Center-Level Portfolio: Black Hills State 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 anonymously 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 **Black Hills State University Center**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
Black Hills State University	2019	2020	2021	2022	2024
	LIGO workshops have been my favorite because they have some interesting applicability with my classes. For application of physics concepts, I find it very useful.		I run a CRMD in my classroom and definitely use LIGO information with my earth science class. I have used Ligo activities with my whole class and have used the cosmic ray e-Lab on an individual basis with students. I do not teach physics, so it is harder for me to incorporated activities.	If I can get my school tech department on board, I will be incorporating Coding (Google Colab) into my environmental science and STEM Lab classes. I like the histogram activities and the coding activity. I really like to use the CRMDs and data individually with students for their science fair projects.	Example: Rolling with Rutherford

Table (con't.)
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 **Black Hills State University Center**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
	2021	2022	2023	2024
Black Hills State University	Each of these has been helpful in continuing my understanding of particle physics--which is why I continue to attend these learning opportunities. I have several activities identified for use this upcoming school year. The activities are well written, provide teacher notes and sample data which are so helpful to busy teachers. Standards that are addressed see how the activities can be used in our curriculum maps.	The project I worked on at this summer's QuarkNet was to import the data from the CRMD into CoLab and use python coding to analyze the results. This is what I plan to do with my own students. In addition, the colleagues that I spent these past few days with also shared their projects which I hope I can also use with my students. This has been a great week of learning and applying coding for data analyses. I am beginning to learn python coding and how to apply it to analyzing data. Making Tracks 1; Energy, momentum and mass; Rolling with Rutherford, Particle Transformations As always, I will leave our time together this week refreshed and renewed in physics teaching. I have gained skills in python coding because of the instructors and assistance given by them and my colleagues. Sharing our projects was very beneficial. I am grateful for the incredible tour we had of SURF and its work--I'm always blown away! Thank you, especially to folks for their expertise and for organizing this summer experience!	Rolling with Rutherford--modeling subatomic particles and helping students build images in their minds. This activity also opens up discussion about how theories are modified and science involves with new evidence.	I plan to teach about the CRMD and collect and upload cosmic ray data to the e-lab with my high school physics students. I will incorporate several of the QuarkNet activities into my physics course including "How speedy are these muons?", and "Mean lifetime: Part 1- dice" to help students understand and apply kinematics and radioactive decay. Examples of DAP activities: Shuffling the particle deck (use every year) Excited to use How Speedy are these muons? and Mean lifetime-dice, Part 1. I always appreciate building upon my understanding of particle physics, learning about new activities/lessons to engage my students in science, and the collaboration with other teachers that create a community of support. QuarkNet is always a highlight of my summer professional development experiences.
	Program Year (Year of Full Survey)			Subsequent Program Year
	2021			2025
	Rutherford Scattering, QuarkNet workbench. QuarkNet workbench is a great summary of information for kids and good resource for teachers. QuarkNet provides great content and resources. QuarkNet provides great content and resources. The development of curriculum, pedagogy and student-centered Inquiry-based learning is a more complex issue that requires more time and support. At Sanford Underground Research Facility, the Education and Outreach team specializes in this along with professional development for teachers.			Getting CRMD's running and teachers trained on operation and integration into their classrooms. Examples of DAP activities: Rolling With Rutherford, particle card sort. It is great seeing how we can easily bring particle physics into the classroom

Table (con't.)
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 **Black Hills State University Center**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year
	2021	2022	2023
Black Hills State University			
	Utilized multiple years of my CRMD in an analysis with Dr. Peggy Norris at SURF. Lots of ideas to implement however implementing them can be difficult. Used CRMD data to describe Hexadecimal to my students. I have an underground experiment at SURF that has been taking up my time that I use to devote to QuarkNet.		CRMD Build and plateau
	Program Year (Year of Full Survey)	Subsequent Program Year	
	2023	2025	
	I teach life science but I would recommend these (DAP) to physics teachers.	I have used the CRMD detector for students interested in an independent project. I have used activities like Rolling for Rutherford when teaching about the structure of the atom. The workshop this year has given me some ideas on how to modify some of the activities for use as a data collection and analysis lesson. Examples of DAP activities: Rolling with Rutherford, shuffle the deck, lifetime study dice roll. Data collection and analysis has been one of the things I have most tried to incorporate into my science classes. My experience with QuarkNet has illustrated the importance of data in scientific research and I want to give my students the most realistic experience possible.	
	Coding Camp because I didn't know anything about how to do it or teach it prior to the camp. Neutrino data, muon data and the colabs for using python for various tasks. I think the resources and the training advances our ability to teach the subject well.	I will use the cosmic ray detector at the Oglala Lakota College Center and plan to incorporate it into outreach to reservation based high schools as well as using it in my college courses. I would like to build some Cosmic Watches to use in outreach. I teach Physics 1 so I will use the lesson on velocity and speed of muons. I also want to host World Wide Data Day. Examples of DAP activities: Mean lifetime dice, standard model deck, muon dimuon (used previously and will continue to use). Adding how speedy are muons and lifetime study for muons. I think my experience also allowed me to find additional ways to apply my knowledge outside of the classroom. I completed a MS in Chemistry and my experience in QuarkNet helped me in the atomic theory/quantum mechanics class. I also organized community outreach activities related to radiation during a community theater production of the play Radium Girls. I used the mean life time activity with dice at that event.	

Table (con't.)
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 **Black Hills State Hills University**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year
Black Hills State University	2021	2022	2023
	As a first time participant and STEM teacher, this workshop allowed space for my learning and to find ways to incorporate data activities in my high school STEM classes which will enhance the learning experience for the students. I am excited to see how students engage with QuarkNet as I use this tool in my lessons this coming school year! QuarkNet gave me the opportunity to network with teachers and scientists in my home state and surrounding states.		Have not used the DAP. As a life science teacher, my interactions with particle physics teachers is nonexistent before this workshop

Program Year (Year of Full Survey) 2022
This is my first one so I have no comparison. This was a very good experience and look forward to learning more and using this with my students. I am a Middle School teacher and would be happy to recommend this program to them, but I am more interested in taking this to middle and elementary teachers to keep science alive with our younger students. We're learning coding and have had a briefing on the experiments at SURF. This together with the conversations with fellow participants has created a pool of knowledge that will end to further research assisted by a new network of people. Thank you for the opportunity. I am taking this class in anticipation of my students' learning next school year. Ask me next year and I will be happy to share what impact The Coding Workshop has had with my students. I look forward to doing more QuarkNet collaborations and to bring in more teachers in my district to the program.
All have been good to take back to my students or for my students to experience like masterclass. I have taken my students to masterclass each year that it has been available, and I think that has the most impact. They are good activities, and masterclasses have been a good way to expose students to particle physics. QuarkNet has been a valuable resource to me as a student and teacher of physics. QuarkNet has made it possible to discuss particle physics in my classroom at the level that we do. It has helped me connect with scientists who have mentored my students on projects and who have shown a genuine interest in their work.

Program Year (Year of Full Survey) 2022	Subsequent Program Year 2023
(First year) Looking forward to using this year.	The coding 1 and 2 both built on each other, and I found them valuable
I haven't used any yet (DAP), this is my first workshop.	
This is my first QuarkNet experience.	

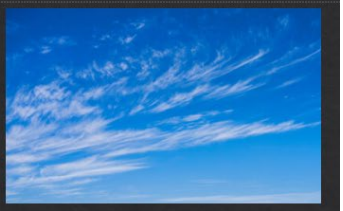
Table (con't.)
Self-reported Use of Data Activities Portfolio Activities: Based on Responses from the Full Survey and then Responses from the Update Survey in Subsequent Years **Black Hills State University Center**

Center	Program Year (Year of Full Survey)
	2023
Black Hills State University	This coding 2 camp will be helpful because I will be able to expose my students to physics and different coding approaches. (First year) As a teacher who doesn't have a particle physics background, this workshop has given me enough knowledge on it to be able to bring it back to my students and have a starting spot to keep learning. It was a great experience, and I look forward to more interactions with QuarkNet. I'm glad to have joined this group.
	Program Year (Year of Full Survey)
	2025
	Cosmic Ray Workshop - First one I've been to. I enjoyed the hands on activities and the opportunity to explore with cosmic watches. Shuffling the Particle Deck - to introduce the idea that there are more than just protons, neutrons, and electrons out there. How Speedy are these Muons - draw back to previous knowledges students had earlier. I would use these instructional materials. Many break down complex science/math content in to ways that students can explore and make sense of the content. Perhaps explore more math concepts. As a chemistry teacher I felt a little out of my league with all these math experts.
	I think the cosmic ray workshop has been most useful because I got more comfortable with the e-lab.
	The 6- and 20-sided dice roll to demonstrate half life. It facilitates a streamlined process.

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 pages provides examples of posters created by participating teachers during the 2025 Cosmic Ray Workshop@SURF.

The Effect of Convective Clouds on Muon Flux



Introduction: This experiment intends to investigate whether a convective cloud can affect cosmic ray flux

Procedure: Three orientations are used. First vertical, then angled toward cloud, then angled toward clear sky

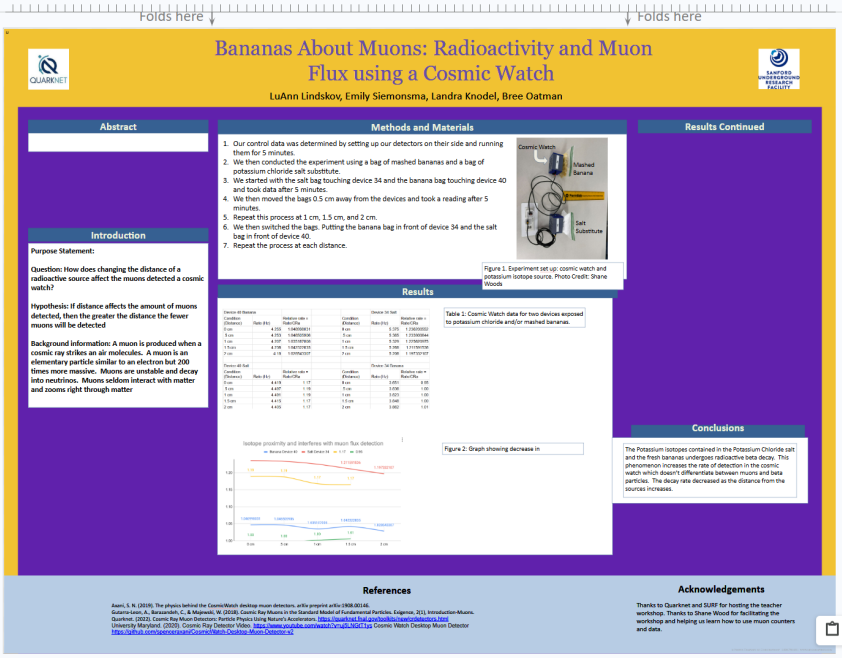
Data:

	M/S
Vertical orientation	3.42/.093
Angle toward cloud	3.14/.058
Angle toward clear sky	3.17/.058

Notes: The angles were aligned to the North and South at roughly 60 degrees. The cosmic watches were separated by about 2 inches. The "clear sky" was littered by high cirrus clouds. The convective cloud was of moderate intensity and approximately 5 km to the north.

Conclusion: There is not enough evidence to support a significant effect by convective clouds on muon flux. However, there was a significant deviation due to the angle of the stack

Future Studies: More intense and proximate convective cloud should be tested using the same methodology.



Group Members:

What is the relationship between muon count and depth?

Background:
Muons are fundamental particles that are produced in the upper atmosphere.
Due to their relatively high mass, muons are able to penetrate into matter. Muons can interact with detectors producing noise. In order to filter this noise, muon signals need to be vetoed out of data or detectors placed deep enough underground to limit muons from reaching the detector.

Procedure: Sanford Underground lab was chosen as a location to take count and depth reading. A cosmic watch was used to measure muon count. Measurements were taken from the top of the Yates shaft and recorded every minute as the cage descended down to the 4850 level of the Underground Lab. Depth was reported as minute. The cage descend at approximately 400 feet per minute.

Conclusion: Is there a relationship between count and depth. The count data show a decrease in the count as time (depth) increases. The cage ride corresponds to minutes 10-14. The count prior to descending corresponds to minutes 1-10. The count from minutes 15-42 are at the 4850 level. The count rate also shows a steady decrease in the frequency of signals as (time) depth increases.

This indicates that the granite rock is able to limit a significant number of muons from reaching the lab space at the 4850 level. This also gives researchers an indication of how much background noise they can expect in the detectors.

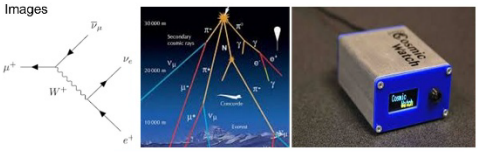
References:
4 stars data group. (2025). *Quarknet summer teacher workshop*. SURF.

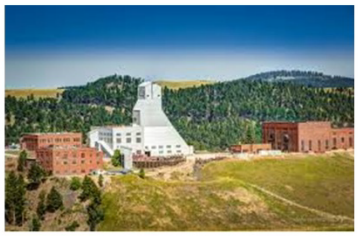
Problem:
Can a relationship between muon count and depth be determined?

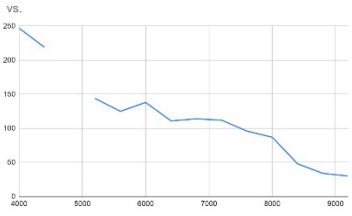
Research Question:
What is the relationship between muon count and depth?

Hypothesis:
It is hypothesized that muon count will decrease with depth.

Images

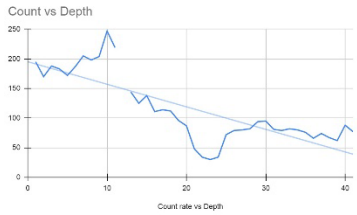




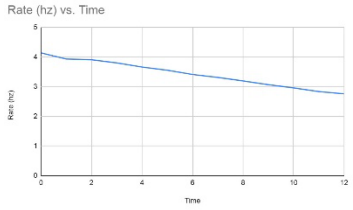


Sample Data

Minute	Count	Count per minute
0	0	
1	195	195
2	365	170
3	553	188
4	736	183
5	908	172
6	1095	187
7	1300	205
8	1498	198
9	1702	204
10	1949	247
11	2168	219
12	2517	
13	2661	144



The above graph shows that count as the cage descended down the shaft.



The above graph shows the rate (Hz) as the cage descended down the shaft.