Center-Level Portfolio: University of Minnesota

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 **University of Minnesota Center**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
University of Minnesota	2019	2020	2021	2022
	Penny Histograms, Rolling for Rutherford, That's How We Roll (Dice Histograms) - good hands on ways to show how Histogram data is useful.		Rolling with Rutherford	
	Data Camp. It taught me a lot about particle physics; to the level that I felt confident enough to talk to and teach my students about particle physics. Quark Workbench and others. These are valuable resources because I know that have been vetted for accuracy and correct. They also have wonderful directions and teacher notes.	I'm interested in doing a masterclass now that I'm teaching upper-level science courses. I also intend to continue using the lesson examples in the resources that are in QuarkNet. Examples: Quark Workbench Rolling with Rutherford.		I have used a lot of the content in various ways. Primarily with introducing the basic ideas of particle physics with students and then giving them resources to continue exploration on their own. I also have the resources for activities in various ways to have students collaborate in full blown lessons focused on particle physics. Examples: Quark Workbench, Rolling with Rutherford.
	Data Camp (2009, 2016) and CERN - both gave a deeper understanding and a longer time for the information to be set for my understanding. Masses of a Penny QuarkNet Workbench Dice, Histogram, & Probability Calculate the Mass of the Z CMS Masterclass Cosmic Ray e-Lab. I would, and have done so (recommend DAP), for the students better understanding of particle physics	Using the e-lab the deal with conservation momentum and vector analysis; along with using the Cosmic Ray detector with students to analyze data and have then choose what they want to explore. Examples: Mass of U.S. Penny, Quark Workbench 2D/3D, Histograms: The Basics, Calculate the Z Mass. Just wish we had a bit more time … to be able to put into practice all the information that we have access to.		

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 **University of Minnesota Center**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
University of Minnesota	2019	2020	2021	2022	2023
	Cosmic Ray e-Lab Workshop helped me prepare my students for their use of the e-Lab. Example: Rolling with Rutherford. Recommend (DAP) because they help students understand difficult concepts. QuarkNet is an exceptional program for physics teachers. Meeting with scientists and colleagues is extremely valuable.	Use CMS & Cosmic Ray e-Labs, Masterclass, W2D2, Data Activities Portfolio, and neutrinos extensively in Particle Physics Research Hybrid course. Use these resources to a small degree in AP Physics 1. Examples: Mass of U.S. Pennies, Quark Workbench 2D/3D, QuarkNet: Changing the Culture, Rolling with Rutherford. Very valuable!	e-Labs for several activities; to explore conservation laws and standard model; use CMS detectors and CMS data. Examples: Rolling with Rutherford Calculating the Z Mass Cosmic Ray e-Lab. Great resource, very helpful.	Cosmic Ray detector studies, Cosmic Ray e-Lab, CMS e-Lab. All are used in physics classes. Examples: Rolling with Rutherford, Calculate the Z Mass, Cosmic Ray e-Lab, Wonderful resource.	I use Rolling with Rutherford as a good intro, indirect measurement activity (and also have tacked on some error analysis application to it too). I also have used the Top Quark activity for 2D momentum and by-hand vector analysis. I use the Cosmic Ray time of flight and also Cosmic Ray lifetime activities too, tying them together to apply as an example of relativity. Anytime students get to work with and analyze data is a good day in physics, from my standpoint at least. Many of the data activities portfolios give such an opportunity and also tie in to core intro physics concepts.
	All of these activities have been extremely helpful. QuarkNet is by far the most helpful professional development I have ever been involved with. Anytime teachers can get together and share ideas is super helpful. With all of the QuarkNet activities not only am I getting great ideas from others but also advancing my own knowledge base in particle physics. If I had to pick one activity I would say the CERN experience because I was able to discuss teaching strategies with teachers from all over the world as well as hear lectures from the physicists working at CERN. Calculating the mass of the Z boson is probably the most used activity. It is easy to incorporate into the momentum unit. I've also used the quark workbench, rolling with Rutherford, and a few others. I haven't found any that I would not recommend. I would recommend all the activities - they are well thought out and seem polished and ready to use with students. They are all well written and can easily be followed and/or modified.	I began by incorporating individual lessons into my regular and advanced physics classes (data activities mainly). I also have had student interest in a "particle physics group." Examples: Quark Workbench Rolling with Rutherford, Making it 'Round the Bend.	Preparing an Introduction of Particle Physics based on Data Activities Portfolio activities.	I have consistently incorporated QuarkNet materials in my classroom; about 10-12 of the activities from the data activities portfolio with my students. Learned several teaching methods by working with QuarkNet staff: how to create exceptional group work/cooperation; how to engage students and catch their interest. Consistently been bettered through my interactions with QuarkNet staff and other teachers. Examples: Making it Round the Bend, Quark Workbench, Rolling with Rutherford.	I've used at least half of the activities, maybe 3/4 of them. Mass of the Z Boson is used every year Also: Quark Workbench Making it Round the Bend Masterclasses

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 **University of Minnesota Center**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
University of Minnesota	2019	2020	2021	2022	2023	2024	2025
	Rolling for Rutherford Pennies Dice Histogram. The deeper learning about the topics makes me more confident to teach the concepts in the classroom. The activities are clear and easy to adapt to the level of the students at the current time. QuarkNet staffer is amazing; very knowledgeable, great sense of humor. We stay on task and learn a lot! The idea that students can analyze REAL data. This makes the concepts so much more real world - even though we are talking about particle physics! Student Interactions. The students are DOING - not just watching. They are communicating with each other and coming up with explanations based on reasoning from data. They are gathering evidence themselves.	Conservation of Momentum, Vector Addition - The Case of the Hidden Neutrino and The Mass of the Top Quark Calculate the Z-Mass. The use of Real Data and 'discovery' is what really engages the students. They like to work with data they can read about with real applications. Examples: Quark Workbench 2D/3D Z-Mass Top Quark Hidden Neutrino. The use of Real Data and 'discovery' is what really engages the students. They like to work with data they can read about with real applications This is such a fantastic program. I get to learn higher level concepts, have direct application ideas to the classroom. Come away with great enthusiasm and get to work with top notch Physics teachers				I intend to use the Water Waves - Interference Experiment and the Electron Diffraction Experiment during the Waves unit. I intend to use the Millikan Photoelectric Activity and the LED experiment in the Modern Physics unit. Wave Particle Duality is very nicely shown with these activities. The QuarkNet Workshop is well structured with student perspective activities and then follow up teacher perspective/implementation discussions. I have gained greater fundamental understanding of particle physics concepts and can easily incorporate the well designed experiments into the current curriculum.	

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 **University of Minnesota Center**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
University of Minnesota	2019	2020	2021	2022	2023	2024	2025
	All - however, Data Camp at Fermilab has been an especially enriching experience. Examples: Quark Work Bench, Mass of US Pennies, Cosmic Rays and the Sun, Cosmic Ray e-Lab. I would recommend that any teacher take a look at all of the Data Activities. The level 0 activities are most accessible to those teachers with limited particle physics background. Also, many of the e-Lab activities are not suited to classes that don't have the necessary time to devote to those. It seems that the lower level Data Activities can be used as a replacement within existing curriculum more readily. This has been a very rewarding week and I feel that, even as a long time QuarkNet Participant, I have significantly increased my understanding of the Standard Model and the ways physicists use data to discover particles. I feel much better prepared to try and implement some of the more challenging data analysis activities into both my chemistry and physics classes. The activities performed this week have been as useful in helping me to develop a nation-wide network of fellow teachers to collaborate with as it has been in building upon my knowledge of the Standard Model.	I try to sprinkle in as many activities as I can in my various classes. I also lead the Particle Physics Club at our school. I do plan on adding the Careers in Physics activity this year as well as. Examples: - Step Up: Careers in Physics -Quark Workbench -Rolling with Rutherford.		Examples: Quark Workbench, Histograms: The Basics. QuarkNet Changing the Culture, Rolling with Rutherford, Careers in Physics, CMS e-Lab.		**E**xamples: Quark Workbench Shuffling the Particle Deck Histograms: The Basics Calculate the Top Quark Mass Rolling with Rutherford The Case of the Hidden Neutrino Step Up: Careers in Physics TOTEM 1 Cosmic Ray E-Lab. The activities are well developed and provide a way to teach traditional high school physics topics while also introducing students to the new research being done in the field of physics.	New things to implement: - Shuffling Particle Deck Activity - in Honors Science 9 prior to stellar nucleosynthesis - Purchase and "play" with Puck.js to see if it can replace or supplement existing sensors (accelerometers, etc) - Purchase and try to build a Cosmic Watch. If successful, create a class set - Use the Cosmic Ray Muon Detector to gather data for a lifetime study in Modern Physics class - Contact IT department to see if I or my students are able to gain access to Google CoLab. Examples: Quark Workbench Totem 1 and 2 Shuffling the Particle Deck. It has been an amazingly helpful professional development opportunity that has been more influential in my career as a teacher than any other

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 **University of Minnesota Center**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
University of Minnesota	2019	2020	2021	2022	2025
	Data Camp & Annual Summer Center Workshops. Opportunity to meet & work with other physics teachers. We share ideas about teaching and how we can apply ideas in the classroom. Examples: Rolling w/Rutherford, Top Quark, Cosmic Ray Experiments of Time of Flight and Lifetime. Most of them are pretty good and fairly easy to adapt to your class. Many are guided inquiry based too and use references to real data and student made graphs/diagrams that ask students to look at their analysis and then form conclusions from it. QuarkNet is great! I look forward to our annual workshops every year. It mixes opportunities for me, as a teacher, to learn more about modern physics and also gives ways for me to bring modern physics into my high school physics classroom. QuarkNet has increased my awareness of physics research that is happening right here, locally, at the University of MN. In addition to making that connection, we have a great group of physics teachers that we all look forward to seeing and sharing with each summer. QuarkNet has really impacted my ability to see how actual science research happens. The combination of my QuarkNet experience, plus my experience with Modeling Instruction has really helped me put together a scientific inquiry based classroom when I teach physics.	Introduction content - Use Rolling with Rutherford. Planning to use Careers in Physics and Changing the Culture this coming year as well. End of intro kinematics/constant velocity use Cosmic Rays. Examples: Rolling with Rutherford Top Quark Speed of Cosmic Ray Muons. QuarkNet has always offered some of the best, applicable professional development opportunities that I've been a part of. I love the connection between active, particle physics research, and the high.	Rolling with Rutherford for data collection (and achieving an indirect measurement result), Time of Flight cosmic ray experiment for constant velocity, Muon lifetime cosmic ray experiment for relativity. Examples: Rolling with Rutherford, Making Round the Bend, Top Quark. I always enjoy our annual QuarkNet Workshop. It's really the way professional development should be. The ability to connect with local physics teachers, work together, develop and experience new material.	I use many QuarkNet activities for data analysis. Showing how data can be collected, working with (in spreadsheets and python notebooks) and with outcome results presented. Also, when they tie in to the current topic being covered (time of flight of cosmic ray muons in the constant velocity unit as an example). I try to use QuarkNet activities as I'm able to. Examples: Python notebooks, cosmic ray detector time of flight and muon lifetime experiments, top quark vector analysis, Rolling with Rutherford, Making it Round the Bend. QuarkNet is fantastic. It's the primary place I turn to for physics teacher professional development and I feel so grateful that QuarkNet exists and very honored to be a part of it.	I use a lot of QuarkNet based materials in my classroom. I tend to use a "sprinkle" type of approach using them as they fit within the Physics curriculum I teach. Biggest implementation I have is using Python notebooks with my students for data analysis and graphing. I also have done rolling with Rutherford as an indirect measurement and have adjusted it to include uncertainty analysis. I do a time of flight with my QuarkNet cosmic ray detector as a capstone constant velocity data analysis Examples: Rolling with Rutherford, cosmic ray time of flight, cosmic ray lifetime, making it round the bend. I always feel QuarNet is the best professional development I've ever had as a physics teacher, with my modeling instruction course being a close 2nd...but that was only a one time experience compared to the long standing years of QuarkNet opportunities I've had the good fortune to participate in. Particularly how many of these experiences expose me to challenging topics tied to current physics research, pushing my brain in ways teaching the same physics course every year would not.

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 **University of Minnesota**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
University of Minnesota	2020	2021	2022	2023	2025
	I like programs that are flexible for time commitment. I integrate particle physics into various units. Examples: Rolling with Rutherford, CMS e-Lab. I plan on using the Neutrino oscillation material. The Neutrino Oscillation looks great because it is new and fascinating science, students have to interpret data and I see this fitting well into the inquiry model. I am also looking forward to using the careers in physics because it is very important that minorities and women feel represented in physics. Keep doing what you are doing, I feel like this is a great way to learn from other teachers and you go out of your way to fit this in to all sorts of different teaching styles and backgrounds. I really like how you bring in different speakers that cover local research that is being done like the Mu2e experiment. I really enjoy learning with the scientists in the current field, I feel that quark is one of the only programs out there that does that for physics. I enjoy how content specific it is. Sometimes I feels a little intimidating working with other teachers that have done so much out of the Data activities Profile because the main class I teach is pretty full of things we need to do. Yes time is often the issue. I also work with Driven to Discover to bring more of an ecological/ environmental approach to physics.			It is always useful to brush on the standard model. I like how we modeled with acting how two protons turn into a Z particle then becomes 2 muons. by having students do this they will make more meaning out of it. Examples: Rolling with Rutherford. NOvA Neutrino data.	Shuffling card deck - intro to science. Again later in the year for introducing the standard model. I can try to bring in the python collab notebooks. Examples: Shuffling the card deck, Quark work bench, careers in physics. QuarkNet has been very beneficial and the best staff development for physics. Making it relevant and new. Love the discovery and finding out about the new research.

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 **University of Minnesota**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
University of Minnesota	2020	2021	2022	2023	2025
	STEP UP - verification and encouragement to keep going with inclusion strategies. Examples: Women in Physics - Career Profiles, and follow up data slides. It's another resource (DAP) for high level, current, relevant activities in physics. I haven't been active in QuarkNet since seeing students, so I'm not comfortable measuring this yet - but I plan on implementing more activities this year.	Using Python notebooks to analyze large data sets and to perform numerical modeling of phenomena. Examples: Dice, Histograms, Probabilities Histograms: The Basics QuarkNet STEP UP: Careers in Physics	Last month I used the Standard Model cards, and the Quark Workbench lessons with my physics class, and I plan to do so even earlier next year. I hope to get rolling on the CRD earlier in the year as well – not sure if we'll run a club, or I'll just get some enterprising students to take care of it during class. Examples: Standard Model Card Sort, Quark Workbench, STEP UP lessons. I am hoping that a "return to normal" after the pandemic will offer a chance for teachers to open up a bit- and that students might redevelop that natural curiosity that seems to have dissipated somewhat.		
	Great opportunity to illustrate fundamental concepts of physics with particle physics data. Our QN staff member does a great job leading the workshops.	Using Python notebooks to analyze large data sets and to perform numerical modeling of phenomena. Examples: Dice, Histograms; Histograms: The Basics, QuarkNet STEP UP: Careers in Physics. QuarkNet professional development has consistently been high quality and very applicable.			

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 **University of Minnesota**

Center	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year	Subsequent Program Year
University of Minnesota	2022	2021	2022	2023	2024
	The sustained Professional Development through QuarkNet and being a part of the QN community of teachers.			Rolling with Rutherford, Quark Workbench, Pennies, etc. Excellent introductions to the topic	I no longer teach HS physics but continue to participate in QN as a lead teacher.
	Program Year (Year of Full Survey)	Subsequent Program Year	Subsequent Program Year		
	2023	2024	2025		
	Rutherford Roll? Or maybe I'm not thinking of the correct activities you're asking about. Great way to get students involved in 21st Century Science				
	(First Year) The activities seemed useful and interactive.				
	Too new (to QuarkNet) I loved the workshop it was very informative				I plan to incorporate this into the end-of-the-year wave/ modern physics material with my AP physics and IB classes. I will try to use all of the activities in my end of the year lesson plan
	This is my first workshop, still have much to explore with all the resources. Have not used it (DAP) yet since this was my first workshop. Will be implementing things this year.				
	(First year) I am looking forward to using the data analysis graphing and coding with my students related to the water quality data they collect around the Twin Cities. New (t)his said I can see how what I have learned will make an excellent impact on what I will do in my classroom next year.				

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 **University of Minnesota**

Center	Program Year (Year of Full Survey)	Subsequent Program Year
University of Minnesota	2024	2025
	Really nice to see how model instruction strategies can be utilized in the physics classroom. Have not used yet but i am excited to measure the interference pattern in a double slit experiment to calculate wavelength and to show wave-particle duality.	I am getting my first Cosmic Ray Detector. This will give me the opportunity to work with some ambitious students who want to engage in an exciting project. I am excited to measure the speed of a muon as well as implement python notebook in my class. Rolling with Rutherford. I want to use this in the beginning of class so students can learn about the nature of experimentation, measurement, data, and error analysis. Great professional development
	Neutrino workshop, because it's the only one I've done so far. New to program. Thank you for the experience!	
	Program Year (Year of Full Survey)	
	2025	
	I have only attended this one workshop in full, however I have been to other QuarkNet events/workshops in tandem with other professional development such as at Fermilab while participating in a summer RET and attending one day of a QuarkNet data camp. I definitely intend to use activities from the Data Activities Portfolio. I am new to the program however the Data Activities Portfolio is very impressive. New to the program, have not yet implemented with my students.	
	I am looking forward to participating in QuarkNet and for bringing this into my classroom.	

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.

In a supplemental document to this portfolio, examples of student and teacher work are presented including implementation plans, a presentation by a QuarkNet staff educator and an article published by a former QN student.