Evaluation Results:2023

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Evaluation Themes

Focus

Develop (and use) Program Theory Model (PTM)

Measure Outcomes (teacher, student and long-term)

Measure Center-level Program Outcomes

Program Strategies → Measurable Program Outcomes

Sources of Outcomes Data

Teacher Full Survey

Primary Focus: Quantitative analyses of teacher, student and long-term outcomes

Update Survey

Primary Focus: Qualitative analyses of QN content and material use in the classrooms

Center Feedback Process

Primary Focus: Comparing center-level and teacher-level responses

Virtual Workshop Visits by Evaluator

Primary Focus: Implementation plan discussions

Multiple Sources of Information

Workshop Summary Table compiled from:

Workshop Agendas

Annual Reports from Centers

Data Activities Portfolio alignment with:

NGSS Science Practices

Workshop Engagement

Enduring Understandings

Acknowledge and Review other Information

(e.g., cosmic ray studies, use of comic watches, professional presentations; masterclasses; student-collected data)

Program Information/Outcomes Data

Used to:

Compare *designed* to *implemented* program

Provide context in which program is implemented

Informs outcomes assessment

Quantitative Outcomes Analyses

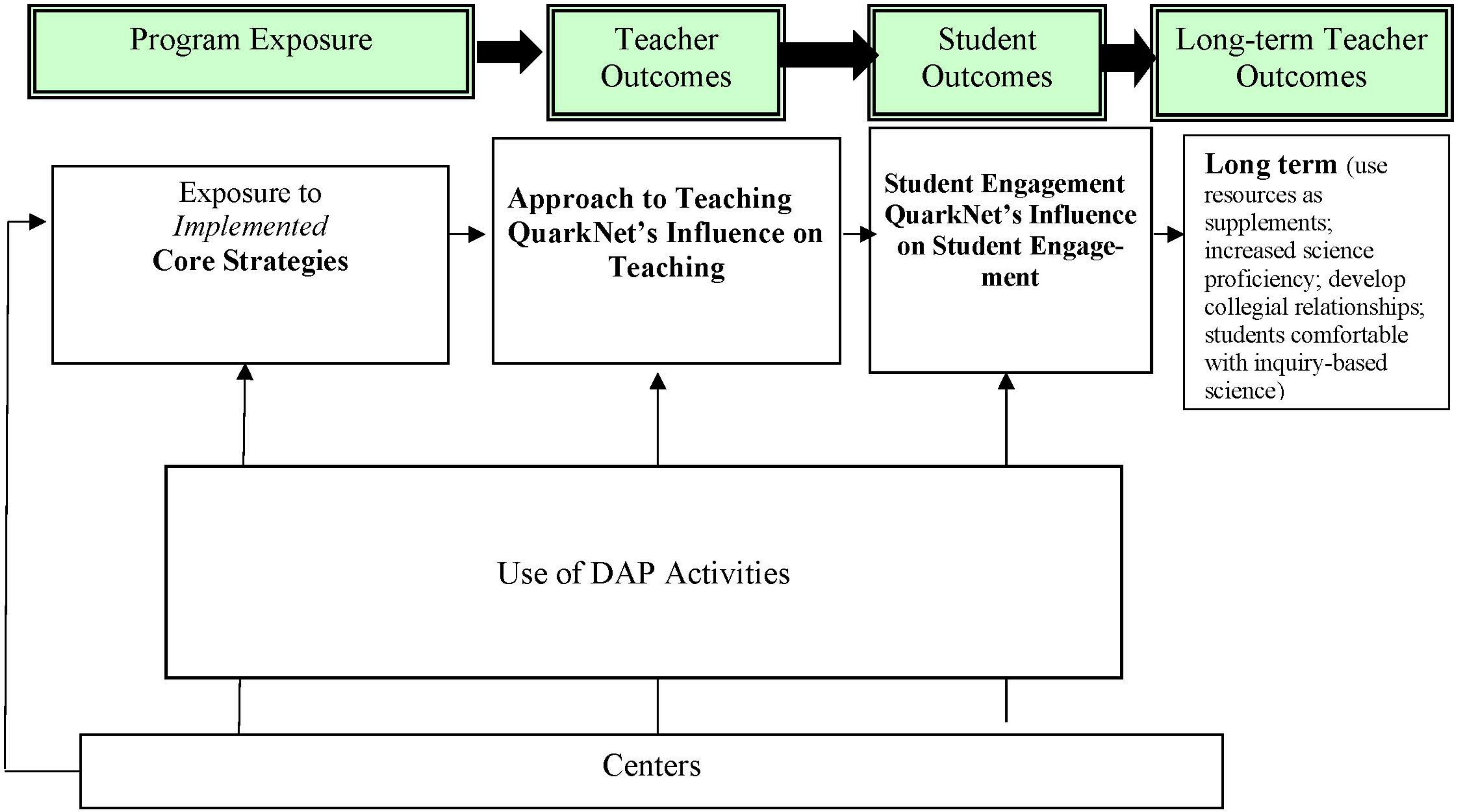

Program Exposure
Teacher Outcomes
Student Outcomes
Long-term Teacher Outcomes
Exposure to *Implemented* **Core Strategies**
Approach to Teaching QuarkNet's Influence on Teaching
Student Engagement QuarkNet's Influence on Student Engage-ment
Long term (use resources as supplements; increased science proficiency; develop collegial relationships; students comfortable with inquiry-based science)
Use of DAP Activities
Centers

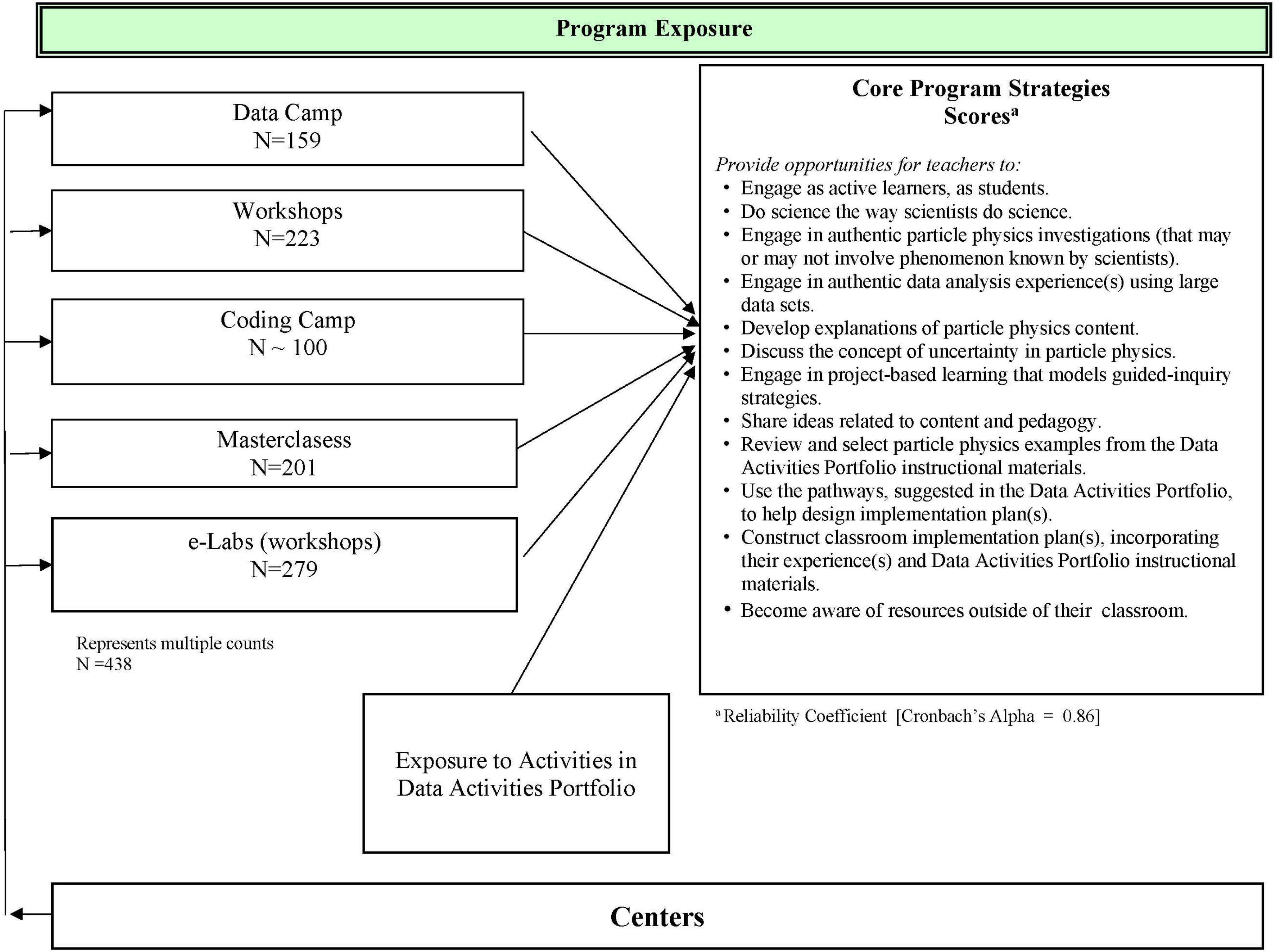
Table
Summary of Scale Development and Supportive Statistics

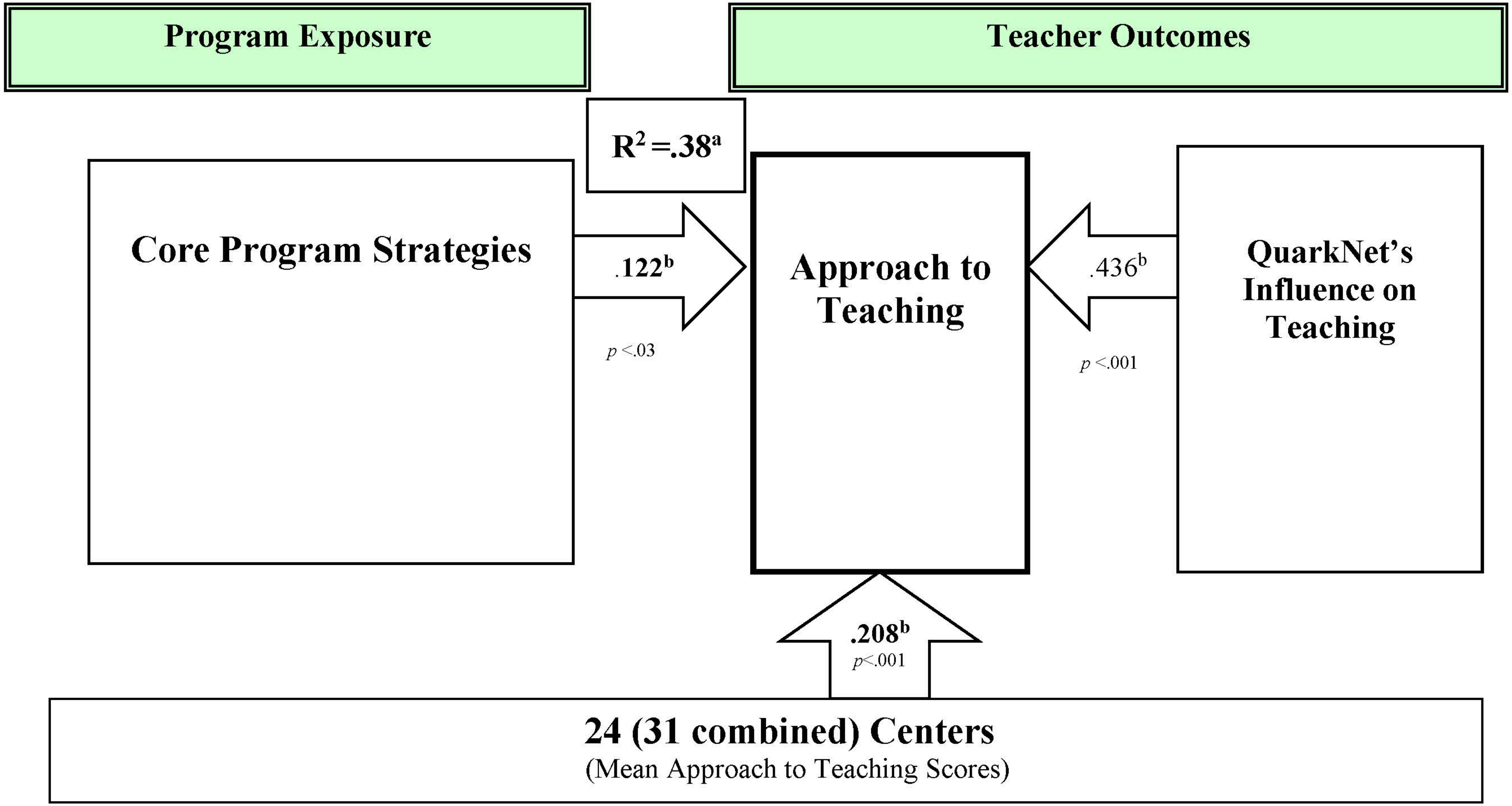
Scale	What's Measured	# of Items	N	Mean	Standard Deviation	Cronbach's Alpha
Core Strategies	Teachers' perceived exposure to program core strategies articulated in PTM	12	464	54.10	6.97	**0.86**
Approach to Teaching	Perceived assessment of QN teacher outcomes	12	447	42.85	8.38	**0.87**
QN's Influence 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**
Long-term Teacher Outcomes	Teachers' perceptions related to long-term behaviors such as use resources as supplements; increase science proficiency; develop collegial relationships; and students more comfortable with inquiry-based science.	4	450	17.53	2.56	**0.82**

Table
Comparative Analyses of Individual QuarkNet Components:
Unique Contributions of Each

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

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


Program Exposure
Data Camp
N=159
Workshops
N=223
Coding Camp
N ~ 100
Masterclasess
N=201
e-Labs (workshops)
N=279
Represents multiple counts
N =438
Exposure to Activities in Data Activities Portfolio
Core Program Strategies Scores[a]
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.
[a] Reliability Coefficient [Cronbach's Alpha = 0.86]
Centers



Reliability Coefficients:

Core Program Strategies	0.86
Approach to Teaching	0.87
QN's Influence on Teaching	0.91

$F_{(3,\ 316)} = 65.66$, $p < .001$

[a]Percent variance explained

[b]Standardized beta weights

Qualitative Analyses: Implementation Plan Examples

Table _

Self-reported Use of Data Activities Portfolio Activities: Based on Reponses from the Full Survey and then Responses from the Update Survey in Subsequent Years **Johns Hopkins University**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Johns Hopkins University	2019	2020	2021	2022
	I think Rolling for Rutherford is an easy way for them to understand the experiment through experience and inquiry. I would adapt it to more than just rolling a marble at dice. I would also have them roll a marble at a mystery shape underneath a piece of cardboard and predict what the shape was.	This year, we did more related to online learning because of the circumstances related to the pandemic. Having content that can be used virtually, like the QuarkNet e-Labs, will be super useful. Examples: Rolling with Rutherford; The one where you use the detector information.	Next year I will be teaching astronomy in addition to physics, so the cosmology topics and activities that we just happen to focus on this year will be particularly helpful. The new ones I will incorporate are: Mapping the Poles and Particle Transformation.	I was doing Coding Camp 1. The obvious thing from this experience is that I would incorporate is the coding in Python. I will have some introductory coding activities, but ultimately I envision it as a tool that they will be using to help them with labs, homework or projects. I would love to do the muon decays or the leptonic mass coding activities if we get that deep into particle physics.
	I have not had the opportunity to really share with other teachers and, unfortunately, in today's test happy society, it is difficult to fit these topics into class and to convince others to fit them into class.		I plan on using the spectral analysis activities we were working on this past week into my ninth-grade physics course. Examples: Mass of the pennies; What Heisenberg knew; CMS masterclass.	When teaching forces, I have a unit on the fundamental forces of nature where I present and the students explore the standard model and the reason why we have Fermilab and the LHC. The first lab is based on the Millikan experiment using histograms and searching for patterns.
	Rolling with Rutherford, calculating energy and momentum, quark puzzle activity	Conservation laws, the standard model. Examples: Rolling with Rutherford, conservation of energy and momentum, quark model	I plan to use the blackbody radiation activity and the Hubble's law activity as culminating activities for my introductory physics class. Examples: Cosmic microwaves, Hubble's law	
	Top Quark mass	I plan to teach a unit on particle physics using activities from the data portfolio and the cosmic ray detector in my classroom. Examples: Top quark mass, mean lifetime, shuffling the particle deck	I teach particle physics and astrophysics/ cosmology in my Physics course. I will use many of the activities we worked on this week including from the Data Portfolio and new activities developed at JHU. Examples: Top Quark Mass, Hidden Neutrino, Particle Transformations	I teach a unit on quantum physics including particle physics. This includes the standard model and activities from the data activities portfolio. Examples: Top quark mass, Hidden Neutrino, Quark workbench.
	The I2U2 site examples, specifically modern physics puzzle	1. Use of the materials in classroom is great: The subparticle puzzle to start modern physics 2. Masterclass involvement and implementation 3. Standard model discussions, etc. Examples: 1. Quark puzzle/map involving learning color charge, bosons, etc. 2. Penny/coin activity	I have used a significant number of resources involving the QuarkNet workbench, some investigations and more. Overall, my last 10+ years at QuarkNet have really increased my knowledge of certain areas. Examples: The quark workbench, masterclass, J psi (occasionally)	I intend to use my QuarkNet experiences in my own modern physics unit with all physics classes as well as having my Science National Honor Society students to listen to some of the speakers who come to our high school. Examples: The Quark Puzzle, Z mass activities, missing momentum, etc.
	Rolling with Rutherford. It's the most approachable, with a small amount of prep for students.	I am going to consider new physics principles, such as pulsars and microwave telescopes. Example: Rolling with Rutherford	I will use some of the new cosmology lessons with my Astronomy class. I teach them about the Big Bang, black body radiation and the HR diagram. I will use DAP activities as well as conservation tools. Examples: Signal and noise 1, signal and noise 2, and histograms. Rolling with Rutherford	

Table 14

Johns Hopkins University Summer Workshop July 23-28, 2023 Implementation Plans/Coding Projects

<table>
<tr><th>Plan #</th><th>Title</th><th>Brief Description</th><th>Implementation Plan</th></tr>
<tr>
<td>1</td>
<td>Spring Mass</td>
<td>Understand how masses behave on (vertical) springs as well as how to create and apply code to express this behavior.

Brief Summary: This is a modified Mass on a Spring JupyterLite notebook. The use of the Lite notebook is for educators whose students are not able to access normal Jupyter notebooks due to security/IT issues.

The Mass on a Spring has been modified for use in an AP Physics 1 and AP Physics C mechanics class. This will serve not as an introduction to the topic but instead is more of a culminating set of activities to incorporate coding with physics</td>
<td>Mass On A Spring with JupyterLite

<table>
<tr><th>Topic</th><th>Comments</th></tr>
<tr><td>Intro to Physics, Kinematics and Projectile Motion</td><td>Possible use of the Graphing notebooks and/or the Falcon9 notebook to introduce coding with physics</td></tr>
<tr><td>All Basic Forces, Pulleys, Ramps</td><td>Possible use of Pulley notebook adjusted with ramp activities</td></tr>
<tr><td>Energy</td><td></td></tr>
<tr><td>Momentum</td><td>Use of QuarkNet workbench activities (Top Quark)</td></tr>
<tr><td>Rotation and Angular</td><td></td></tr>
<tr><td>Simple Harmonic Motion</td><td>Use of Spring code notebook as presented here</td></tr>
</table>

Spring Notebook Background:
This collaboration Spring notebook is serving as a summary experience for students that takes place near the end of the Simple Harmonic Motion topic. It is taking place as a mini coding activity for students to demonstrate competence of spring motion and the relationships governing the position of a spring mass. Furthermore, the coding aspects of the activity serve to help the student navigate the difficult parts of spring motion analysis.

The students will have access to a separate document they will use to answer the questions and paste their code analysis and results. I leave it to the reader to decide whether to have this as an individual project or a pair collaboration project.

Students are expected to be able to determine the spring constant of a basic vertical spring with mass on it through the analysis of a graph based on student created data. In addition, students will be able to graph the position of a mass on a spring as a function of several different variables, and be able to justify how changing a variable affects the positions outcome over time.

Spring Notebook Application:

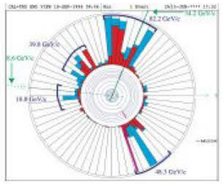
Students will be introduced to the Spring notebook with at least 45 minutes in the period. A class wide conversation will introduce this notebook and the goals behind it, along with the importance of being able to represent the physics ideas involved through a coding approach. From there, students will be introduced to the actual task. From there, students have a number of built-in checks for students to come to the instructor that will serve as a way to judge student progress.</td>
</tr>
</table>

Implementation Plan Example: Catholic University Center July 2023		
AP Physics, Honors 11th grade Physics and On-level Physics		
Standard Learning Goals	Assessments	Lesson/unit ideas
• Understand energy on Macroscopic as well as Atomic scale • Analyze momentum conservation • Data analysis by collecting data and graphing it • Make real world connections with particle physics	• Students will do some sort of data analysis from CERN data (I have heard it's available) • Perform muon detector lab (Cosmic watch lab, demonstrated by Ken) • Have students explore the activities from the QuarkNet website. (showed by Ken)	These activities will be incorporated in units of energy, energy and momentum conservation, graphing and data analysis!! Show videos on Standard Model in particle physics Share the QuarkNet net experience, Jefferson lab presentation
If there's time … I would like to talk about the Mayan pyramids and how the secret chambers are detected via cosmic ray detectors to address CROSS-DISCIPLINARY SKILLS		Show videos, share presentations

Implementation Plan Example: Catholic University Center July 2023
12th grade - Research Practicum - Physical Sciences
Student learning Goals: - Develop an understanding of the Standard Model in general, Muons in the context of cosmic rays in particular (using video(s)) and of muon tomography (using pyramid example → annotated bibliography) - Be able to present data graphically (scatter plots, histograms) and interpret graph - Be able to describe and calculate the mean of a set of data - Be able to describe and calculate the measures of the spread of data (variance, standard deviation) - Be able to conduct and interpret hypothesis tests for two population means. Assessment: - Application to data collected during a Physics lab in the previous year - Ongoing

Group 2

- Physics
  - Muon Particle Detector will come back into use.
  - Probability of radioactivity decay.
- Chemistry
  - Examination of the Standard Model looking at the exotic particles.
  - Modeling quantum numbers
- All labs
  - Include error on predictions and measurements using bar graphs and bell curves
  - Virtual labs: Cosmic Ray Studies, Phydemo, Falstad, PhET
  - Use eV/c^2 as a dimensional analysis exercise



Group 3

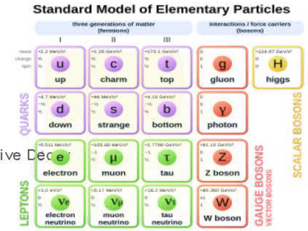
What are you looking to do?

Data collection and analysis through Histograms (FWHM for uncertainty)

Dice Probability tied into Coin Probability. Exploring misconceptions of Probability between single and compound events

Using Fermilab data to measure momenta via vector addition in 2D to discover evidence of particles(momentum)

Introduction to Standard Model/Particle Physics (Shuffle the Deck Activity)



What class?

Physical Science, Chemistry, Physics

What unit?

Lab/Data Skills, Conservation of Momentum/Energy Units, Waves and Radioactive Dec

Group 4

Physics/ Chemistry/ Physical Science

- The “Dice, Histograms, and Probability” activity supports student data collection, graphing, and analysis skills. This can also be applied for radioactive decay.
- After introducing subatomic particles and quarks, the “Shuffling the Particle Deck” data activity is a great way to introduce the standard model.
- As a possible extension activity, students could be placed into groups and have them research different neutrino experiments such as ATLAS, NOvA, DUNE, MINERva, LHC, etc. being conducted around the world.
- For high school physics students, the “Case of the Missing Neutrino” activity is a great application of conservation laws to a more interesting situation than two carts on a track.

Table _

Exemplar of Coding Activity/Implementation Plan Development

<table>
<tr>
<th>Summary of Coding Activities: PNW Center[a]
(What happened during QN Workshop)</th>
<th>Four-Part Motion Lab: Coding Project</th>
</tr>
<tr>
<td>Day 1:
Motivating the use of computer programming and computational thinking in high school physics classes. Using interactive Jupyter coding notebooks, participants were able to model a projectile's motion in the earth's atmosphere; teachers progressively increased the model complexity to more accurately model effects such as air resistance, changing density with altitude, and changes in the force of gravity with altitude. The participants also completed a computational lab example. Participants used their smartphone accelerometer and the PhyPhox app to measure their acceleration as they walked; then utilized numerical integration techniques to calculate their velocity and position as they walked, using only acceleration data.

Day 2:
Participants completed a mini-bootcamp in coding with Python. Using interactive coding notebooks, the teachers were able to both edit and run the code while also completing small learning assignments throughout the notebooks. Many teachers went from having no experience with Python to being able to import data and make a plot with Python.

Day 3:
QuarkNet coding fellow Tracie Schroeder joined virtually and led the group to complete multiple QuarkNet coding activities using real data (muon mass, periodic table of elements, sunspot, and solar position).

Day 4:
Participants were tasked by Tracie to develop a teaching lab and an associated coding notebook for analyzing any collected data. Using pair programming techniques, the participants developed a four-part motion lab for high school students utilizing Jupyter Notebooks. (In conversation with Tracie during a debriefing meeting held with coding fellows on August 27, 2023, the small group of five participating teacher made this approach possible.)

Day 5:
Machine Learning. Our goal was to provide a foundational understanding of machine learning concepts so that teachers could answer questions about machine learning in the classroom. To this end, Dr. Dolen walked the workshop participants through two interactive learning notebooks. Using open cosmic ray data from the Major Atmospheric Gamma Imaging Cherenkov Telescopes (MAGIC), the notebooks introduced multiple concepts involved in machine learning classification tasks. Initially, the participants were tasked with identifying gamma-ray cosmic ray events while rejecting hadron initiated cosmic rays. Participants identified data-based observables that could be used to separate gamma-ray and hadron events. They applied thresholds to these observables, measured signal efficiency and background reject rates, and developed Receiver Operating Characteristic (ROC) curves based on their choices. Participants were then exposed to decision tree and ensemble method machine learning tools. These machine learning methods were chosen because they are both powerful and easy to understand.</td>
<td>Velocity and Acceleration Lab

Part A - Setup
Part B - Measuring Constant Velocity
Part C: Measuring Constant Acceleration
Part D - Using Python to Calculate Acceleration of a Cart Rolling Down a Ramp

Excerpt of Coding:

Velocity and Acceleration Lab

Part A - Setup

Today, we're going to
• Determine the velocity of the constant velocity car
• Confirm that the velocity is constant
• Measure the constant acceleration of an object falling under the influence of gravity
• Measure the constant acceleration of an object rolling down a ramp

First, we need to import the required libaries so our code can work. Click play below to import them.
+ Code + Text

# this cell only needs to be run once, but re-exectuing it doesn't hurt anything either
# imports software packages (not too exciting)
import pandas as pd
import numpy as np
%matplotlib inline
import matplotlib as mpl
import matplotlib.pyplot as plt

Part B - Measuring Constant Velocity

Now, we are going to determine the velocity of the car by measuring the time it takes the car to travel 2 meters. We will take two times, the first from the starting line to 1 meter and then from 1 meter to the finish line.

Using python to verify acceleration = 0

This is where you come in, input your data for the times from 0 (starting line) to 1 meter and from 1 meter to 2 meters and run the code.

#Take out the first hashtag (#) of the line and put in your data.
t_a = [.5,.61,.54,.59]
t_a = sum(t_a)/len(t_a) #calculates the average time by summing your time measurements and dividing by the number of trials

#Now, repeat to input the times from 1 meter to 2 meters
t_b = [.5,.61,.54,.59]
t_b = sum(t_b)/len(t_b) #calculates the average time by summing your time measurements and dividing by the number of trials

t0 = (t_a + t_b)/2 #averages t_a and t_b from both t_a and t_b
v0 = 1/t0 #calculates velocity by taking average distance of 1m and dividing by the average of t_a and t_b
print("The average time of your car is: ",t0, "s")
print("The average velocity of your car is: ",'{:0.3g}'.format(v0), "m/s")

The full coding project/activity is available here:
https://colab.research.google.com/drive/1jk6cgg4TfXs5V3v74i_jr65fAO-efXWc?usp=sharing</td>
</tr>
</table>

[a]Excerpts from Annual Report submitted by James Dolen; https:/quarknet.org/content/pnw-quarknet-center-2023-workshop-annual-report.

Comparing Center and Teacher Responses

Table _
Comparison of Center-level[a] and Individual Teacher[b] Responses

Program Component	**Engage Teachers as Active Learners, as Students**	**QN provides opportunities for teacher to engage as an active learner, as a student**	**QN's Influence on Teachers (on this behavior)**
Opportunities for Teachers to Engage as Active Learners, as Students	*Almost all* Teachers 17/21 centers	83% of teachers reported opportunities as *Excellent*	Rated as 12/21 centers *High*
Teachers interact with Mentors Other Teachers	*Almost all* Teachers 14/21 centers 18/21 centers	82% of teachers reported opportunities as *Excellent*	Rated as 19/21 centers *Very High/High* 18/21 centers *Very High/High*
Form Lasting Collegial Relationships	*Almost all/Most Teachers* 15/21 centers	72% of teachers reported opportunities as *Excellent*	Rated as 16/21 centers *Very High/High*

[a]Based on 21 (28 combined) centers
[b]Based on teacher survey data from three program years (2019-2022) to be updated

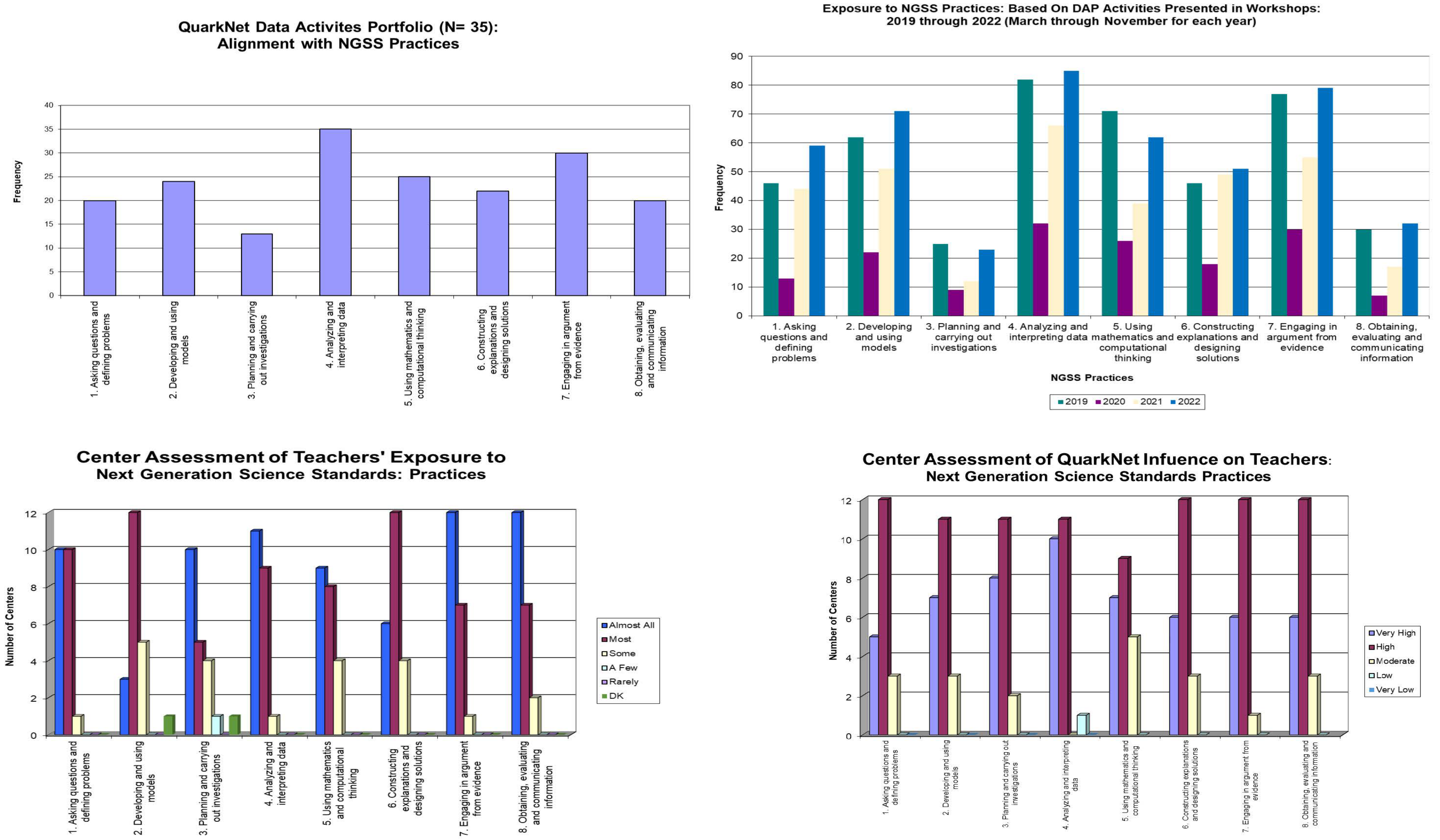


Figure Set 15. Alignment of Next Generation Science Standards (NSS) science practices and activities from the Data Activities Portfolio as designed (upper left-hand corner). Then, the exposure to NGSS practices based on *implemented* QuarkNet workshops held during the 2019 through 2022 program years (upper right-hand corner); and finally based on QuarkNet program content and DAP activities as assessed by center-level assessment of individual teacher engagement (lower left-hand corner) and then the same for perceived influence of QuarkNet on this alignment (lower right-hand corner).

Bringing into the Evaluation

Next Steps:

Acknowledge/Review Additional Data/Sources

Cosmic Ray studies (data/examples)

Masterclasses (focus on students' collection of data)

Professional Presentations (by QN staff, teachers, and students)

Cosmic Watches