher) this was an important part of the workshop. It was clear that these kinds of interactions, and with facilitators, increased the confidence levels of the teachers.

Addressing what they learned, questions they still had and implementation methods appeared to provide a risk-free format for teachers to ask their relevant (or even not so relevant) questions. That a mentor was there for most of these discussions showed teachers that their participation was valued, as well as mentors providing expertise from someone who works in the field of particle physics.

2. In what ways did the workshop reflect “effective” or best practices? There were few times when the entire workshop was not effective or utilized best practices. Several practices were exemplary:

* A lot was covered but did not feel rushed. Relevant and appropriate information was provided then teachers were referred to resources to access; not too much (more is less) nor was anything left unaddressed.
* Talks were also at an appropriate level. They followed an important instructional design principle - present the ‘big idea’ then discuss the component parts/concepts. That way, the participants always have a context for what the presenter is addressing.
* Activities were done in groups so that teachers could experience them as would a student, then discussed as adults (adult-level talks and discussions of the science) and as teachers, i.e., classroom implementation.
* Teachers‘ questions were answered at their level of understanding. A couple of question and answer sessions included information that went over some teachers’ heads but was great for the majority who could follow along. The atmosphere encouraged an easy exchange between mentors and teachers, teachers and facilitators.
* Implementation was discussed throughout and focused on each day and at the end. Teachers were left with multiple ways to engage students with particle physics and specifically with CMS data.
* Teachers had plenty of opportunity to interact with the data and engage in activities in pairs or groups. The workshop was an excellent model for how to organize and conduct the activities and data analyses with their students.
* Ending each day with what they learned, questions they still have and implementation is a terrific way to connect teachers to the goals and objectives of the workshop.

3. In what ways did the workshop reflect ineffective practices? The few things that did not work out quite so well mostly related to time for addressing everything in two days. While most was not rushed, the introduction was rushed with regard to goals, objectives, expectations and alignment with standards (see more below under suggestions for improvement). Then, at the end, there was no time to include student assessment such as how do teachers assess group work.

4. What are your suggestions for improvement? Change the goals and objectives. It seemed appropriate for the facilitator to just say the bottom line is… What about an introduction that just states what the Data Workshop is all about and the expectations? That is, that teachers will involve their students in one of the three levels: the activities, data analysis in the classroom or at a local masterclass; then perhaps involve some students in research through an e-lab. For future workshops, follow the best practice of this workshop to let teachers know they will be learning as students and getting information at an adult level for background information, and address implementation. There was nothing in the workshop about inquiry-based teaching and learning – but as the NGSS are becoming adopted, they would be a better focus.

***Criterion DP1-1b:*** Workshops improve over time with regard to best practice and participant satisfaction.

***Introduction:*** Since the data portfolios are new to QuarkNet and the masterclass workshops are under development, data on improvement will start to be collected next year.

***Criterion DP1-2a:*** Survey shows that 80% of workshop participants are engaging their students in working with data at a minimum of level 1 and at least 40% at level 2.

***Introduction:*** As above, data are not available during this time of transitioning to data portfolios.

***Criterion DP1-2b:*** Workshop participants “agree” that the workshop has prepared them to implement having their students work with data at levels 1 and/or 2. Participants describe how they are implementing what they learned and note any constraints or barriers.

***Introduction:*** Since the data portfolios are new to QuarkNet and the masterclass workshops are under development, data on implementation will start to be collected next year.

**Question DP2:** *To what extent do CMS/Cosmic Ray e-lab workshops provide content and skills (including implementation) for facilitating student research in classrooms? To what extent do teachers report satisfaction with the content and organization of the workshops?*

***Criterion DP2-1a:*** Evaluators provide formative feedback; workshops improve over time with regard to best practice and participant satisfaction.

***Introduction:*** As above, data are not available during this time of transitioning to data portfolios.

***Criterion DP2-1b:*** Workshop participants “agree” that the workshop has prepared them to implement having their students work with data at level 3.

***Introduction:*** Over the years, Cosmic Ray e-lab workshop participant surveys have been collected to provide data about the quality of the workshops with regard to participant satisfaction. The Cosmic Ray e-lab workshops have been found to be mature and effective. They will be evaluated if substantively changed and/or every two to three years. CMS e-lab workshop participant surveys were collected from 50 respondents from four centers, between June and August, 2013.

***Findings:*** For the numerical data, means were between (1) “Strongly Agree” and (2) “Agree,” out of a possible (4) “Strongly Disagree” indicating this criteria was met to some extent. Questions included: “The objectives of the workshop were met,” “The workshop provided time to consider ways to use what I learned in the classroom,” “The workshop helped me feel more comfortable with the topic(s),” and “My understanding of the material increased.” These components appear to contribute to preparing the participants to implement having their students work with data at levels 3.

Comments indicate that the workshops were not consistent in terms of the participants being at the same level for understanding the content, and that the facilitators varied in their presentation of the material. For example, when asked “What related topics would you like to know more about, their comments ranged from, “Are there any teacher guides? I'm still making sense of it myself” to “Pseudorapidity improving analysis techniques.” Comments also indicated some of the workshops provided broader content and others basic information about analyzing CMS data.

As shown in the table below, means of responses from CMS workshop participant surveys were between (1) “Strongly Agree” and (2) “Agree,” out of a possible (4) “Strongly Disagree.” Means and variation (standard deviation) were similar for CMS Data workshops (see Metrics section).

**Table: CMS e-lab** Survey Items with Means and Standard Deviations for Each Item

|  |  |
| --- | --- |
| **Item** | **n = 50; 4 centers**  **Mean/SD** |
| a. The workshop was well organized. | 1.4/0.5 |
| b. The facilitator clearly stated the objectives of the workshop. | 1.4/0.6 |
| c. The objectives of the workshop were met. | 1.4/0.5 |
| d. The instructor(s) facilitated the workshop effectively. | 1.3/0.5 |
| e. The schedule allowed sufficient time to meet the objectives. | 1.4/0.7 |
| f. The workshop provided time to consider ways to use what I learned in the classroom. | 1.5/0.6 |
| g. The workshop provided opportunities to ask questions and/or discuss ideas. | 1.1/0.4 |
| h. The workshop helped me feel more comfortable with the topic(s). | 1.4/0.4 |
| i. My understanding of the material increased. | 1.3/0.5 |
| j. Questions were answered/addressed at my level of understanding. | 1.4/0.5 |
| k. I experienced inquiry-based teaching techniques. | 1.4/0.5 |

***Criterion DP2-2a:*** Survey shows that at least 20% of workshop participants are engaging their students in working with data at level 3.

***Introduction:*** As above, data are not available during this time of transitioning to data portfolios.

***Criterion DP2-2b:*** Participants describe how they are implementing what they learned and note any constraints or barriers

***Introduction:*** As above, data are not available during this time of transitioning to data portfolios.

**Question DP3:** *To what extent do QuarkNet teachers create environments (opportunities) for students to interpret, evaluate and provide explanations for phenomena in the natural world with a goal towardincreasing students’ awareness and knowledge?*

***Criterion DP3-1a:*** Teachers report at least 20% relative amount of class time devoted to students exploring and providing explanations of physics phenomena using scientific methodology. Data show an overall increase in use over time including moving from level 1 to 2 and to level 3.

***Introduction:*** As above, data are not available during this time of transitioning to data portfolios.

***Criterion DP3-1b:*** Participants describe how they are implementing what they learned and note any constraints or barriers.

***Introduction:*** As above, data are not available during this time of transitioning to data portfolios.

***Criterion DP3-1c:*** E-lab posters, on average, “meet” standards as described in the rubric; teachers provide appropriate instruction.

***Introduction:*** In several teachers’ classes and/or clubs, students who conducted an e-lab were asked to complete a poster that included an abstract, introduction, procedure, results, figures (charts and graphs), discussion and conclusion, and bibliography. The expectations in general are that the students achieve a layman’s understanding of the particle physics and scientific process included in the e-lab.

***Findings:*** The findings indicate that overall, the LIGO and cosmic ray student posters did not meet expectations using the new (2011) rubric; the CMS posters exceeded expectations to a small extent using the 2010 rubric. The posters assessed were selected at random therefore *represent* the posters submitted overall. Issues that were apparent in the CR and LIGO posters were:

* Few students appeared to provide evidence to support their claims. It was somewhat clear that the teachers were not asking their students to do so even when the state/local/course standards included, e.g., ”valid conclusions and support by the data…” The rubric provided by one teacher did not include anything related to claims/evidence/reasoning (CER), perhaps indicating that CER is not a current focus for many teachers.
* Interestingly only two teachers had reportedly asked or encouraged their students to look at studies that had already been published, and readily available. This is somewhat reasonable in that the data available were not always “blessed” therefore, may not have been valid and reliable. However, there was no reason students couldn’t repeat some interesting research, such as commonly done in the scientific research community. The results were often trivial questions, endlessly repeated meaningless perfunctory investigations that it is difficult to imagine students gaining much from.
* Few posters included anything about variables, including confounding variables. Many wrote in the *Discussion and Conclusion* section that one or two days of data analyzed “proved” some claim. Several discussed something about “further studies” seemingly as directed or required by the teacher. Many seemed meaningless and not insightful.

The table, below, summarizes some of the main aspects of implementing the e-labs. For “duration,” the ‘I’ is introduction, the ‘E’ is students doing the e-lab and the ‘C’ is closure which could include presentations of the poster or project and/or discussions (see details above). Units, unless otherwise indicated, are hours.

**Table:** Summary of E-Lab Contextual Data

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Tchr | Scores | Course | Duration | Resources | Comments/Quotes |
| CMS  (n = 3) | Mean 22;  Range 19-28  (using 2010 rubric) | 11-12th grades physics magnet school; semester course on particle physics research | I – 30  E – one month;  I – 60  E – 2.5 weeks time outside class  C- 0-1/group;  I – 10  E – 20  C - 10 | bubble chamber, *Particle Adventure*, Z-boson activity, in-class masterclass; Particle Adventure, guest speakers, Particle Zoo, video conferencing; online resources | These longer-term, focused projects using e-labs appear to be highly effective, especially in relation to addressing scientific inquiry standards and movement of standards to more project-based scientific research (as in the two states represented by these teachers.) |
| LIGO  (n = 1) | Mean  12.5  Range  6-13 | Advanced freshman physical science, one semester; unit on “scientific methods” | I – 2  E – 3  C - 2 | None indicated | Many students did not fully complete the e-lab posters indicating that the time frame was short and there was not much dedication to quality. |
| CR–A | Mean  15  Range 5-20 | IB physics\*, honors physics, astronomy club\*  \* students did not complete posters | I – 1-2  E – 8 classes + time outside class  C- 2.5 | PowerPoint slides about cosmic rays, “animations on the Internet” and videos, one CRMD | Teacher: The e-lab provides the opportunity for longer-term research rather than “quick, superficial involvement…then move on to the next topic;” students have to think critically, evaluate sources and come to conclusions. |
| B | Mean  16  Scores  15,16 | Semester course on particle physics research | I – 10  E – 20  C - 10 | cloud chamber, *Particle Adventure*, guest speakers, online resources, CRMD | Teacher: Students are adequately challenged with the rigor in the e-lab and also have the support of e-lab resources to help explain the science of high energy particle physics. |
| C | Mean  17  Scores  11,19, 20 | Regular physics – 12th grade students | I – 2 days  E – 4 days  C – none specific | CRMD, *Particle Adventure*, information from a trip to CERN, video of a cloud chamber | Teacher: gave the students more credit for understanding scientific research than they were due and actually needed more guidance. “They were so used to having a question handed to them that they needed to experiment with that they didn’t even know how to begin.” |
| D | Mean  18  Scores  13, 18, 22 | Regular physics 11th and 12th grade students | I – 3  E – 8 over five weeks  C - 5 | *Particle Adventure*, “A Century of Cosmic Rays” in *Physics Today*, e-lab resources (e.g. *Cool Science*) | Teacher: the e-lab generally addresses the NGSS |
| E | Mean  19  Scores  16,22 | College, Engineering Physics 2 | I – 2  E – 12  C – 4 | CRMD, e-lab resources | The posters were more like a college paper with a lot of background/ introductory information. Teacher focusing on error analysis, statistics, technical writing, oral communication and overall nature of science. |
| F | Mean  18  Scores  18,18, 19 | IB physics 1 course (taught as a research project; will learn particle physics next year) | I – 2-3  E – 10-15  C – 1.5 | None indicated | Teacher: “the experience gained by working with the database and analysis software is not one I can replicate other places so I feel it is irreplaceable in the scheme of practical work the students complete.” |
| G | Mean  20  Scores  19,21 | IB physics with 12th grade students; conducted within a particle physics unit | I – 1  E – 4  C – 1-2 | CRMD, *Particle Adventure*, “numerous other resources on particle accelerators, particle detectors and the Standard Model.” | Learning objectives were for students to carry out their own research, generating a question, testing an hypothesis and presenting to their peers  Teacher: e-lab “fit nicely” into achieving these objectives. |

This summary chart shows that there are few discernible patterns to what works and what does not in conducting an e-lab. Whether honors or college or just regular physics, the duration, resources used and the extent the teacher reflects that the e-lab was effective, appears to depend more on what the teacher expects. If the expectation is just to complete a research project, the teacher appears to be satisfied. These posters “do not meet” QuarkNet effective projects as indicated by the rubric appear to be largely satisfactory from many of the teachers’ perspectives. Hopefully with implementation of the NGSS and Common Core, the teachers can be encouraged to emphasize more authentic research methods.

Two significant patterns in the contextual data were: 1) short term projects using e-labs that focus on research and do not include the science are not effective in achieving expectations as described in the rubric; 2) e-labs appear to fulfill the objectives and standards for conducting research to a great extent. In some contexts, the e-lab uniquely addresses some standards. One teacher noted that the data analysis and “performing their own studies” is “how the standards are heading” such as NGSS.

**Question DP4:** *To what extent are the support structures and resources effective in reaching DP goals 1 through 3?*

***Criterion DP4-1a:*** Help desk provides support to teachers and students.

***Introduction:*** Data were collected between September 2012 and April 2013 and reported by the QuarkNet staff teacher who focuses on Help Desk. In past years, data were reported for a full year. This year it was decided to stop gathering these data, so nothing is reported for the fourth quarter.

***Findings:*** Twenty-two of the 48 centers made contact with or were contacted each quarter. The log sent monthly to evaluators includes compiled numbers of information provided in the following categories: Presentations (29%; mean 29; total 113), Hardware Issues (54%; mean 26; total 208), Software Issues (54%; mean 26; total 207), Server (8%; mean 4; total 30), Content Q&A (10%; mean 5; total 39), Pedagogy Q&A (8%; mean 4; total 32).

Categories of people contacting the Help Desk were: QuarkNet Fellows (38%; mean 18; total 145); Teachers (39%; mean 19; total 151); Students (9%; mean 4; total 34); QuarkNet Mentors (20%; mean 10; total 78); QuarkNet/I2U2 staff (58%; mean 28; total 222): Researchers (14%; mean 7; total 57).

***Criterion DP4-1b:*** Teachers report they got support when needed.

***Introduction:*** Evaluators have data to address this criterion from several sources. During the summer of 2013, leadership fellows visited institutes at four QuarkNet centers and interviewed nine teacher participants and three teachers who hold leadership roles at the centers. During spring 2013, visits were made to nine teachers’ classrooms and telephone interviews were conducted with a total of four teachers.

***Findings:*** Twenty of the 25 teachers interviewed commented on interactions with QuarkNet Staff teachers and only three did not know who they are. Interactions and support include: detector support, moral support, Friday Flyer, Emails/Calls/Support, runs masterclass and presents at QuarkNet “meeting.” Three reported having no interactions. One staff teacher did an inventory of detectors, which were spread out over 20 schools; many teachers have left the program, with their detectors becoming lost.

***Criterion DP4-2:*** Introductory activities meet best practice standards; teachers report ease-of-use and that activity goals are achieved.

***Introduction:*** Since the data portfolios are new to QuarkNet and the activities are under development, feedback from teachers will start to be collected next year.

***Criterion DP4-3:*** Web sites meet ‘best practice’ standards; teachers report ease-of-use, that the postings are useful and that needed resources are available.

***Introduction:*** The Drupal site is not fully set up and in use in time for review

**Previous Evaluation Matrix Questions: Transition Section**

**Note – questions are from the previous evaluation matrix.**

**Question 3:** *To what extent do QuarkNet teachers create environments (opportunities) for students to interpret, evaluate and provide explanations for phenomena in the natural world with a goal toward increasing students’ awareness and knowledge?*

***Introduction:*** CMS/ATLAS national/international masterclass (MC) is not one program within QuarkNet, but actually as many programs as there are MC sites. Each site has different presenters, tour guides, exercise and videoconference facilitators as well as different teachers and students. A presenter could be excellent or ineffective; a videoconference can have multiple technical issues or none. Although several MC sites may need some small improvements, the program overall is mature and has achieved its goals and objectives, overall, for three years. So, now that CMS/ATLAS masterclass has been shown to be effective, and characteristics of an effective MC have been identified, teacher and student surveys will only be collected every three or more years and/or whenever MC substantively changes.

***Findings:*** This year data were collected for the purpose of providing further information on MC effectiveness, and to add support for claims made about factors that lead to effective masterclasses. These factors were first presented in the 2011 report. After two more years of data collection, the *Characteristics of Effective Masterclasses* are provided in the *Metrics* section, below, with high confidence. Key findings from this years’ data are.

* The students matched the demographic shown to have the more positive experiences and outcomes from attending masterclass (MC) with regard to grade level (96%) and being enrolled in a physics class (82%); also was a relatively elite group of students with more enrolled in or having been enrolled in advanced than general or basic level courses and reported by their teachers as high achievers.
* 84 percent of students reported having some form of preparation for MC. All but five of the 36 teachers who completed surveys used topics, activities, resources with their students to prepare them for MC. Several teachers who reported not using or using few resources, commented that in the future they would prepare their students better next year. Teachers reported that the resources and support for MC were “very good” at means of 4.4 to 4.7 out of ‘5’.
* Students were asked how much they know the several particle physics-related terms (particle physics in general, Standard Model, quarks and leptons, particle accelerators and detectors) before MC, then they were asked the extent to which they had learned something new about the terms through MC. For each, there were statistically-significant differences (<.001) between pre-and post-survey responses.
* Students rated all aspects of MC more toward interesting, easy to understand and good (means of 3.1 to 3.8 out of 5). Videoconferencing at some sites continued to have technical issues, mostly related to quality of sound. Teachers rated the aspects higher at means of 3.9 to 4.7.
* After attending MC, 68 percent of students reported they were more interested in physics. One student commented, “I had made up my mind to double major in Engineering Physics and Computer Engineering, but then I was reminded how great other areas of science were by those lectures.”
* When students were asked the extent to which they liked the masterclass they attended the overall mean was a 4.1 with a low standard deviation of 0.8. The majority (65%) also reported that the level was “exactly right.”
* Overall student opinions of MC were positive such as the highest rated (4.3 out of 5) “After attending masterclass, I know more about particle physics” to “Physics in this masterclass shows a relation to everyday life” (3.4 out of 5).
* A study at one site comparing data from students who were currently enrolled in physics with those who were not showed that: students who are not currently enrolled in a physics class have a significantly less satisfactory experience than students currently enrolled in physics even when appropriately prepared for MC.

**Question 4:** *To what extent do students learn particle physics content and research, and, more particularly LHC physics and research with a goal toward increasing students’ awareness and knowledge? (Do the opportunities provided by QuarkNet show evidence of being effective [see Question #3]).*

***Introduction*:** Similar to CMS/ATLAS national/international masterclass (MC), student research programs are not parts of one program within QuarkNet but actually as many programs as there are student research sites. Each site has different mentors, teachers, and research focus. And like MC, some sites may need some small improvements, but overall for the four years data have been collected on student research programs, there have been statistically-significant difference between pre- and post-tests. So, now that student research program, overall, has been shown to be effective, and characteristics of an effective student research program have been identified, student testing will only be collected every three or more years and/or whenever research programs substantively changes.

***Findings:*** Overall, for all four years student programs have shown to be effective in increasing students’ scientific literacy with regard to scientific methodology.This year data were collected for the purpose of providing further information on student research program effectiveness, and to add support for claims made about factors that lead to effective student research programs. In past years, there were issues with pre-tests and no post-test matches, and a greater number of tests that were unequal in effort. After contacting mentors of these programs individually by emailing their center’s individual results, and effort by staff to remind mentors that students should complete both pre- and post-tests, the number of unmatched pre- and post-test decreased dramatically. This may have had an unintended effect in that the T-test significant difference also decreased. That is, in getting a better response rate, students who may not have completed tests in the past (particularly post-tests), were doing so this year; whereas in the past maybe only committed students were completing the tests conscientiously.

A full, internal, *Student Research Programs: Summer 2013*report was provided to QuarkNet staff. This section provides key findings from that internal report with a focus on the purpose as stated above.

* A T-Test analysis indicated that the difference in pre- and post-test scores was statistically significant. This year there was only a slightly statistically significant difference between pre- and post-tests (P = .03). In previous years the differences were <.01 and even <.001. For the 2010 programs the pre- and post-test difference for longer-term programs was <.001 and for shorter programs (less than a month) p = .05. Individual student’s mean scores ranged from pre 17-33; post 19-42.
* This year, as in the past, changes in propositional statements indicated a more in-depth understanding of scientific methodology. Chains of thought indicated a better idea of how scientists engage in actual research, as opposed to a linear, “The” scientific method. The “propositional statements” that link concepts showed that what students are taught in schools for “pre” (often not incorrect although many insightful) and what they learned through their research experience “post” (the more “scientifically literate” way to look at science process) are fundamentally different.
* The propositional statements this year unambiguously showed changes in four major areas: links were integrated, less linear, and more meaningful; data analysis and related links was separate from the physical place where experiments were done (‘laboratory’ and related links); as in past years, concepts and statements used showed a better understanding of the environment in which authentic research is done; and, several maps across many of the programs looked more like a decision-point tree with links than a classic concept map. In addition, several students added concepts related to technology, e.g., “programming,” “internet,” “Excel.”

**Metrics: Success Factors**

**Center Success Factors**

Data have been gathered for 10 years. The rating system was refined in 2005-2006, after six years of data collection. Ratings are 1 = minimal; 2 = satisfactory (the standard); 3 = outstanding (exceeds standard). Having a highly effective mentor or an effective teacher leader does not indicate a more effective center and vice versa.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Center/Year** | **A** | **B** | **C** | **D** | **E** | **F** | **G** | **H** | **I** | **J** |
| 2012 |  |  |  |  |  |  |  |  |  |  |
| OO | 2 | 1 | 1 | 1 | 1 | 2 | nd | 2 | 2 | 1 |
| MM | 1 | 2 | 2 | 2 | 2 | 1 | 1 | 1 | 0 | 1 |
| LL | 3 | 3 | 2 | 3 | 2 | 3 | 3 | 1 | 2 | 2 |
| KK | 3 | 3 | 3 | 2 | 1 | 3 | 2 | 1 | 2 | 2 |
| JJ | 0 | 3 | 2 | 3 | 1 | 3 | 0 | 3 | nd | 2 |
| 2011 |  |  |  |  |  |  |  |  |  |  |
| II | 3 | 2 | 3 | 2 | 2 | 3 | 2 | 3 | 3 | 3 |
| HH | 2 | 2 | 1 | 3 | 2 | 2 | 1 | 2 | 1 | 1 |
| GG | 2 | 2 | 3 | 3 | 3 | 3 | 2 | 1 | 2 | 2 |
| FF | 2 | 3 | 2 | 3 | 3 | 2 | 1 | 2 | 3 | 3 |
| 2010 |  |  |  |  |  |  |  |  |  |  |
| EE | 3 | 3 | 2 | 3 | 3 | 2 | 3 | 3 | 3 | 3 |
| DD | 3 | 3 | 1 | 3 | 3 | 2 | 1 | 1 | 1 | 1 |
| CC | 1 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 2 | 1 |
| BB | 2 | 3 | 3 | 2 | 2 | 2 | 3 | 3 | 2 | 3 |
| AA | 1 | 3 | 2 | 2 | 3 | 1 | 1 | 1 | 0 | 1 |
| Z | 3 | 2 | 1 | 1 | 1 | 2 | 3 | 3 | 2 | 2 |
| Y | 3 | 3 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 1 |
| X | 1 | 3 | 3 | 3 | 3 | 2 | 3 | 3 | 1 | 2 |
| 2009 |  |  |  |  |  |  |  |  |  |  |
| W | 0 | 3 | 3 | 2 | 2 | 0 | 1 | 3 | 1 | 2 |
| V | 3 | 3 | 1 | 3 | 3 | 1 | 1 | 3 | 1 | 2 |
| U | 1 | 1 | 2 | 3 | 1 | 3 | 1 | 1 | 1 | 3 |
| 2008 |  |  |  |  |  |  |  |  |  |  |
| T | 0 | 1 | 1 | 2 | 1 | 2 | 1 | 1 | 0 | 1 |
| S | 3 | 2 | 0 | 2 | 1 | 1 | 2 | 1 | 0 | 1 |
| R | 2 | 2 | 2 | 1 | 0 | 0 | 1 | 1 | 1 | 0 |
| 2007 |  |  |  |  |  |  |  |  |  |  |
| Q | 2 | 3 | 1 | 3 | 3 | 1 | 2 | 2 | 2 | 2 |
| P | 0 | 3 | 1 | 2 | 1 | 3 | 2 | 1 | 1 | 2 |
| 2006 |  |  |  |  |  |  |  |  |  |  |
| O | 0 | 1 | 3 | 2 | 2 | 2 | 2 | 2 | 3 | 3 |
| N | 0 | 3 | 1 | 2 | 2 | 1 | 1 | 2 | 1 | 1 |
| M | 0 | 2 | 1 | 3 | 2 | 2 | 1 | 2 | 1 | 1 |
| L | 3 | 2 | 1 | 2 | 2 | 2 | 2 | 1 | 0 | 2 |
| 2005 |  |  |  |  |  |  |  |  |  |  |
| K | 3 | 1 | 2 | 2 | 3 | 0 | \*\* | 3 | 2 | 1 |
| J | 2 | 3 | 2 | 1 | 2 | 2 | 0 | 1 | 1 | 1 |
| I | 0 | 3 | 2 | 2 | 3 | 2 | 3 | 2 | 1 | 1 |
| H | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 2 | 1 | 0 |
| 2004 |  |  |  |  |  |  |  |  |  |  |
| G | 0 | 2 | 2 | 1 | 2 | 1 | 0 | 3 | ND | ND |
| F | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 3 | 2 | 3 |
| E | 2 | 2 | 2 | 2 | 2 | ND | ND | 1 | ND | ND |
| D | 1 | 1 | 1 | 1 | 3 | 0 | 0 | 1 | ND | 2 |
| 2003 |  |  |  |  |  |  |  |  |  |  |
| C | 2 | 3 | 1 | 1 | 3 | ND | 2 | 3 | ND | 3 |
| B | 3 | 1 | 3 | 3 | ND | ND | 2 | 3 | ND | 2 |
| A | 3 | 1 | ND | 1 | 3 | 0 | 0 | ND | ND | ND |

*\*\* applied for grant*

*A = Strong Teacher Leader; B = Strong Mentor; C = Meet Regularly; D = Meaningful Activities; E = Classroom Implementation; F = Staff Support; G = Money/Grants for Additional Activities; H = Stable Participant Base; I = Teacher Professionalism; J = Learning Community*

**Characteristics of an Effective Masterclass**

The following success criteria were first listed in the informal MC 2011 report and further expounded upon in the 2012 report. The list of characteristics, based on the data over several years, and a new section on teacher orientation are:

1. ***Target audience.*** Students who best meet the criteria of having the most effective masterclass experience are currently enrolled in a physics class and NOT in grades nine, ten or below. And, that even if students are high-achieving and have been prepared for MC, they should meet this criterion. This year the study underscores, and provides further data, to support this claim.
2. ***Lectures*.** The lectures have to be focused, relatively short, engaging with not so much text on each slide of the PowerPoint presentations. They also have to be interactive. When students are *not* involved, they report that the lecture is boring, too long, etc. Students like most when they can ask questions and are answered at their level of understanding.
3. ***Exercises.*** They like working with actual data and the “real-world” nature of the exercise. It is important to focus on the fact that analyzing data as part of actual scientific investigation is very different than what they often experience in classrooms investigations that are not part of a long-term project.
4. ***Vidoconferencing***. This is the main area that needs improvement and has needed improvement for several years. While students like to interact with other students, especially those in other countries, as one student summed it up, “Very interesting, but technical difficulties detracted.”
5. ***Discussions before Videoconferencing***. It was suggested in the 2010 MC report that there be a short discussion before the videoconference to discuss what questions students would be asking as well as having the mentor answer their questions before the conference. Comments by some students this year indicate that discussions and preparation for videoconferencing are not being included at some sites.
6. ***Teacher Orientation***. It has become clear over the last couple of years that teachers attending orientation does appear to make some difference~~s~~. Student preparation, expectations, including goals and objectives, and resources for masterclass, are all essential aspects of MC orientation.
7. ***Tours***. Including tours helps students better understand particle physics research better and how physicists do their work. This has implications for students wanting to go into physics careers and becoming more scientifically literate—two major goals of QuarkNet.

**Characteristics of Effective Student Research Programs**

The goal of QuarkNet student research programs is to increase students’ understanding of scientific research and make them more scientifically literate. While there are no specific data on how each individual center implements their student research program, it is clear from the pre- and post-tests that the following are critical factors in having an effective program to achieve the program goal.

1. *Have students participate in authentic scientific research for at least a month.*

Data from several years, particularly 2012 indicate when programs last less than a month pre- and post test scores are similar, i.e., no student showed significant gains.

*2.*  *Make sure students have the opportunity to participate in every level of research, even if it is through discussion, of every part of your science process.*

The maps of students in programs that showed no differences in pre- and post-test scores also did not indicate, through propositional statements, differences in understanding of scientific methodology. These students, therefore, did not appear to become more scientifically literate.

3. *Point out the difference between “the” scientific method and how science is actually done while emphasizing that there are actual steps* – name the steps for them.

It is clear that there is a difference between the perceptions of students before participating in a student research program and after a rich research experience. In pre-maps, students write propositional statements such as “leads to” and “uses” while in post-maps links include phrases such as “”helps in determining” and “verifies.” Some students have fairly scientifically literate pre-maps but change, sometimes subtly, in post-tests. In 2013, the many students who included decision points, clearly got the idea of science process being iterative, precise, and messy.

**Fellows Survey**

There are five leadership fellows, one of whom is Fermilab staff. Leadership Fellows completed Participant Workshop Surveys at the end of the third training session that was held October, 2012. Means for all items on the surveys were between (1) “Strongly Agree” and (2) “Agree,” and there were no answers in the (3) “Disagree” or (4) “Strongly Disagree” categories.

**CMS Data Workshop Forms**

Survey data were collected for June – August 2013 using a QuarkNet workshop participant survey for CMS Data workshops from three centers. All respondents were high school teachers. There were 17 CMS data workshop respondents. As shown, means were between (1) “Strongly Agree” and (2) “Agree,” out of a possible (4) “Strongly Disagree.” Means and variation (standard deviation) were similar for CMS e-lab workshops.

**Table:** CMS Data Workshop Survey Items with Means and Standard Deviations for Each Item

|  |  |
| --- | --- |
| **Item** | **n = 17; 3 centers**  **Mean/SD** |
| a. The workshop was well organized. | 1.5/0.5 |
| b. The facilitator clearly stated the objectives of the workshop. | 1.4/0.5 |
| c. The objectives of the workshop were met. | 1.2/0.5 |
| d. The instructor(s) facilitated the workshop effectively. | 1.5/0.5 |
| e. The schedule allowed sufficient time to meet the objectives. | 1.2/0.7 |
| f. The workshop provided time to consider ways to use what I learned in the classroom. | 1.2/0.4 |
| g. The workshop provided opportunities to ask questions and/or discuss ideas. | 1.2/0.4 |
| h. The workshop helped me feel more comfortable with the topic(s). | 1.4/0.4 |
| i. My understanding of the material increased. | 1.2/0.4 |
| j. Questions were answered/addressed at my level of understanding. | 1.4/0.5 |
| k. I experienced inquiry-based teaching techniques. | 1.7/0.5 |