QuarkNet
Evaluation Section: NSF Annual Report
September 2012

The following QuarkNet evaluation data were collected between September 2011 and September 2012. Questions from an Evaluation Matrix developed by QuarkNet program director and NSF program director are addressed, preceded by a summary of data collection and analysis. This is the fourth year using the Matrix. Collection strategies were updated based on findings from last year and included in this year's evaluation section. This is the last annual report under the 2008-2012 grant from The National Science Foundation (NSF) and the Department of Energy (DOE).

(Note: In the years since this report, the project transitioned to focus on Data Portfolios. In response, the evaluation was formative rather than providing the outcome data that is included in the following report.)

Data Collection and Analysis: Teachers

Data collected for teacher programs to address Evaluation Matrix questions:
1. To what extent does QuarkNet support and create opportunities for teachers to learn particle physics content and research with a goal toward providing the necessary environments for students to learn?
2. To what extent do teachers use modern physics examples in an interactive way when teaching subjects such a momentum and energy with a goal toward increasing students' awareness and knowledge of particle physics concepts?
6. 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?
The instruments are available upon request.

Center Programs:
Data were obtained using a Site Visit Protocol, Classroom Observation Protocol and Telephone Interview Protocol. The cadre of leadership fellows trained to gather data by evaluators over the past four years (beginning summer 2009) obtained these data for the following: fall 2011 visit to one center whose institute was not held summer 2011 and summer 2012 site visits to five centers, spring 2012 visits to 12 classrooms of teachers from five 2011 summer institutes and telephone interviews with 12 teachers from five 2011 summer institutes.

Site Visit Protocol:
The Protocol was adapted from the *Template for Site Visits* that has been in use to assess QuarkNet center programs for 12 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 Site Visit Protocol was changed slightly from last year in an attempt to be more user-friendly. Feedback from leadership fellows indicates that the adjustments made it easier to gather data, and evaluators found the data to be more complete than in past years. If needed, further revisions will be made to ensure thorough data collection in the coming year.
The mentor interview protocol includes ten 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). For interviewing teacher participants, an interview guide was developed for brief interviews to obtain critical in-

formation on participants, such as their reasons for participating and plans for implementation. In 2012, 6 centers were visited by leadership fellows.
Analysis of Data: Data are analyzed qualitatively (content analysis) and summarized into the annotated "success factors."

Classroom Observation Protocol:
The 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 Protocol includes ten questions including demographics, classroom implementation, perceptions of the center teacher programs, and support from QuarkNet staff. The Protocol is used by teacher leaders during site visits to summer institutes and for classroom visits and 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 2012, a total of 12 teachers, or two to three each from five centers were interviewed by telephone.
Analysis of Data: qualitative (content analysis)

Teacher Survey:
The Survey was developed to collect data related to the QuarkNet goals and objectives to corroborate and supplement data gathered using other instruments. Evaluators worked with QuarkNet staff to solve technical problems with the online survey that were identified in 2010-2011, to ensure more complete data gathering.

The survey was placed online by QuarkNet staff in early spring of 2012. One hundred and nine teachers were selected to complete the survey with the expectation of a 70% minimum response rate, or 76 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 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 2011-2012 school year, from March to September 2012, QuarkNet teachers were asked to complete an online survey. Teachers were chosen from a database provided by QuarkNet staff. The database was said to have information on 544 "active" teachers and 291 "passive" teachers. Twenty per cent of the teachers from the "active" category were picked, for a total of 109 teachers. Emails were sent to a total of 132 teachers requesting that they respond to the online survey.

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.

Emails were sent on eight separate occasions, once to the whole group and then to subgroups who had not responded. Other individual and small group emails were sent in addition to the eight mass emails. 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)
When emails were returned as undeliverable in six cases, other teachers were chosen from the database. Of the teachers emailed using the database, 38 did not respond. There were 11 duplicate responses. Valid responses were received from 72 teachers. The overall response rate is 68 per cent, after exhaustive efforts to

achieve a greater number of responses. While the selection cannot be considered purely random, the data can be said to largely *represent* QuarkNet.
Issues and concerns that arose this year will be addressed next year before the survey is placed online for spring 2012.
Analysis of Data: Quantitative (frequency distributions) and qualitative (content analysis).

Boot Camp:
There are two kinds of findings: 1) Participant Workshop Survey (satisfaction) and 2) pre- and post-tests. The *QuarkNet Participant Survey* was the same as those used for QuarkNet workshops (see below), with questions added to assess specific topics and activities. In past years, content and pedagogical knowledge were being tested using a pre- and post-test. While the content portion yielded results, the pedagogy section proved to be unsatisfactory. This year, in collaboration with QuarkNet staff, the evaluators developed and tested an on-line Lesson Plan as the pedagogical section of the test. A rubric was developed for assessment of this part of the test based on Boot Camp learning objectives. Results indicated that a type of Lesson Plan format could prove effective for future Boot Camp assessment. Twenty-five participating teachers completed the content part of the test and 14 completed the pedagogical part of the test.
Analysis of Data: Quantitative analysis of the items including frequency distribution, means and standard deviations, and hypothesis testing (t-tests); qualitative analysis of the open-ended questions.

Workshops—Cosmic Ray e-lab and LHC
Workshop facilitators (QuarkNet staff, and Cosmic Ray e-lab and LHC fellows) 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 material presented will be useful, if their understanding was increased. They are finally asked to respond to open ended questions: "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

Masterclass Study:
In the spring 2012 a fourth Masterclass (MC) Study was conducted to provide data for making programmatic decisions specifically related to what kinds of preparation and background knowledge is most effective for students to achieve the intended objectives associated with masterclass. Contextual data from teachers was obtained using the *Masterclass 2009 Form and Transmittal Sheet*. The form asked teachers to provide information on: topics and resources used in regular class time and MC preparation including videos and activities used as well MC-related principles addressed. The year four study included contextual data from 11 U.S. Masterclass sites. Teachers in the study were asked by a staff teacher to participate; with one exception all had been involved with masterclasses in previous years.
Analysis of Data: Teacher contextual data were analyzed on an individual basis with a purpose of explaining the test results as a function of masterclass preparation, masterclasses, content and resources that may have been addressed prior to masterclass. The amount of data submitted was insufficient to be able to conduct various statistics such as correlating contextual data with students' test data. The analysis, therefore, was qualitative—looking for patterns in the data.

Data Collection and Analysis: Students

Data collected for student programs to address Evaluation Matrix questions:
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?

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.
The instruments are available upon request.

Student Programs:
Student programs are assessed using pre- and post-tests to assess gains in understanding of scientific inquiry (science research methodology), and abstracts developed by student groups about their research experience using a rubric. 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 test 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 2012 (from 5/31to 8/30) 11 QuarkNet centers conducted student programs. Of those, ten submitted two or more (two to 18) pre and post concept maps on "Scientific Methodology." The 11th program provided post-only data, which were not used in the analysis. The purpose of the concept maps was to assess the extent to which students became more scientifically literate as a result of participating in a student research program.
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. A majority of students (70%) showed equal effort on the pre and post concept maps. This was up from 2011 (63%) and down from 79% for summer 2010 data. The 48 usable concept maps were included in the analysis; 21 were not used because of unequal effort. The response rate was 78 percent defined as number of tests provided, including no post or no pre, compared to number of pre-post matches.

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). Once the total score was counted, data were analyzed both quantitatively (means, range, frequency distribution; t-test) and qualitatively (assessment of propositional statements). Effect size was conducted for individual sites using Cohen's 'D'.

Masterclass Questionnaire. The survey was modeled after the European masterclass (MC) survey and adapted for use with the 2008 MC and subsequently the 2009, 2010, 2011 and 2012 masterclasses, with very few editing changes along the way. There were 23 U.S. masterclasses and seven international masterclasses; the U.S. were compiled and each international masterclass was analyzed separately. There were 284 surveys from 17 U.S. sites. Of the 280 students who addressed the question, 160 were male and 120 female. Number of respondents at each site ranged from 30 to two. There was one ninth grader, 20 tenth graders, 126 eleventh graders, 136 twelfth graders. The majority of students, 88%, reported currently being enrolled in physics and 91% reported having taken physics. Therefore 91% of students comprised the target audience (note: the "target audience" is based on masterclass data from prior years—students who appear to have the most positive masterclass experiences).

The survey was 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 masterclass. Part II asked them about several aspects of masterclass such rating the four parts of the masterclass program (videoconference, lectures, exercises, tours), rating specific aspects of the videoconference, then choosing which of the four parts of masterclass they liked best. A final question asked students to pro-

vide their opinions on several aspects of masterclass. Part III asked for students to comment on the four parts of the masterclass program.
Analysis of Data: qualitative and quantitative. Quantitative included frequency distribution, means and standard deviations and t-tests. Qualitative included content analysis of student comments. U.S. masterclass data were compiled; international masterclass data was provided individually and not included in the overall statistics as formative data for the program or included in this report.

Teacher Survey: The teacher data mainly provides contextual information for analysis of the student data as well as overall impressions of masterclass. They also provide important suggestions for improvement as well as comments about what worked well. The teacher survey was in three sections: student demographics, classroom instruction, resources and materials (preparation for masterclass and topics/resources used prior to masterclass plus an open-ended question); perception of masterclass including rating elements of masterclass and degree different factors contributed to student learning (and an open-ended question).
Analysis of Data: qualitative and quantitative. Quantitative included frequency distribution and means and standard deviations; t-tests. Qualitative included content analysis of comments.

Masterclass Study: The Study was conducted using two instruments: 1) pre- and post-test for students and 2) teacher contextual data (see Teacher section, above). The student test was designed to be conducted in three time periods: pre-preparation, after masterclass preparation (mid-point) and after any post-masterclass instruction or discussion of students' masterclass experience. The test had ten items. Three were interpreting a construction that require students to interpret an event display or diagram. Four were application-type questions in which students had to apply information, that information sometimes being related to a diagram or display. Three were fact-based. The content of the questions addressed learner outcomes. There were 113 pre-tests, 77 mid-point tests and 94 post-tests from 12 U.S. masterclass sites.
Analysis of Data: A t-test analysis was conducted between tests in three time periods: pre-preparation, post-preparation and post-masterclass follow-up. Students' scores were compared across time periods. Effect size for pre, mid (post preparation) and post MC were calculated for each teacher. Effect size was conducted for individual sites using Cohen's 'D'.

Data Collection and Analysis: Fellows

Data collected about fellows to address Evaluation Matrix question:
5. To what extent do fellows provide workshops and support for their QuarkNet colleagues with a goal toward becoming more professional including contributing to the quality and practice of colleagues in the field of science?

Fellows Program:
A group of fellows (VLHC, e-lab, LHC) are assigned to support a staff teacher; leadership fellows are in a support role to centers and gather evaluation data. When a fellow facilitates a workshop, data are collected through workshop forms (see above). When a fellow assists at a center, they are asked to submit a brief report of activities.

Leadership Fellows Training:
Evaluation Matrix questions 1, 3 and 6 refer to "after being trained, leadership fellows make site visits" (see also *Center Programs* above). Training continued during the third year of data collection. Evaluators interacted with leadership fellows by email and phone conference calls regarding institute visits, classroom visits and telephone interviews. There are five leadership fellows, one of whom is on the Fermilab education outreach staff and who also acts as the liaison among fellows, staff teachers and evaluators.

Background. In 2008, QuarkNet staff proposed establishing a leadership fellows program that would draw on the experience of QuarkNet teachers in assisting centers. Evaluators suggested that in order for the teachers to best help the centers, it would be beneficial for them to know how to identify the needs of the centers.

Through conference calls, QuarkNet principle investigators and evaluators determined that the leadership fellows would be recruited and trained (see the *Evaluation Section* of the 2009 annual report for details).

Status. **Winter, Spring** 2012: Fellows made classroom visits and conducted telephone interviews to teachers from centers they had visited in the summer and fall 2011, resulting in reports on 12 classroom visits and 12 telephone interviews. Centers were identified by staff teachers for summer institute visits, and one each was assigned to the fellows.

Summer 2012: Fellows visited five summer institutes during June–August. Fellows submitted reports to evaluators during August.

Fall 2012: A Leadership Fellows meeting will be held October 10-11, 2012. Fellows will be asked to complete a survey at the end of the fourth meeting/training session, results of which will be reported in 2013.

The purpose of the fall meeting is to develop *Success Factors Toolkits* for assisting staff teachers in improvement of QuarkNet centers. In the past the stated objectives of the meeting were to review and address: evaluation procedures, protocols, and reporting; overview of QuarkNet programs led by staff teachers; centers with deficits/challenges; fellows assisting staff teachers at centers; and the Fellows' schedule for classroom visits, telephone interviews and summer institute visits during the school year. Evaluators continue to be available for technical assistance related to gathering evaluation data.

Formative Evaluation Reports

Following are formative evaluation reports, previously sent to QuarkNet:

- Emails to 18 masterclass mentors, 6 March 2012
- Emails to 15 student program mentors, 18 May 2012
- QuarkNet Boot Camp 2012, 21 August, 2012
- Masterclass 2012: Survey Results, August 2012
- QuarkNet Teacher Survey Report - 2011-2012, 21 September 2012
- QuarkNet Telephone Interview Report 2011, 6 September 2012
- Masterclass 2012: Survey Results, 18 September, 2012
- Classroom Visit Report, 19 September, 2012:
- QuarkNet Teacher Survey Report - 2011-2012, 21 September 2012
- QuarkNet Student Research Programs, 25 September, 2012
- Staff Reports & Help Desk, 27 September 2012
- QuarkNet Summer Site Visit Report 2011, September 2012

Evaluation Matrix Questions

Question 1: *To what extent does QuarkNet support and create opportunities for teachers to learn particle physics content and research with a goal toward providing the necessary environments for students to learn?*

Q1-1. Criterion: At least 70% of teachers (Boot Camp participants) show an increase in knowledge by answering 80% of the questions correctly.
Introduction: During the summer 2012 Boot Camp, 25 participating teachers completed the content part of the test, and prior to and following Boot Camp 14 completed the pedagogical part of the test. Facilitator and evaluators worked to develop a pre- and post-test for Boot Camp that would accurately capture what participants learn. Based on an item analysis of prior tests, the 2012 content test was developed. In collaboration with QuarkNet staff, the evaluators developed and tested an on-line Lesson Plan as the pedagogical section of the test.
Findings: This criterion was not met. One of the six content questions showed the participants increased content knowledge to a significant degree (<.001 level of significance) and another to a lower level of significance (<.05). Three of the test questions were correct at 80% or over for 16 to 17 teachers (about 64% of teachers). The pedagogy part of the test indicated three of the 14 teachers showed increases in Boot Camp learning outcomes related to pedagogy. This pilot test of the lesson plan idea showed that a truncated version of this part of the test, given at the same time as the content test, could provide appropriate data. The content and pedagogy parts of the test will be adjusted for use in next year's Boot Camp.

Q1-3a. Criterion: Center programs include opportunities to learn particle physics.
Introduction: Evaluators have these data from several sources. During the fall of 2011 and summer of 2012, leadership fellows visited institutes at five QuarkNet centers. The fall visit was to a center that did not hold an institute during summer 2011. Twenty-six teachers were interviewed using questions from what is called a "Participant Interview Guide" that includes a brief, focused form of the interview protocol. In-depth interviews were conducted with five mentors and seven teachers who hold leadership roles at the centers. During spring 2012, visits were made to 12 teachers' classrooms from centers visited in summer 2011, and telephone interviews were conducted with a total of 12 teachers.
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:

- Leadership fellows interviewed 26 teachers at five institutes using an abbreviated protocol and seven teacher leaders using an in-depth protocol for a total of 33 teachers; 27 (81%) teachers indicated that their participation in QuarkNet helped them implement particle physics in their classrooms at frequencies from 1-2 lessons to long-term projects. Four used e-labs and *Particle Adventure*; five masterclass; eight had students do research with a detector; nine taught the Standard Model and 20 "sprinkled" topics such as conservation of momentum and energy throughout their curriculum. Six mentioned that they are new and they are not implementing QuarkNet yet.
- Of the teachers interviewed by phone, all 12 of the respondents mentioned that they are better able to integrate the topics into their teaching because they gained content knowledge through QuarkNet events. Four said having a detector in the class helps them explain ideas and the process of research. Three said that exposure to researchers and current topics helps them teach students about the work that is going on in particle physics and one said, " if not for the QuarkNet workshops, there is no way I would be doing this….it's essential." Teachers reported there were direct connections for how to use QuarkNet in the classroom such as sharing how to apply particle physics content (42%), current topics (33%) and particle physics research (35%). They also appreciated being exposed to making posters online, detectors in relation to physics curriculum, new lab ideas and leading independent study projects for students. 17 (59%) are teaching the Standard Model, 42% Particle Adventure, and 25%-33% e-lab, masterclass, research with a detector and "sprinkling" examples such as conservation of momentum and energy at frequencies ranging from 1-2 lessons to long-term projects.
- Classroom visits were made to 12 teachers from five centers whose institutes were visited in 2011. Their years of participation in QuarkNet ranged from 1 to 12 years. Eight were relatively new to QuarkNet, at one

to three years. While they were not all implementing particle physics when fellows observed their classrooms, all 12 teachers introduced particle physics content and current topics in science and research in their classrooms during the year. The leadership fellows' observations show that the teachers' intended outcomes and topics taught were related to particle physics, physics and physical science. Eleven of the twelve had students who solved problems in whole groups, small groups or individually. Eleven were using lab equipment and eight used computers during the class. Nine engaged in instructional strategies and emphases that reflected inquiry-based teaching. Half of the teachers presented classroom activities that had an inquiry focus. Ten (83%) had students who did long-term projects related to e-labs, masterclass, Standard Model and research with a detector. Five (42%) teach Standard Model, research with a detector or "sprinkle examples" for 1-2 weeks at a time. Others teach 1-2 lessons or 3-5 lessons on topics related to QuarkNet and particle physics. All of the teachers visited stated that their participation in QuarkNet enhanced their ability to introduce particle physics in their classrooms. Eight said they gained knowledge that gave them confidence for teaching modern physics or working with a detector.

Q1-3b. Criterion: 80% of teachers (survey respondents) report that they benefit from interactions with mentor.

Introduction: Data were gathered from an online teacher survey. Evaluators worked with QuarkNet staff to correct technical problems that were identified in 2011. The revised form was placed online by QuarkNet staff early spring, 2012. Between March and September 2012, QuarkNet teachers were asked to complete the online survey to provide information regarding their classroom practices, perceptions of QuarkNet, and report on their teacher professionalism.

Teachers were chosen from a database provided by QuarkNet staff. Valid responses were received from 72 teachers. The overall response rate is 68 per cent, after exhaustive efforts to achieve a greater number of responses. While the selection cannot be considered purely random, the data can be said to largely *represent* QuarkNet.

Findings: The criterion that 80% of teachers (survey respondents) report that they benefit from interactions with mentor was met somewhat.

- 68 (94%) teachers responded to a request to "rate aspects of their QuarkNet Center" that included "Support from QuarkNet mentors." Of the 68 teachers who rated "Support from QuarkNet Mentors," 51 (75%) chose a 'positive' response, 17 (25%) chose 'neutral' and no one chose 'negative.' Four did not respond.
- Comments about the level of support from mentors were very positive:

"…without question the most helpful and influential was the QN mentor at [my center], without whom none of this would have been possible for me;" "[The mentor] at my QuarkNet center, has been a tremendous leader. Always willing and able to assist me with equipment, conceptual or pedagogy related questions, yet he always treats us as equals and professionals. Under his direction, QuarkNet has been a very positive environment."

- Teachers were also asked to rate aspects of the program that reflected on their interactions with the mentor, such as support for transfer to the classroom (71% 'positive,' 29% 'neutral,' and 1% 'negative'), quality of workshops (82% 'positive,' 16% 'neutral,' and 1% 'negative'), quality of resources (84 % 'positive,' 18% 'neutral,' and no 'negative'), and comparison with other programs (84% 'positive' and 16% 'neutral,' and 1% negative). In comparison, ratings for support from staff teachers were slightly higher (77% 'positive) and for lead teachers (78% 'positive').

Q1- 3c. and d. Criterion: Fellows and evaluators use "effective practices" as a measure. (Staff get data to correct ineffectiveness). Centers show an increase in effective practices.

Introduction: Over the 12 years of evaluating QuarkNet, evaluators have identified 10 "success factors" that describe the effectiveness of a center. It is these factors that leadership fellows rate to ascertain what challenges and issues centers face that will be addressed, in collaboration with staff teachers, to develop the *Success Factors Toolkits*. A description of the ten factors was elaborated on in a document developed for leadership fellows training and is available upon request. The success factors are rated as "minimal," "satisfactory" and "outstanding." "Satisfactory" is the standard. Those that are "outstanding" have practices and procedures

that might be disseminated to other centers, especially those that are struggling in these areas. Leadership fellows can help with that task. Data collected for success factors started in 2003 for which there are some data and in more recent years, data are available for all of the factors. See charts under the DOE Metrics.
Findings: The criterion for fellows and evaluators use "effective practices" as a measure was met. The criterion for centers show an increase in effective practices was met to some extent. Over the past three years there have been increases in almost all of the practices so that in 2011 all practices were in the satisfactory or above category. However, the 2012 data show seven of the ten practices are in the "satisfactory," or above category. The data show that 70 percent or more of centers met or exceeded three of the factors and 50 percent or more of centers met or exceed for eight of the ten factors that indicate a successful center, as shown below. Only 30 percent met the factor, "Address teacher professionalism such as attending meetings of professional organizations." The ten factors and data for 41 sites are as follows from 2003 to 2012.
A and B - Strong teacher leader, and strong mentor who understands education and professional development. If there is a strong teacher leader, a strong mentor is not as important as s/he would be if there was a weaker teacher leader. The reverse is also true. In some cases there is no teacher leader at the center. For teacher leaders, there were 15 "3", ten "2" and six "1" ratings. Ten centers did not identify a lead teacher. A total of 61% of teacher leaders met or exceeded the standard. For mentors there were nine "1", 11 "2" and 20 "3" ratings, therefore, 76% of mentors met or exceeded the standard.
C - Participants meet regularly. There were two "0" ratings for this category meaning the center did not meet the minimum; 17 "1", 14 "2" and eight "3" ratings indicating 54% met or exceeded the standard. There was one 2003 center for which there were no data.
D- Meaningful activities, not just talks and trips. There were nine "1", 18 "2" and 14 "3" ratings, indicating 78% met or exceeded the standard.
E - Directly address classroom implementation of activities for all teachers. There were no data for one 2003 and one 2012 center, and three "0," meaning three centers did not meet the minimal for the factor; eight "1", 15 "2" and 14 "3" ratings, indicating 68% met or exceeded the standard.
F - Specific support and/or follow up from staff such as helping troubleshoot cosmic ray detectors. There were no data for two 2003, one 2004 and one 2012 centers, and six "0" ratings, meaning the factors did not meet the minimum for six centers; eight "1", 18 "2" and five "3" ratings, indicating 54% met or exceeded the standard.
G - Money for additional activities and/or have additional grants. While it was not expected that centers seek extra money or fund additional activities, those that did appeared to be especially effective. The earlier data had one "No Data" in 2003 and one applying for grant in 2005. Otherwise, there were four "0", 16 "1", 13 "2" and six "3" ratings, indicating 44% met or exceeded the standard.
H – Stable participant base. There was one center for which there was no data in 2003 and two in 2012; 14 "1", nine "2" and 13 "3" ratings, and one "0" rating, indicating 54% met or exceeded the standard.
I - Address teacher professionalism such as attending meetings of professional organizations. This success factor is described in detail in the *QuarkNet Evaluation Report, Year Seven*, 31 July 2006, pages 13 and ff. There were no data except for one center during 2003-2004 as this factor was not identified and described until 2005. Between 2005 and 2012, there were six "0" ratings, meaning that the center did not meet the minimum for this success factor; 13 "1", ten "2" and four "3" ratings. 34% met or exceeded the standard.
J - Establish a learning community, which means that teachers at other levels, e.g. middle school, undergraduates, graduates or others are working together at the center or through outreach. There were three centers for which there were no data in 2003 and 2004. For all the years there were four "0" ratings, meaning that the center did not meet the minimum for this success factor; 12 "1", 13 "2" and eight "3" ratings, indicating 51% met or exceeded the standard.
Leadership fellows work with staff members to determine the centers' needs. In the coming year there will be a focused effort for leadership fellows to provide specific support related to the Success Factors.

Q1-4. Criterion: Survey shows at least 80% report an increase in content knowledge.
Introduction: Survey data were collected June–August, 2012, using the QuarkNet Participant Workshop Survey form for cosmic ray e-labs and LHC 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:

E-Lab Surveys: The criterion, survey shows at least 80% report an increase in content knowledge was met. Seventy surveys from e-lab workshops representing nine QuarkNet centers were reviewed. Responses for items (h) and (i) indicated greater than 80% increase in content knowledge. For item (h) and (i), all 70 (100%) respondents chose (1) "strongly agree" or (2) "agree." For both items none chose (3) "disagree" or (4) "strongly disagree."

LHC Surveys: This criterion was met. Surveys from 11 respondents who participated in an LHC workshop representing one QuarkNet center were reviewed. For both items (h) and (i), all 11 (100%) respondents chose (1) "strongly agree," indicating an increase in content knowledge.

Q1-5. Criterion: Staff reports show support provided to all centers on a quarterly basis and more support to centers identified as not operating effectively.

Introduction: Data were collected between September 2011 and August 2012 using a revised Staff Report Protocol. One staff teacher focuses on Help Desk; those entries were included in the analysis.

Based on success factors, evaluators identified centers that appeared to not be operating effectively. Then, after checking with staff teachers, nine centers were selected. Three centers were identified as "on sabbatical' and four were identified as reconfiguring so "not effective yet."

As in years past, Help Desk continues to provide a vital role in addressing issues that are not readily available through other aspects of the QuarkNet program. Staff teachers appear to rely on Help Desk for various issues (30% of contacts are with staff). While it is primarily for help with cosmic ray muon detectors (CRMD's), Help Desk has become a clearinghouse for other issues as well, such as workshops (cosmic ray workshops for teachers), pedagogical and content questions. Teachers are the primary users, as intended.

Findings: This criterion was met for 40 of the 45 active centers. It was not met for centers that are considered as "not operating effectively." However, only two of the nine centers that were not operating effectively were not supported every quarter.

The Protocol for reporting staff teachers' contacts with centers was reviewed during fall 2011, revised and put into use January 2012. The significant changes to the protocol were the removal of the "Task" code that described the category of contact, and a change of the word "Category" code to "Support" code. Two staff teachers used the new protocol from January to August. One used the previous protocol. The difference in protocol version used does not affect the metric, which is reported in a table under DOE Metrics. The staff teacher who focuses on Help Desk entries uses a different protocol.

Staff coded Contact (mentor, teacher, student), Method of contact (email, phone, video conference, personal contact) and Support (detectors, e-lab, masterclass, student research, local workshop, year 1 research, year 2 institute, other).

Contact codes were mostly mentor (first quarter = 101; second quarter = 88; third quarter = 154; fourth quarter = 126). Staff teachers appear to focus on contacts with mentors (469 or 54 %) consistently throughout the year. Teacher contacts were 46 percent of the total (first quarter = 54; second quarter = 75; third quarter = 116; fourth quarter = 153). Contacts with teachers occur more frequently during the second half of the year, when teachers typically implement QuarkNet in the classrooms (spring) and attend workshops and institutes (summer). Three students were listed as contacts over the four quarters.

Contact methods were mostly emails (n = 686) followed by phone (n = 60) and personal contacts (n=52). There was a low number of videoconferences (n=13).

Support codes were mostly "Local Workshop" (n=178), especially during the summer when the workshops occur. The next highest number is in the "Other" category (145) which includes a variety of topics such as setting up visits or phone conferences, discussing centers' issues or needs, answering content questions, etc. Detectors (n=109) and masterclass (n=115) have similar numbers of supports.

Cosmic Ray e-lab Help Desk

The log sent monthly to evaluators includes compiled numbers of information provided in the following categories:

- Presentations (24%; mean 20.1; total 241): such as planning workshops; workshop details.

- Hardware Issues (35%; mean 29.6; total 355): such as plateauing/testing; GPS troubleshooting; request for CRMD; set up cloud chamber; request for parts/parts not working.
- Software Issues (28%; mean 23.9; total 287): mostly new accounts, forgetting passwords; school computer problems; how to…(e.g., e-lab analysis).
- Server (1%; mean 1.2; total 14): such as upload failed; server down.
- Content Q&A (7%; mean 6.1; total 73): such as questions and comments about the e-lab user manual; cosmic ray questions; new features that help with content such as new workshop PowerPoint.
- Pedagogy Q&A (5%; mean 3.8; total 46): poster content and help with posters; inquiry questions for students; building a QuarkNet center community; evaluation questions and comments.

Categories of people contacting the Help Desk were:

- QuarkNet Fellows (19%; mean 18.3; total 219): all categories including workshop information and help for students.
- Teachers (26%; mean 25.1; total 301): mostly QuarkNet teachers all categories.
- Students (2%; mean 1.5; total 18): majority were students using the e-lab—research questions such as designing investigations; content or 'how to' questions such as plateauing, e-lab analysis; setting up a cloud chamber.
- QuarkNet Mentors (15%; mean 15.0; total 180): all categories but especially workshop plans, preparation and dates; request for teacher lists; requests for CRMDs.
- QuarkNet/I2U2 staff (30%; mean 29.1; 349): all categories including workshop information; CRMD lists (for locating and possible redistribution of CRMD's); "bugs" in the software; building new accounts.
- Researchers (9%; mean 8.3; 111) all categories but especially troubleshooting; requests for manuals, request to purchase CRMD.

Other data were:

- The largest number of contacts was in August (150) followed closely by June (138). The smallest number was during December (41). The average was 98 per month with December and 103 excluding December. This average was up from the previous four years: 66 per month (2010-2011), 87 per month (2009-2010), 65 per month (2008-2009) and 61 per month (2007-2008).
- This year staff report codes were the highest used at 349 or 30% of the total number of codes. Teacher codes were a close second at 301 or 26% of the total.
- Also included were QuarkNet centers that were served through Help Desk. These data are included in the section on staff reports.
- Examples of no follow up (22%; mean of 21.4 per month; total 257): mostly creating new accounts, looking up account information; also instructions, sending parts and questions about data.
- Examples of Non-QuarkNet contacts (16%; mean of 29.5 per month; total 192): such as requests to purchase CRMDs and manuals and wanting to learn more about workshops.

Question 2: *To what extent do teachers use modern physics examples in an interactive way when teaching subjects such a momentum and energy with a goal toward increasing students' awareness and knowledge of particle physics concepts?*

Q2- 1a. Criterion: Teachers report using examples of particle physics when teaching momentum/energy-related topics at least "to some extent" for 80% of teachers surveyed. Data show an overall increase in use over time in QuarkNet.

Introduction: From March to September 2012, an online teacher survey to gather data on teachers' experience with the QuarkNet program was completed by 72 teachers, representing 68% of the 106 teachers who made up 20% of the "active" teachers. While the selection cannot be considered purely random, the data can be said to largely *represent* QuarkNet.

Findings: The criterion, teachers using examples of particle physics when teaching momentum/energy-related subjects "to some extent" for 80% of teachers surveyed was met. The percentage of teachers using examples of a number of topics ranged from 67-86%. Of the 72 respondents to the online survey, the following numbers of teachers stated they have used these particle physics examples when they teach, from one to many times: conservation laws 59 (82%), momentum 55 (76%), vectors 48 (67%), energy 62 (86%), nuclear physics/energy 56 (78%) and energy–mass conversion ($E=mc^2$) 52 (72%).

Q2-1b. Criterion: Benchmark for classroom observations is using examples whenever appropriate. Data show an overall increase with number of years of participation.
Introduction: During spring 2012, four leadership fellows and one independent evaluator made classroom visits to 12 teachers. The evaluator was recruited to one center where language was a barrier for the assigned leadership fellow. The teachers represented five centers whose institutes were visited in summer and fall 2011. While they were not all implementing particle physics when fellows observed their classrooms, all 12 teachers introduced particle physics content and current topics in science and research in their classrooms during the year. Their years of participation in QuarkNet ranged from 1 to 12 years. Eight were relatively new to QuarkNet, at one to three years. During the observations, the teachers were teaching a variety of topics such as: conservation of energy or momentum, use of or research with detectors, electricity and magnetism and physical science topics.
Findings: The criterion, benchmark for classroom observations is using examples whenever appropriate was met, and data show an overall increase with number of years of participation was also met.

The teachers' intended outcomes and topics taught were related to particle physics, physics and physical science. Eleven of the twelve had students who solved problems in whole groups, small groups or individually. Eleven were using lab equipment and eight used computers during the class. Nine engaged in instructional strategies and emphases that reflected inquiry-based teaching. Half of the teachers presented classroom activities that had an inquiry focus. During the visits, when introducing physics topics, teachers related them to particle physics.

Interviews with the teachers during the visits indicate that all of the teachers include particle physics topics in the classroom. Ten (83%) had students who did long-term projects related to e-labs, masterclass, Standard Model and research with a detector. Five (42%) teach Standard Model, research with a detector or "sprinkle examples" for 1-2 weeks at a time. Others teach 1-2 lessons or 3-5 lessons on topics related to QuarkNet and particle physics. All of the teachers visited stated that participation in QuarkNet enhanced their ability to introduce particle physics in their classrooms. Eight said they gained knowledge that gave them confidence for teaching modern physics or working with a detector.

Other data, such as telephone interviews and teacher interviews during site visits indicate that teachers use particle physics examples with their students (see Question 1, Criterion 3a).

Q2- 1a. and Q2-1b Addendum
Introduction: Since student achievement is often linked to the context in which a test or student product is conducted, the Masterclass Study included collecting contextual data from teachers. The *Form and Transmittal Sheet* provided data on how teachers prepare students for masterclass specifically and throughout their physics course(s) in general as "Relevant topics addressed in regular class time" and "Principles addressed." It is what teachers reported doing in general and principles addressed that relate to Question 2.
Findings: Of the 12 teachers who provided contextual information, nine (75%) reported using particle physics examples to teach vectors and conservation laws. Seven (58%) reported using particle physics examples to teach the Standard Model and detectors; six reported using particle physics examples to teach accelerators. Between 10 and 11 of the 12 teachers (over 80%) reported teaching particle physics principles such as "physicists make inferences from indirect observations," "there are four known fundamental forces," "all matter is made of quarks and leptons," and five others.

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?*

Q3-1a. Criterion: Teachers report (through a survey) 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 in QuarkNet.

Introduction: From March through August 2012, an online teacher survey to gather data on teachers' experience with the QuarkNet program was completed by 72 teachers, representing 68% of the 106 teachers who were identified to be 20% of the "active" teachers.

Findings: The criterion that teachers report at least 20% relative amount of class time devoted to students exploring and providing explanations using scientific methodology was met. When asked to rate the frequency of use of classroom practices, results show that 50-72 (69-100 %) of the survey respondents frequently use more than half (six of the 11) of the practices that support the goals of QuarkNet (support inquiry-based learning, collaboration and research). These findings show that six of the practices that support QuarkNet goals were used at mid to high frequency. "Frequent use" is considered to be a range from "Almost every day" to "Once or twice a month."

Four of the practices that support inquiry-based learning, collaboration and research were used similarly at mid to high frequency, 30-42 (42%-58%) and at low frequency, 29-42 (40%-58%).One practice that ***does not*** support inquiry-based learning, collaboration and research is used infrequently by 49 (68%) of the respondents. Of concern is that five practices that ***do not*** support inquiry-based learning, collaboration and research were shown to be used frequently by 44-70 (61-97%) of the teachers.

To summarize these findings: 69-100% of the survey respondents frequently use more than half (six of the 11) of the practices that support the goals of QuarkNet (support inquiry-based learning, collaboration and research). Four of the practices that support inquiry-based learning, collaboration and research were used similarly at mid to high frequency. Five practices that represent traditional teaching methods were shown to be used frequently by 44-70 or 60-96% of the teachers. Data from the high numbers of participants new to QuarkNet may have contributed to lower frequency of use of practices that support inquiry-based learning, collaboration and research.

Q3-1b. Criterion: Teachers engaging students in investigations are using scientific inquiry (based on a protocol). Data show an overall increase in use over time in QuarkNet.

***Introduction*:** During spring 2012, leadership fellows made visits to classrooms of 12 teachers from five centers that were visited in summer 2011. An online survey was used to gather data from 72 teachers who were considered to represent QuarkNet.

Findings: The criteria, teachers engaging students in investigations are using scientific inquiry (based on a protocol), and data show the criterion for an overall increase in use over time in QuarkNet was met. While they were not all implementing particle physics when fellows observed their classrooms, all 12 teachers introduced particle physics content and current topics in science and research in their classrooms during the year.

Observations show that the teachers' intended outcomes and topics taught were related to particle physics, physics and physical science. Eleven of the twelve had students who solved problems in whole groups, small groups or individually. Eleven were using lab equipment and eight used computers during the class. Nine engaged in instructional strategies and emphases that reflected inquiry-based teaching. Half of the teachers presented classroom activities that had an inquiry focus. During the visits, when introducing physics topics, all the teachers related them to particle physics. Interviews with the teachers during the visits indicate that all of the teachers include particle physics topics in the classroom. Ten (83%) had students who did long-term projects related to e-labs, masterclass, Standard Model and research with a detector

Data from the online survey show that when asked to rate the frequency of use of classroom practices, results show that 50–72 (69-100 %) of the survey respondents frequently use more than half (six of the 11) of the practices that support the goals of QuarkNet (support inquiry-based learning, collaboration and research). These findings show that six of the practices that support QuarkNet goals were used at mid to high

frequency. “Frequent use” is considered to be a range from “Almost every day” to “Once or twice a month.” These practices were used to some extent by all of the teachers.

Q3-2. Criterion: Masterclass teachers create instruction that reflects the appropriate environment.
Introduction: A *Masterclass Teacher Survey* provided contextual information for the student questionnaire data. The questionnaire asked about student demographics, perceptions of the masterclass to which they brought their students, and preparation. Preparation asked about topics/activities addressed for at least one class period and topics/resources used; items were chosen based on data from prior masterclasses. Data from the 2009 study provided a better idea of what prior knowledge was needed for masterclass. Prior knowledge and suggestions for related activities were included in the 2010, 2011, and 2012 masterclass orientation. The orientation PowerPoint stated: “These [recommended] activities—directions and materials and a PowerPoint—meet the requirement for student preparation.”

In addition, a masterclass study was conducted this year with 12 U.S. centers providing contextual data about student preparation, generally (topics, resources, related principles covered) and specfifically (videos, activities) on the *Masterclass 2012 Form and Transmittal Shee*t.
Findings: This criterion related to providing students appropriate preparation for MC, has been met by 80% of teachers based on data from the *Masterclass Teacher Survey* and all 12 teachers completing the *Masterclass 2012 Form and Transmittal Shee*t. On the Teacher Survey, respondents reported that preparation was: 28% activities such *as Rolling with Rutherfor*d; 15% cloud and/or bubble chamber; 44% particle accelerators and detectors; 71% classic topics in physics that use particle physics examples and particle physics topics (e.g., Standard Model); 20% particle physics software; 10% “using indirect evidence to support a claim.” (Note: these percentages do not equal 100% because they were addressed in two different survey items.) This year 40% of students reported being prepared and 49% well prepared for a total of 89% reporting being prepared for masterclass.

On the masterclass study form, teachers reported the number of hours used in preparation ranged from two (n = 3 teachers) to six (three teachers). The average was four hours. A minimum of three hours was recommended. The number of videos ranged from ‘0’ (one teacher) to three out of four. The average was 1.0. The range for activities was ‘0’ (two teachers) to four out of the possible five (one teacher); and an average of 1.7 activities. Generally, the number of topics addressed ranged from ‘0’ to all eight. The average was four. Number of resources used ranged from ‘0’ to all seven with an average of three. Student test score difference between pre- and midpoint, indicating the effect of preparation, were statistically significant overall at <.001; average effect size for individual sites was 1.7 or large effect size.

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]).*

Q4-1a. Criterion: Students show an increase in knowledge by gaining statistically significant differences between scores on the pre and post-test.
***Introduction*:** This year’s Masterclass Study pre- and post-test for students was adapted from one used for the 2010 masterclass study. Based on an item analysis of the 2010 test, there were six questions found to be appropriate and repeated, and four new questions. There was also some data from the masterclass student questionnaire that address this criterion.
Findings: Data from these sources indicate that students show an increase in knowledge at highly statistically-significant levels (<.001). The masterclass study tests showed statistically significant differences (level < .001) between pre-test and midpoint tests, between midpoint tests and post-tests and between pre- and post-tests. These findings show that overall, masterclass preparation and participating in masterclass were effective in increasing content knowledge and skills included on the test. Knowledge and skills tested related to the learning outcomes for masterclass in application, interpreting a construction and fact-based questions.

Effect size was calculated for each site. The pre-mid score showed the affect of masterclass preparation; the mid-post showed the effect of masterclass and pre-post showed overall effect. There were two instances where the total scores on tests decreased (- 0.3), but the effect size was small. All but one teacher's students achieved a large effect size (0.8 and higher) between the pre-and post-tests.

Student-reported changes in understanding particle physics terms all also showed statistically-significant differences at <.001. These data indicate that students better understood these terms (particle physics in general, Standard Model, Quarks and Leptons, Particle detectors, Particle Accelerators) after participating in masterclass.

Q4-1b. Criterion: Masterclass students report they were engaging in and better understanding the nature of scientific research.
***Introduction*:** On the *Masterclass Student Questionnaire*, students were asked the extent to which they agreed that they learned how scientific research is organized and carried out. In addition a few students indicated that they could not learn in school what they experienced through MC.
Findings: The data indicate this criterion was met. Students "agreed" to "totally agreed" (3.7 out of a total ''5') that they "learned how scientific research is organized and carried out" through participating in masterclass. A slightly larger mean (3.8) was obtained for "this masterclass informs me about the role of physics for modern technological developments."

Q4-2. Criterion: Student tests before and after engaging in research programs show evidence of knowledge of scientific practices and discourse through statistically significant differences between pre and post.
***Introduction*:** The purpose of the concept maps was to assess the extent to which students became more scientifically literate as a result of participating in a student research program. Pilot data 2009-2010 indicated that concept maps best provide the data necessary to address this criterion. During the summer 2012, eleven centers conducted student research programs; 10 provided pre- and post-test data for analysis.
Findings: The concept maps showed a statistically significant difference between pre and post overall, therefore, the criterion is met. A t-test analysis indicated that the difference in pre- and post-test scores was statistically significant (<.01) overall. Individual student's mean scores ranged from pre 14-38; post 15-41.

Changes in many propositional statements indicated a more in-depth understanding of scientific methodology. These included: 1. A better understanding of the environment in which authentic research is conducted such as research is a collaborative effort. 2) Research is iterative even within science process such as the propositional statement "Compare to other scientists' observations performing the same or similar tests." 3) After the conclusion, the process begins again with a new hypothesis or revised experiment. 4) Using library/resource materials to develop an hypothesis as well as publishing results. 5) Research includes data representation such as "graphs" and the importance of the scientific notebook. One student noted that the 'Journal/Notebook' "is for organization" not just a place to record data. 6) Better idea of how data are used, for example, one student added the term "analysis" to the map. Except for some students who linked 'Conclusion' back to 'Library/Reference Materials' or 'Experiment' none of these was on any of the pre-maps. These ideas expressed in the post-maps appear not to be taught in schools but are discovered by students when conducting, or being involved in, an authentic research experience.

Q4-4. Criterion: Student responses on e-lab posters indicate they have attained knowledge of particle physics and research to a great extent (rubric shows 70% meet or exceed expectations).
Introduction: Poster data were collected for the 2010-2011 year and assessed July 2011 using a six-item rubric. Two reviewers attained an inter-rater reliability of over 80%. The rubric focused on making claims based on evidence, data analysis and clear communication. The cosmic ray e-lab is intended for use with high school physics students or students in a physical science course. It is particularly relevant for students who have access to a cosmic ray muon detector (CRMD) provided by QuarkNet.
Findings: This criterion was met as 84% of students met or exceeded expectations. The cosmic ray e-lab posters exceeded expectations by three points overall and in particular, introduction and when evidence sup-

port claims, which provides data on students attaining knowledge of particle physics. Individual total scores ranged from a low of 12 to a high of 26 (a perfect "meets expectations" score would be 20).

There were four teachers whose student posters exceeded expectations overall; one by two points and the other three by one point. The posters of the teacher's students who scored the highest ranged from 17-26 indicating a high degree of understanding of the content and scientific process. This teacher taught the e-lab in three courses, IB physics 1 and 2 and AP physics. All students conducted a student-directed research project. An on-site CRMD was available.

There were two teachers whose student posters did not meet expectations overall. Interestingly, both were from AP and honors physics classes. One acknowledged that in the past the students had done the e-lab as a long-term project but not this year. Only one poster from the other teacher was assessed; it was incomplete. This teacher reported having a CRMD available but provided a limited introduction to the e-lab.

Question 5: *To what extent do fellows provide workshops and support for their QuarkNet colleagues with a goal toward becoming more professional including contributing to the quality and practice of colleagues in the field of science?*

Q5- 1. Criterion: Surveys show a satisfaction rate of 80% and at least 80% report increasing content knowledge.

Introduction: Survey data were collected for June–August, 2012, using a revised QuarkNet workshop participant survey form for cosmic ray and LHC workshops. Survey items that indicate satisfaction with the workshops are: (a) "The workshop was well-organized," (c) The objectives of the workshop were met," (d) "The instructor(s) facilitated the workshop effectively," (e) "The schedule allowed sufficient time to meet the objectives," (f) "The workshop provided time to consider ways to use what I learned in the classroom," and (g) "The workshop provided opportunities to ask questions and/or discuss ideas." Question 1 Criterion 4 addresses increase in content knowledge.

Findings: Cosmic ray e-lab and LHC participant surveys show this criterion was met.

Cosmic Ray e-Lab Surveys: This criterion was met. Surveys from 70 respondents who participated in e-lab workshops representing nine QuarkNet centers were reviewed. The following numbers of participants chose (1) "strongly agree" or (2) "agree" for the items related to satisfaction with the workshop: (a), (c), (d), (g), (h) and (j) all 72 (100%). Respondents chose (3) "disagree" eight times for item (e) and four times for item (f). There were no (4) "strongly disagree."

LHC Surveys: This criterion was met. Surveys from 11 respondents who participated in LHC workshops representing one QuarkNet center were reviewed. For all items 11 (100%) respondents chose (1) "strongly agree" or (2) "agree." There were no (3) "disagree," or (4) strongly disagree.

Q5-2. Criterion: Forms indicate at least 50% of fellows are providing support for their colleagues. Data shows an increase with number of years of participation.

Introduction: During the year, fellows provide feedback forms (Workshop Participant Surveys) to staff and evaluators. Data were gathered October 2011 to August 2012 to address this question.

Findings: Two T&L fellows acted as facilitators, assisting QuarkNet staff at Boot Camp, and supporting participants with content topics, at FNAL in July 2012.

The five leadership fellows met at FNAL in October and carried out evaluation activities throughout the year. They held monthly phone conferences with evaluators who provided technical assistance for data gathering activities. In August, one of the fellows met with a mentor who was frustrated by being unable to recruit teachers because he felt another organization was 'competing' with QuarkNet activities. The fellow suggested to the mentor that it wasn't a competition and QuarkNet could draw from the other organization. This prompted the mentor to initiate a presentation at the next meeting of the other organization, to explain what QuarkNet has to offer. No other leadership fellows reported assistance to centers.

Question 6: *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?*

Q 6 - 1a. and b. Criterion: At least 50% of teachers indicate they have provided workshops, presentations or other forms of leadership with their colleagues. Most (about 90%) report sharing ideas with colleagues. Data show an overall increase over time in QuarkNet. Note any increases in professionalism.
Introduction: From March to August, 2012 an online teacher survey was done to gather data on teachers' experience with the QuarkNet program. Professionalism data were gathered from 72 teachers. Also during spring 2012, telephone interviews were conducted and professionalism data were gathered from 12 teachers.
***Findings*:** Teachers responding to the online survey met this criterion to some extent. Of the 72 QuarkNet participants who responded to the online survey, 19 (26%) have given a workshop or presentation at a local or national meeting of a professional organization (e.g., AAPT); 56 (78%) have shared what they learned in QuarkNet with colleagues; 33 (46%) have developed new materials for courses; 25 (35%) have been involved in reform efforts at the school or district level; 14 (19%) are mentor teachers and/or department chairs at their school. Unusually high numbers (53%) 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 met this criterion. Of the 12 respondents who were interviewed, 5 (41%) reported being involved in giving workshops to other teachers; 7 (58%) have given a presentation; 10 (84%) have attended meetings of professional organizations; and 9 (75%) have been involved in leadership at the school or district level. These results show a higher involvement in activities that indicate professionalism, even though 33% of the teachers interviewed were considered new (with QuarkNet 1 to 3 years).

Q 6 - 2a. and 2b. Criterion: Compare extent of professionalism at centers identified as not operating effectively with survey data and with effectiveness data. Note any increases in professionalism.
Introduction: During spring 2012, telephone interviews were conducted and professionalism data were gathered from 12 teachers. The teachers were from centers that were visited in 2011, and *not* identified as "not operating effectively." During fall 2011, one a site visit was made to a center that held its institute in the fall rather than summer 2011. In the summer 2012, site visits were made to five QuarkNet centers where professionalism data were gathered from interviews with four teachers. Of the five centers visited in summer 2012, four were considered "not operating effectively." The online survey has different questions from the interviews and centers are not identified, so a direct comparison cannot be made.
Findings: The criteria, compare extent of professionalism at centers identified as not operating effectively with survey data and effectiveness data and note any increases in professionalism was met to the extent that it could be determined. Data were gathered in three ways.

Teachers responding to telephone interview questions met this criterion to some extent. Of the 12 respondents who were interviewed, 5 (41%) reported being involved in giving workshops to other teachers; 7 (58%) have given a presentation; 10 (84%) have attended meetings of professional organizations; and 9 (75%) have been involved in leadership at the school or district level. These results show a high involvement in activities that indicate professionalism, even though 33% of the teachers interviewed were considered new (with QuarkNet 1 to 3 years). Three of the five teachers interviewed were from centers that were rated "satisfactory" for having strong teacher leaders and mentors, both of which contribute to effectiveness of centers. Results of the interviews are similar to the online survey data which are reported in Q6 – 1a & b.

Seven teacher leaders were interviewed during site visits to six centers. Six of the seven have given workshops or presentations at local, state, regional and national conferences. Four have been involved in leadership at the school or district level. Of the 26 teacher participants who were interviewed at institutes, very few (3 or 12 %) have been involved in professional activities. This could be related to the high numbers (50%) of teachers new to QuarkNet.

DOE Metrics

Boot Camp

There was a six-point pre- and post-test on content and a pilot-test of a pedagogy section of the test.

Content Test-Number Correct, Means and Standard Deviations and T-Test results

Item	# Correct and (Percent)	Mean Pre (SD)	# Correct and (Percent)	Mean Post (SD)	T-Test
1	3 (16)	0.2 (0.4)	12 (63)	0.6 (0.5)	< ,001*
2	14 (74)	0.7 (0.5)	16 (84)	0.8 (0.4)	0.21
3	14 (74)	0.7 (0.5)	17 (89)	0.9 (0.3)	< ,05
4	10 (53)	0.5 (0.5)	9 (47)	0.5 (0.5)	- .36
5	11 (58)	0.6 (0.5)	13 (68)	0.7 (0.3)	0.21
6	15 (79)	0.8 (0.5)	17 (89)	0.9 (0.3)	0.17

Of the 25 teachers participating, 14 completed the pedagogical part of the test. Since this constitutes a 56% response rate, the finding cannot be said to *represent* the Boot Camp participants. This part of the test will be analyzed and an alternative suggested for inclusion in the test for next year's Boot Camp.

Workshop Forms

Survey data were collected for June – August 2012 using a revised QuarkNet workshop participant survey for Cosmic Ray e-lab and LHC workshops. All respondents were high school teachers. There were 70 Cosmic Ray e-lab respondents and 11 LHC 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 Cosmic Ray e-lab and LHC workshops.

Table: Survey Items with Means and Standard Deviations for Each Item

Item	**e-Labs n = 70 9 centers Mean/SD**	**LHC n = 11 1 center Mean/SD**
a. The workshop was well organized.	1.4/0.5	1.3/0.5
b. The facilitator clearly stated the objectives of the workshop.	1.3/0.5	1.4/0.5
c. The objectives of the workshop were met.	1.3/0.5	1.1/0.3
d. The instructor(s) facilitated the workshop effectively.	1.3/0.5	1.2/0.4
e. The schedule allowed sufficient time to meet the objectives.	1.6/0.7	1.4/0.5
f. The workshop provided time to consider ways to use what I learned in the classroom.	1.5/0.6	1.4/0.5
g. The workshop provided opportunities to ask questions and/or discuss ideas.	1.2/0.4	1.1/0.3
h. The workshop helped me feel more comfortable with the topic(s).	1.2/0.4	1.1/0.3
i. My understanding of the material increased.	1.2/0.4	1.0/0.0
j. Questions were answered/addressed at my level of understanding.	1.3/0.5	1.0/0.3

k. I experienced inquiry-based teaching techniques.	1.2/0.5	1.3/0.5

Masterclass There was a 10-point pre- and post-test conducted as part of a masterclass study.

Center	Days	No. of Students	Mean Pre	Mean Post	Mean Diff '12	Mean Diff '10	Mean Diff '11
1	55	7	24	30	5.3	2.6	0.0
2	20	3	23	25	2.0	1.6	2.3
3	32	4	29	29	0	3.0	3.8
4	42	16	25	27	1.8	2.8	4.8
5	38	3	22	23	0.3	3.7	3.3
6	92	2	33	35	2.0	0.7	3.0
7	35	2	17	16	-.05	3.0	1.8
8	24	2	27	28	0.5	0.3	1.8
9						-0.8	2.2
10	ND					ND	1.0
11	39	4	31	31	0.5	ND	
12	39	5	25	24	-0.4		
Mean	41.6	5.3	25.6	26.8	1.1	2.0	2.7

Days = Duration from date of pre-test to date of post-test
Tot # = Number of pre- and post-tests used in the analysis
ND = no data; program was conducted
Spaces indicate that a program was not conducted that year
A t-test analysis indicated that the difference in pre- and post-test scores was statistically significant (<.01) overall.

Center Success Factors

Data have been gathered for 12 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	3	0	2	2	2	2	1	1	2	2
NN	0	3	2	2	ND	ND	3	ND	ND	2
MM	2	3	2	2	2	3	1	3	2	2
LL	3	3	1	1	1	1	2	ND	ND	ND
KK	3	2	1	3	0	1	1	0	0	0
JJ	1	3	3	2	2	2	2	3	2	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*

ND = ND

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