Center-Level Portfolio: Virginia Tech University

The following table, proposed implementation plans by participating teachers, and when available other examples are intended to provide an overall narrative about how and in what ways program participation has influenced teachers in using QuarkNet content and materials in their classrooms (and in-after class events). The value of these qualitative reviews is to expand on the instructional practices measured quantitatively via Teacher Survey responses to specific sets of questions/self-reported by teachers providing narrative examples of implemented or planned instructional practices in teachers' classrooms and in schools. This evaluation approach is consistent with the use of *authentic assessment* to evaluate performance, "teaching for understanding and application rather than for rote recall" (Darling-Hammond & Snyder, 2000, p. 523).

In keeping with Darling-Hammond, Hyler and Gardner (2017), we do not naively expect a single workshop (or event) to have a measurable impact on teachers' knowledge and subsequent classroom implementation. A characteristic of effective professional development is a program of sustained duration, providing "multiple opportunities for teachers to engage in learning around a single set of concepts or practices; that is rigorous and cumulative" (Darling-Hammond, et al., 2017, p. 15). As such, the table summarizes responses by teachers over the course of several program years and likely several QuarkNet programs and/or events.

These responses come from the Teacher Survey (either the full or update version) where each row represents the responses to open-ended questions from the same teacher over time. Also, each row starts with the original responses to the first time a teacher completes his/her full teacher. If a particular box in the table is blank, it likely means that that teacher did not participate in an event for that program year (or, the center may not have had a major event that year). The table provides the essence of these responses; a given response, as presented, may be a direct quote, a paraphrase, or lightly edited; the intent is to convey the overall idea or its essence from that particular teacher.

Because these are responses to open-ended questions, teachers are free (and encouraged) to provide information that he or she thinks most relevant. Each highlighted response is intentionally anonymous to respect the principles of collecting evaluation data (*Guiding Principles for Evaluators*, American Evaluation Association) and to help encourage teachers to respond frankly to these questions. If a reader is familiar with a given center, it may be possible to "reverse engineer" the identify of a particular teacher. We encourage readers to respect this anonymity. At various times, we may have identified a given teacher by name and/or school; when this happens the written approval of that teacher has been obtained. It is also important to note that the full breath of a response by a given teacher may not be fully articulated in this table. For example, responses related to how QuarkNet may have advanced the knowledge of a given teacher or bolstered a collegial network among participants are likely discussed elsewhere in subsequent evaluation reports.

The table is followed by examples of implementation plans, and at times teacher presentations and student presentations when available. The intent of providing these examples is to deepen the narrative as to what and how teachers have planned (and have used) QuarkNet content and materials in their classrooms and in-after class events (e.g., Physics Club). Examples from Annual Center annual reports may be highlighted as well.

Table
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years **Virginia Tech Center**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Virginia Tech Center	2019	2021	2022	2023	2024
	LIGO Lab. The activities in the data portfolio are engaging, and cause students to think outside the box. I have learned a great deal about particle physics from the workshops, and the resources have been helpful in my classroom instruction	By using the lessons we created in sessions to engage students in learning. Examples: Penny Lab, Ligo, Magnetism. Even though some items during the session were a bit over my understanding, I was still able to take a lot of information from the class.			
	Examples; Penny mass histograms. I like the application of histograms because they are useable in Chemistry and Biology		I will use the Dice Histograms and Probability activity in Biology in the unit that introduces Genetic traits. Examples: Mass of US Pennies Uncertainty Dice, Histograms and Probability		
	The most direct application has been related to the Mass of US Pennies to teach the utility of histograms and a statistical approach to physics. They are useful and relevant - adaptable at many levels of instruction	Cosmic ray and particle mass activities, especially as related to conservation laws. Interesting in extending my use of activities/resources to examine statistical analysis of data, especially the use. Examples: Making it 'Round the Bend, Mass of U.S. Pennies (and adaptations), Histograms (The Basics and Uncertainty)			
	Examples: Mass of Pennies, Quark Workbench, Muon Lifetime, Mass of Z-boson, Particle Cards. These are excellent activities that are ready-to-implement. In addition, they can be modified to suit your own classroom needs. QuarkNet has allowed me to bring real, cutting-edge science to my students in a way that I never thought possible before. It has shaped my teaching career, honestly. Thank you!	I plan to teach a stand-alone nuclear and particle physics unit at beginning of year, incorporating labs such as the Particle Cars, Quark Workbench, and Penny Mass. In Momentum/Energy unit. Examples: Z Boson Lab, Particle Card Sort, Penny Mass are all activities I use often. It's the best professional development imaginable for physics teachers. Content AND ready-to-go lessons, I learn more every year!	Examples: Mass of Z Boson, Shuffling the Particle Deck, Mass of US Pennies, Mean Lifetime. I have been a part of QuarkNet since my first year of teaching and it has shaped my curriculum in many ways! Additionally it inspired me to pursue a Master's degree in radiation physics.		It is an amazing resource that can be modified to fit many different classrooms and subjects! QuarkNet provides the most amazing teacher professional development imaginable. You are engaged the entire time because you WANT to be, and you move between learning new physics and collaborating with peers on how to teach that new physics. The relationships and confidence you build as you continue to participate in QuarkNet activities allows you to defeat imposter syndrome and become a much better, more passionate, teacher of science.

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Virginia Tech Center	2019	2020	2021
	Making it Around the Bend (I use this with my circular motion units in reg physics and AP physics classes.) Quark Workbench (I use this as an intro activity with my regular physics and AP physics classes at the beginning of each school year.) The data activities use new and exciting physics concepts that can be quickly and easily incorporated into any physics course and likely even physical science classes. It allows students to see NEW physics and cover content that is frequently left out of many physics classes.	I have used many of the "beginning level" activities like the quark workbench and the mass of the pennies activity to start my physics year with an intro to particle physics as well as histograms. Examples: Making it around the Bend, Dice, Histogram. I love these workshops! I learn so much and we are able to spend time figuring out how to use everything we have learned in our own classrooms. That is INCREDIBLY valuable since it is tough to do.	I will be using the Round the Bend Data Activities along with the Coding Activities I worked to develop early in the summer with a different coding workshop in my classroom to teach about particle physics. Examples: Mass of Pennies, Quark Workbench, Dice and Histograms, Making it Round the Bend Qual and Quant, Calculate the Z Mass, Step-Up Physics Lessons. As I have participated in more QuarkNet type workshops, I have continued learning SO much info. I have become more skilled at incorporating QuarkNet Activities into my classroom. SO very useful!
	Program Year (Year of Full Survey)	Subsequent Program Year	
	2019	2022	
	I've used Rolling with Rutherfurd to reintroduce decay processes and half-life. I've used the quark workbench to introduce quark constructions and conservation laws. I've used the CMS boson screenshots to teach two-dimensional vector addition and momentum and energy conservation. The portfolio is impressive. I would recommend it to any chem, physics, or physical science teacher at the middle school and high school levels. I can't see why any of the material would not be effective in the classroom if executed in the proper way. I think the program is great. I've learned so much over the last few years and have been confident enough to pass it on to my students. My students are the true test when it comes to finding good material and engaging activities to use in the classroom. All of my students enjoyed the activities and have asked many questions even after they complete the work. These resources help make current physics topics interesting and easier to understand, as well as spark student curiosity about quantum and particle physics. This idea has helped me and my students connect what seemed to be a very difficult topic of physics to familiar laws and concepts studied in other areas of our content. The opportunities I have had to meet and work with other physics teachers is priceless. I am the sole physics teacher in my building, so I don't get to share what I am doing or learn from others in my building at all.	I use the quark workbench as a discovery activity for students to identify conservation laws when building two and three quark particles. I have not yet used the master class activities. I just not comfortable with the programs needed and do not know if my students have access to these programs with just a chromebook. My students enjoy them, and it makes them want to study particle physics more	

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Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year
	2021	2022	2023
Virginia Tech	This is my first workshop. I have not used any data activities yet,		
	I have not used any data activities yet. I think it has some good information that can be modified for science classes. The approach to some of the activities allows for student growth in critical thinking skills.		
	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year
	2022	2023	2024
	It is a good source of physics data that can easily be implemented in the classroom to help students make connections to the data and the real world. I was excited to attend this workshop because it covered topics that I needed to expand teaching in my classroom. I attended the workshop virtually and I was happy to have the opportunity, but I missed meeting some of the participates in person.		
	Examples: Shuffle the deck, mean lifetime, speed of muons, relativity concepts, energy, momentum and mass, Z mass. I would recommend the Data Activities Portfolio, the data was easy to access and understand. The teacher and student notes were clean and easy to follow. The data provided by links was easy to manipulate. I am impressed at the overlap with all these labs we went over. I like how the particle concepts fell under so many general physics topics.		

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Virginia Tech Center	2024	
	(First Year.) Yes, I would recommend the instructional materials. It gives a twist on activities involving energy, mass, charge and momentum. In the workshop, we used Shuffling the Particle Deck, Mean Lifetime Part 1: Dice, Mean Lifetime Part II: Cosmic Muons I modified Signal and Noise: The Basics. I was excited to attend this workshop because it covered topics that I needed to expand teaching in my classroom.	
	(First Year) Shuffle the deck, mean lifetime, speed of muons, relativity concepts, energy, momentum and mass, Z mass. I would recommend the Data Activities Portfolio, the data was easy to access and understand. The teacher and student notes were clean and easy to follow. The data provided by links was easy to manipulate. I am impressed at the overlap with all these labs we went over. I like how the particle concepts fell under so many general physics topics. This was a great pd. And I have been in many. This was specific enough in content and provided many labs that should be easy to implement.	
	Calculating the mass of a z Boson: Lots of concepts learned in mechanics are useful in this activity such as finding components of a vector, the addition of vectors, addition of scalars and vectors etc. My Ph.D is in Condensed matter Physics. From this workshop, I learned a lot of activities that can be implemented in my high school classroom. I am going to discuss these activities with my cohorts and implement these activities in all of our classes.	
	I haven't used any yet.	
	(First Year) Mean Lifetime Part 1: Dice, Calculate the Z Mass, How Speedy are These Muons? I feel like their complex but not too complex for the area I'm teaching, and they are fun and engaging while also being useful.	
	(First Year) There were many activities that I can implement in my classroom. Very interesting material and concepts. Example: Calculation of mass of z Great materials that have been well planned and thought out. All of the workshop material was engaging and interesting. I predict my students will enjoy it as well.	
	I would recommend it for the data that can be analyzed and graphed.	
	(First Year) I will implement much of what was presented this week. How helpful it will be is yet to be determined. I would definitely recommend this program. I think the contents and additional references will help me expand my lesson plans. The contents presented and the way it was presented will help me expand my instruction.	
	(First Year) I have been very disappointed in the facilitation of this workshop for the virtual participants. The attention to the virtual attendees has improved throughout the three days but is still insufficient. I could have learned about 90% as much in much less time simply by being provided the links to go through on my own time. In the first day of the workshop, other than the introductions at the start of the day there was zero engagement with the online participants. We were not asked any questions or asked to speak at all. Slides were gone through so quickly that it was nearly impossible to read them or to understand the details.	

Note: Each row presents responses from the same individual teacher from a given center. Empty table cells indicate that the teacher did not participate in QuarkNet in that subsequent program year(s). Or, less likely did not complete the Update Survey; or did not answer specific questions about the use of DAP activities in their classrooms.

The next several pages shows examples of implementation plans proposed by participating teachers during the summer 2024 workshop at the Virginia Tech Center. Other examples of implementation plans are shown on their center page https://quarknet.org/node/2503.

Mass of Pennies
Use student notes
Data Collection

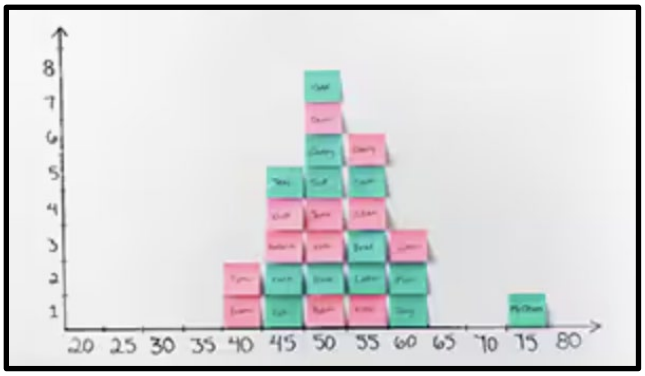
A data table with several quantities may look like this:

Penny	Mass (g)	Mint Year	Diameter
1			
2			
3			

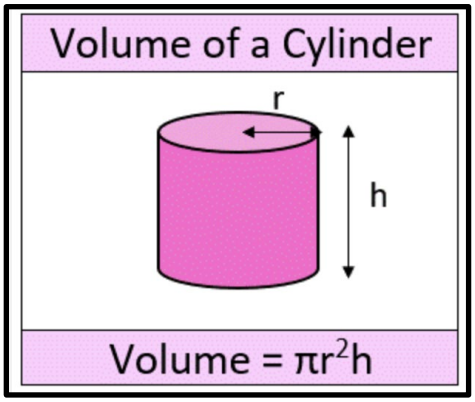
It is also useful to help them with making their first and most important histogram with a table like this:

Mass bin (g)	Number of pennies/0.1 g
0.0-0.1	
0.1-0.2	
0.2-0.3	

Have students make histogram on white whiteboard



Have students go back and compare average calculations versus histogram



Finally, have students calculate the volume of a penny and propagate the uncertainty using

“Noise” in Data

Virginia Physics Standards 2018 PH.1.C

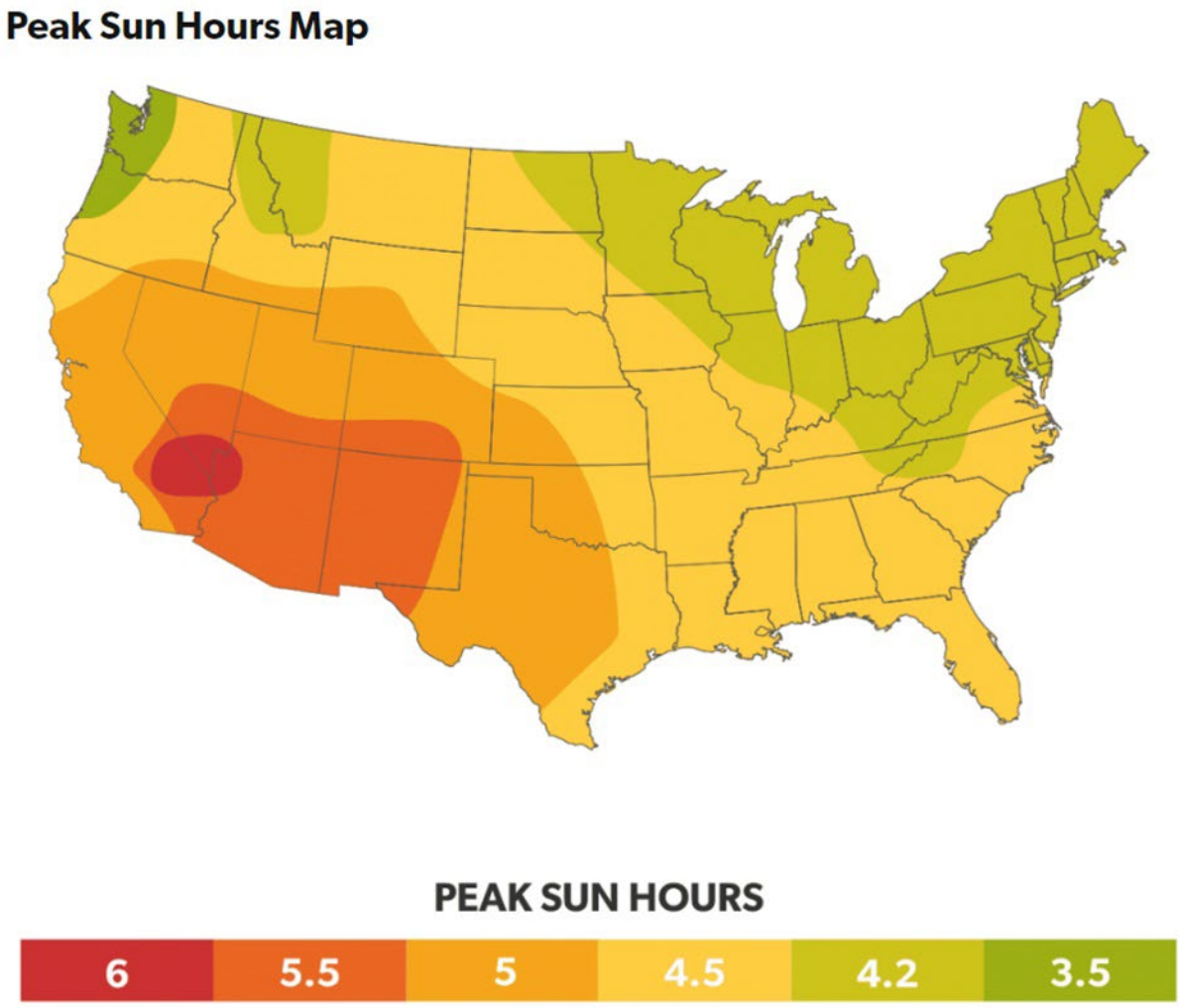
a) ***interpreting, analyzing, and evaluating data***
- ***record and present data in an organized format that communicates relationships and quantities in appropriate mathematical or algebraic forms***
- ***use data in building and revising models, supporting explanation for phenomena, or testing solutions to problems***
- ***analyze data using tools, technologies, and/or models (e.g., computational, mathematical, statistical) in order to make valid and reliable scientific claims or determine an optimal design solution***
- ***analyze data graphically and use graphs to make predictions;***
- ***consider limitations of data analysis when analyzing and interpreting data***
- ***evaluate the impact of new data on a working explanation and/or model of a proposed process or system***
- ***analyze data to optimize a design***

Imagine for a minute that you have been asked to participate in an experiment where you measure both the brightness and amount of direct ultraviolet light exposure on a summer day. Your data will be recorded over each day for several weeks and then published.

There’s just one problem, weather. You have collected data in both perfectly sunny, partly cloudy, and rainy conditions. Do we automatically assume that all of your data is perfectly valid? Do you just go ahead and make a graph of your daily data? Or do you somehow average the data?

If the clouds change every single moment, what should you do?

What about smoke in the air?



Not every location has sunlight 100 percent of the day.

Let's try this…
Each of you will be given five dice. A six represents a perfectly clear day, a one or two represents a rainy day with no possibility of sun.
For each roll, take out the die that you roll where there is a one or two.

Repeat until you have no dice left. As a class, we will record the results for each roll. Create a histogram of the data.

Then the students will participate in the half-life/lifetime experiment from Quartnet.

Momentum Unit Plan

Objectives:

- Use conservation of momentum and energy to determine the mass of a top quark.
- Explain the importance of identifying the missing momentum carried away from the event by the neutrino.
- Describe the properties of a neutrino that make it impossible to detect in the DØ detector.
- Explain the importance of considering the results of several experiments before announcing discoveries.

Prior Knowledge Needed:

- Add vectors in two dimensions.
- Use energy and momentum units common to particle physics: Momentum–eV/c, Energy–eV/c^2 .

Day 1: Introduction to Momentum notes, solving mechanics related momentum problems.

Day 2: Conservation of Momentum-notes, solving mechanics related momentum problems.

Day 3: Collisions-notes, solving mechanics related momentum problems.

Day 4: Collision Lab- uses carts to see the physical collision and observe/calculate how momentum is conserved.

Day 5: Background Information on DZero data and the Top Quark

- This is a recall to particle physics from an earlier unit. Students should have already heard certain terminology. (given, if you start the year off with particle physics)
- Discuss how these detectors work
- Look at some collected data
    - Discuss what the data tells us, what can be analyzed, etc.

Day 6: Calculate Top Quark Mass Activity

- Review how to read the data from the detector
- Go through activity directions
- Students work in groups of 2 to analyze data
- Class comes together to discuss results