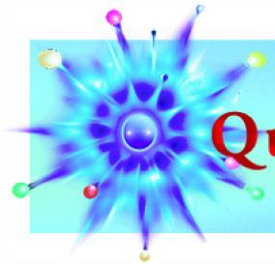

Outcomes-based Evaluation: Results and Plans

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QuarkNet

Approach to Evaluation

Three Themes:

1. **Develop (and use) of a Program Theory Model (PTM) ✓**
2. **Teacher-level Program Outcomes (based on PTM) at National- and Center-level -- *on going***
3. **Center-level Program Outcomes and Program Sustainability Assessment (based on PTM and Sustainability Framework – *on going***

QuarkNet Partners

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

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

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

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

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

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

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

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

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

QuarkNet Program Theory Model

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

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

Program Goals	Participant Selection	Anchors	Program Structure	Strategies	Outcomes
Goal 1	Mentors	Effective PD	Data Camp	Teachers	Teachers
Goal 2	Teachers	NGSS Alignment	Data Activities Portfolio		Students
Goal 3	Fellows	Guided Inquiry	e-Lab	Local Centers	Local Centers
Goal 4			Masterclasses		
			Workshops		

Enduring Understandings

Sustainability

Antecedents	Outcomes

Core Values/Assumptions

Multiple Sources of Information

Workshop Agendas captured from QN website

Used to create a workshop table which summarizes implemented workshops for each program year

Focused on capturing which DAP activities are embedded in workshops, and time allocated for teacher implementation planning and discussion

Center Annual Reports posted on QN website

Provides summary of QuarkNet opportunities at each center each program year; reviewed to inform center-level activities beyond workshop (e.g., masterclass; in-school year meetings)

Data Activities Portfolio (DAP) activities summarized by alignment with

NGSS Science Practices -- as *designed* and as *implemented*

Enduring Understandings

Virtual Workshop Visits by Evaluator

Via Zoom, visits focused on teachers' discussions of implementation plans during workshops (coordinated by QuarkNet staff and center mentor)

Uses to:

Compare *designed* to *implemented* program

Provide context and inform outcomes assessment

Sources of Outcomes Data

Teacher Full Survey (unique count of 483 teachers)

Highlights information about who is the QN teacher

Primary focus: Quantitative analysis of teacher- and student–outcomes (to be explained next)

Update Survey (362 completed – 327 linked to full survey)

Follow up (completed annually) responses linked to full survey

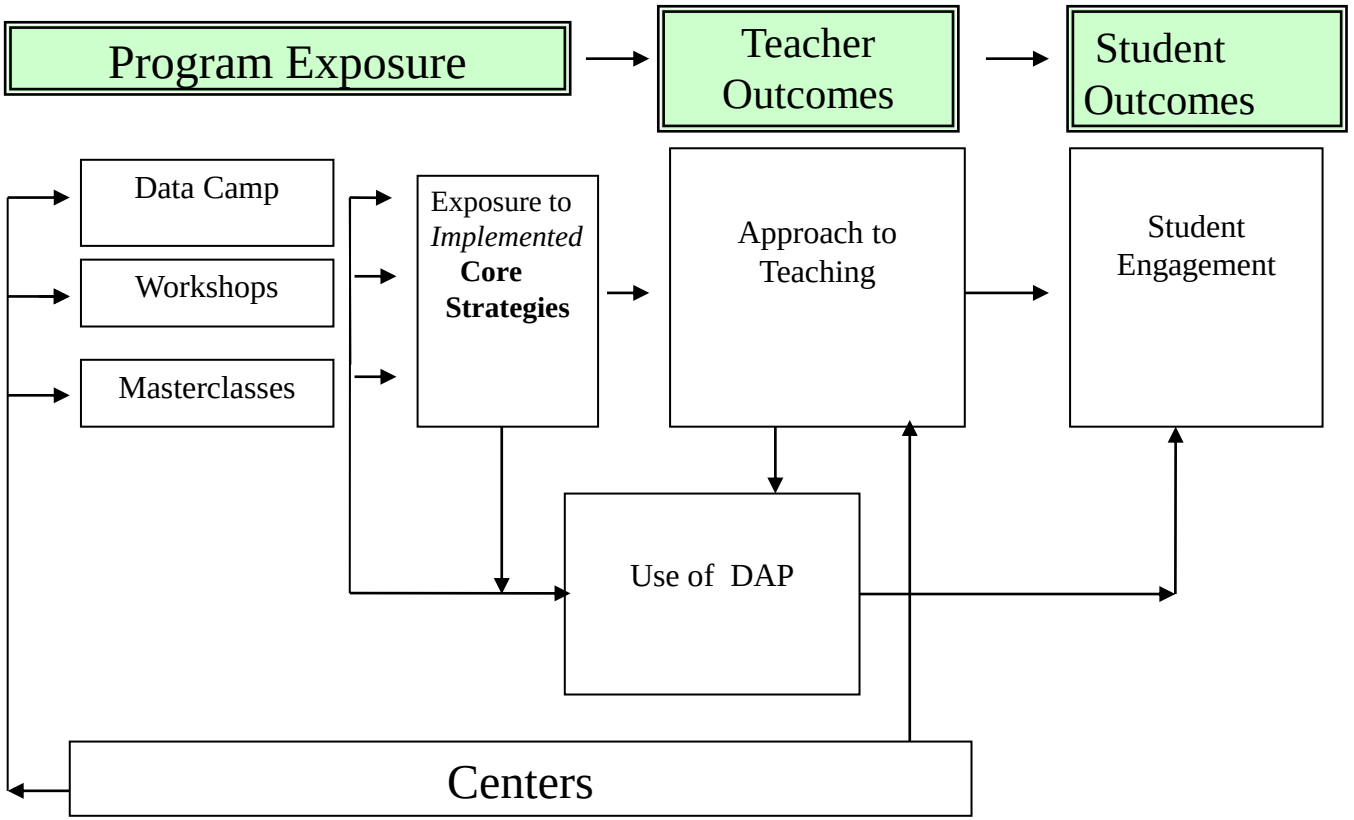
Primary focus: How/what/why QN content and materials are used in the classrooms (e.g., DAP activities)

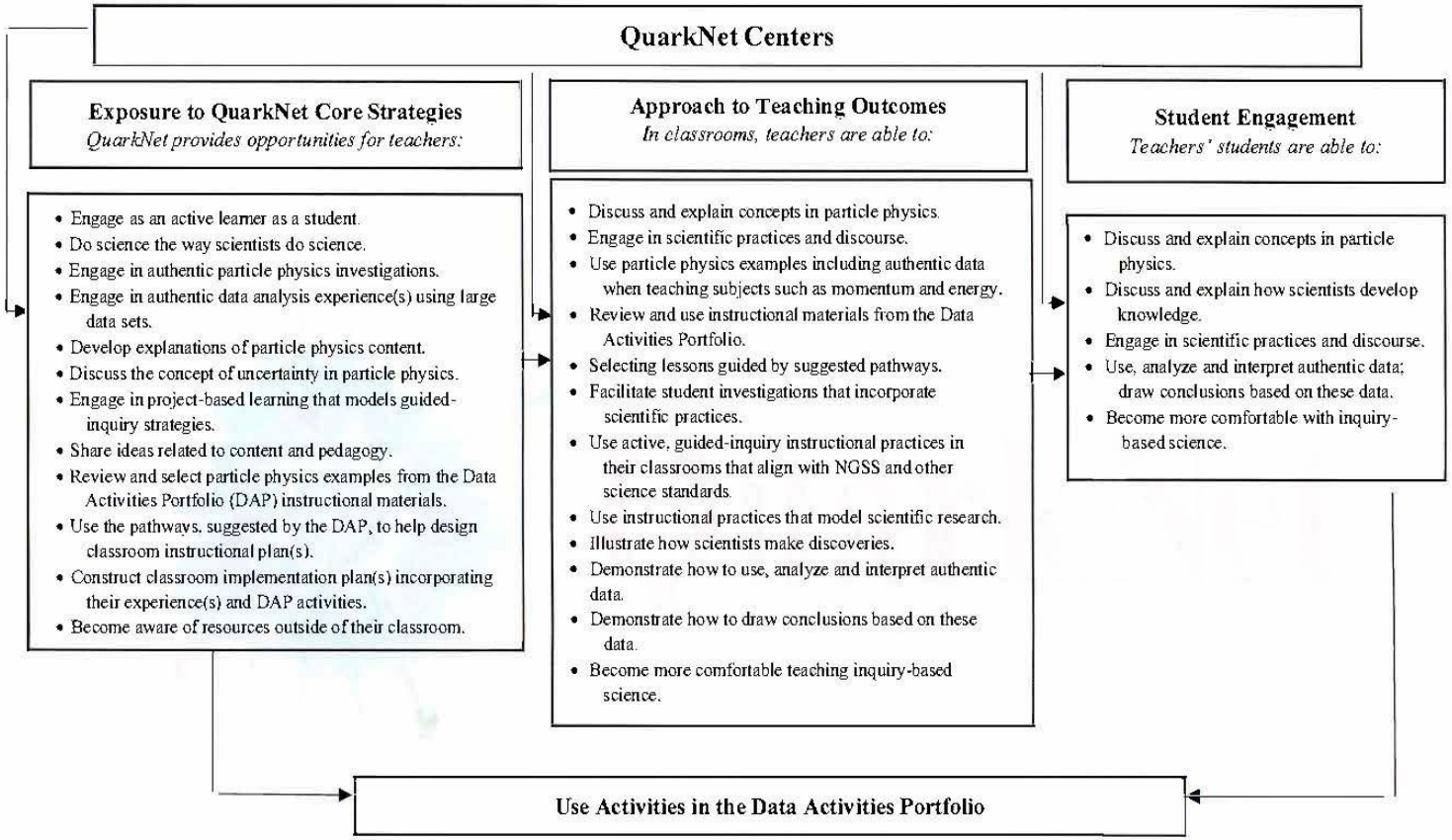
Center Feedback Form: Center-level Outcomes

Used to corroborate (or not) teacher-level responses

Assessed through alignment with NGSS practices and alignment with *Matrix of Effective Practices (***M.J. Young & Associates, September, 2017)**

Overview of Analyses Related to Teacher (and their Students) Outcomes





Teachers in QuarkNet, through partner-centers, participate in: Data Camp, Workshops (Center- or Nationally-led), Masterclasses, and e-Labs during the summer and during the school year. (Each of the following statements is backed by statistical analyses from the QuarkNet evaluation.)

Centers Matter: Centers play an important role in getting to teacher and student outcomes.
QuarkNet Teachers: The more QuarkNet teachers participate in QuarkNet, the more they engage in strategies that are core to the program. These core strategies (and content) are reported as helping teachers achieve many teacher outcomes in their classrooms when possible. Active engagement in activities from the Data Activities Portfolio helps teachers implement these in their classrooms (activities that align with NGSS science practices and address specific topics that support physics curriculum). Teachers report that the program helps them foster the active engagement of their students in their classroom. Teachers report that the QuarkNet experience creates opportunities for teachers to develop and maintain collegial relationships with other teachers, mentors, and other scientists.
Centers: Centers report that their teachers engage in QuarkNet as active learners (as students) and then as teachers often sharing classroom implementation experiences. Centers report, as well, that their teachers often form collegial relationships with other teachers, mentors, and scientists that support the development of a learning community.

We are grateful to the many teachers who have taken the time to complete the surveys requested of them and who provide very thoughtful responses; and to the QuarkNet Centers who have participated in the Center Feedback process; both are part of the QuarkNet evaluation.

Table 4. QuarkNet: Aligning Core Strategies and Program Outcomes

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

Teacher-level Measures

Program Exposure:

Core Strategies

Outcomes:

Approach to Teaching

QuarkNet's Influence on Approach to Teaching

Student Engagement (as perceived by teachers)

QuarkNet's Influence on Student Engagement

Each is measured by a score (based on full survey responses) – where the higher the score the more positive the perception.

QuarkNet

Scale Scores

Table 21

Building Scales for Analysis of Program Engagement and Outcomes

Scale	What's Measured	# of Items	N	Mean	Standard Deviation	Cronbach's Alpha
Core Strategies	Teachers' perceived exposure to program core strategies articulated in PTM	12	464	54.10	6.97	**0.86**
Approach to Teaching	Perceived assessment of QN teacher outcomes	12	447	42.85	8.38	**0.87**
QN's Influence on Teaching	Perceived assessment of how QN has influenced teaching practices and content	12	402	48.04	9.51	**0.91**
Student Engagement (SE)	Teachers' perceptions of student engagement in their classroom	5	425	18.38	3.66	**0.84**
QN's Influence on SE	How QN has influenced this student *engagement*	5	357	19.63	4.06	**0.91**

Exposure to Core Strategies: Assessment

Single-variable analyses suggest that:

Engagement in QuarkNet (the type and degree of program engagement) is positively related to **Core Strategies** scores; and,

Use of activities from the Data Activities Portfolio (**Use of DAP**) is positively related to QuarkNet engagement as well.

Approach to Teaching

In hierarchical linear regression, based on 24 (31combined) centers

Teacher outcomes (**Approach to Teaching scores),** are positively related to *perceived* QuarkNet's Influence on Teaching and Core Strategies scores, and – **also** the QuarkNet Center (as measured by Approach to Teaching center-level means).

Centers play an important role in teacher outcomes

QuarkNet

Approach to Teaching

(slide 14)

Table 23

Approach to Teaching Scores Nested by Centers:
Summary Statistics and Related Variables

Model Summary[a]

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

Coefficients[b]

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

[$F_{(3,\ 316)} = 65.66$, $p < .001$, with an $R^2 = .38$]

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

[b]Dependent Variable: Approach to Teaching

Student Engagement

In hierarchical linear regression, based on 24 (31 combined) centers

Student Outcomes (**Student Engagement scores** as perceived by their teachers) are positively related to perceived QuarkNet's Influence on Student Engagement, Approach to Teaching scores (teacher outcomes) and QuarkNet's Influence on Teaching and – **also** the QuarkNet Center (as measured by Center-level Student Engagement and QuarkNet Influence on Teaching mean scores)

Centers play an important role in student outcomes

Student Engagement

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

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

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

Coefficients[a]

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

[$F_{(5,\ 275)} = 62.73$, $p < .001$, with an $R^2 = .53$].

[a]Dependent Variable: Student Engagement

Teacher and (their Students) Outcomes

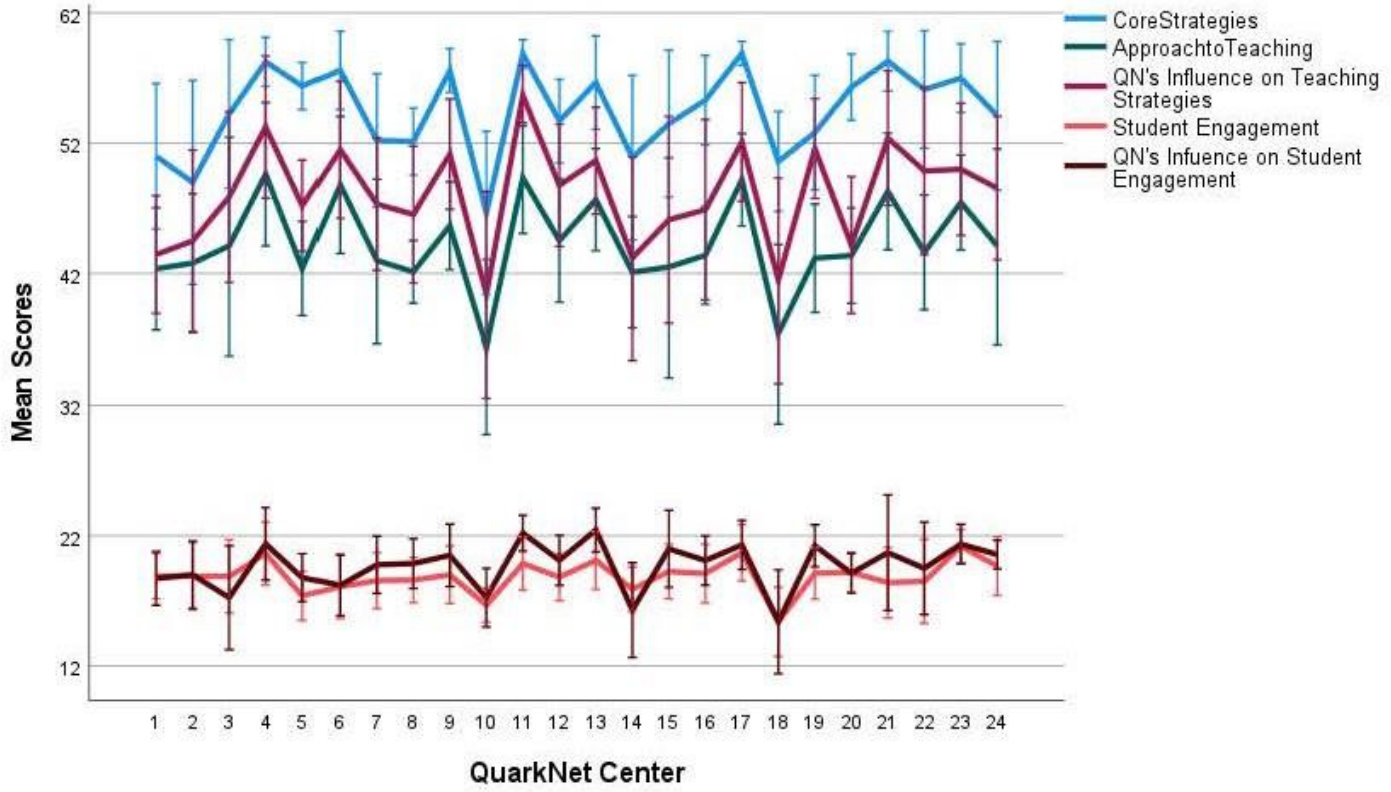


Figure 13. Comparison of mean scores for 24 (31 combined) QuarkNet Centers by core strategies, teacher-level and student-level outcomes (error bars represent 95% confidence intervals). **Please note that student engagement is measured on a different scale. (Slide 17)**

Reported Use of DAP Activities

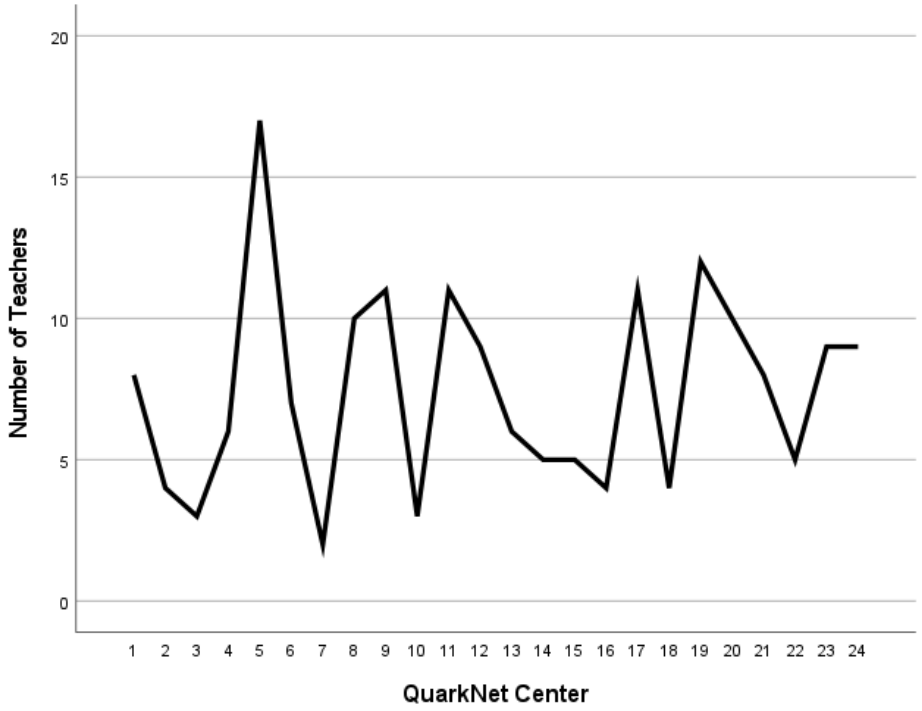


Figure 14. Number of teachers who reported using Data Activities Portfolio (DAP) activities in their classroom for 24 (31 combined) QuarkNet Centers. [Total number of yes/no responses per center ranged from 11 to 41.] **(Slide 18)**

Reported Use/Non-use DAP

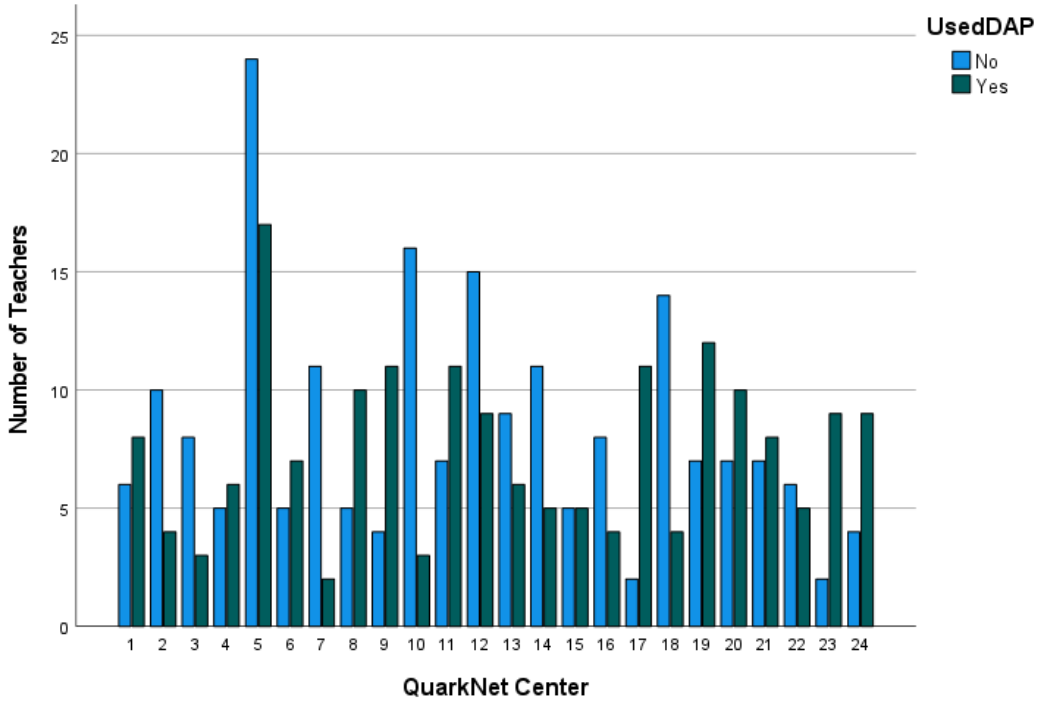


Figure 15. Comparison of use (and not used as yet) of Data Activities (DAP) activities by teachers within 24 (31 combined) QuarkNet Centers. [Total number of yes/no responses per center ranged from 11 to 41.] **(Slide 19)**

Still Exploring: Building on Analyses

Through descriptive analyses:

- **Using responses from Update Surveys to explore how teachers are using DAP activities and QN content and materials in general**

Suggest – that center-level differences in teacher and student outcomes may be due to:

- **Frequency in which DAP activities are embedded in workshops and time allocated for implementation plans and discussion**
- **Centers working more closely with QN staff teachers**
- **Reported use of DAP activities by teachers in descriptive analyses of their teaching practices over time (i.e., repeated responses to Update Survey over time)**

Program Engagement and Teacher Outcomes

The more QuarkNet teachers participate in QuarkNet, the more opportunities to engage in strategies that are core to the program.

These core strategies (and content) are reported as helping teachers achieve many teacher outcomes in their classrooms when possible.

Active engagement in DAP activities helps teachers implement these in their classrooms.

Centers play an important role in getting to teacher and student outcomes.

Center-Level Outcomes

Captured through a combined survey/review process by each center:

Complete an assessment form at the center-level

Based on consensus review among mentor, lead teacher, and/or fellows

Assess workshop engagement through NGSS science practices

Assess the center based on *Matrix of Effective Practices*

Teachers and Centers Tend to Agree, Examples

Teachers report: the program helps them foster the active engagement of their students in their classroom.

Centers report: their teachers engage in QuarkNet as active learners (as students) and then as teachers often sharing classroom implementation experiences.

Teachers report: the QuarkNet experience creates opportunities for teachers to develop and maintain collegial relationships with other teachers, mentors and other scientists.

Centers report: their teachers often form collegial relationships with other teachers, mentors, and scientists that support the development of a learning community.

QuarkNet

Teacher/Center Responses

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

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

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

QuarkNet

Evaluation Plans

Continue to focus on an outcomes-based evaluation that:

Is guided by the Program Theory Model (e.g., update to include Coding Camp)

Uses the Teacher Full Survey (slightly modified) and

the Update Survey

Uses multiple sources of information when feasible and look for patterns in the data

Expands descriptive analyses of teachers' reported use of QN content and materials in their classrooms

Simplifies the protocol used to gather center-level outcomes focused toward review/helping to restart a small group of centers

As confidence in results from these analyses grow, help QN staff work with centers