Race & Associates, Ltd.

2025 KSU QuarkNet Workshop – Cosmic Ray and NOvA Update
June 17-19, 2025

Proposed implementation plans created during the workshop

The following pages provide first examples of proposed implementation plans created by participating teachers.

August 2026

Implementation Plan #1
High-Energy Physics

Prep Work:

- Print and Laminate a Classroom Set of the "Particles and Interactions" Poster
- Print Classroom Set of the PP Bingo Terminology List
- Print, Cut, Laminate the Particle Deck (One set per two students)
- Print, Cut, Laminate Quark Workbench

1) Particle Physics Bingo - Flinn Scientific
    a) Immersion/Vocabulary - students are given a Bingo Card and tokens, along with an information page defining the terminology, and the standard model printout.
    b) Easy - Only the terms are used, it acquaints them with the terminology and pronunciation.
    c) Medium - Read the definition, they have to find the term
    d) Hard - No definition sheet, and the caller calls only the definition. (Students still have the standard model printout to reference)
    e) Note - PP Bingo is done over several class periods as an opening activity. You might do Easy the first day, Medium the next few days, and Hard only toward the end of the unit - it's not expected that students can move Easy to Hard in a single class period.
2) Shuffling the Particle Deck
    a) Having already had some experience with the terminology, students complete the activity on their desks (hard copy).
    b) Once their cards are arranged, they have three post-it notes that define the "rules" of their organization.
    c) Students complete a gallery walk to see other students "rules" and organization
    d) Students revisit their organization to see if other rules (maybe they thought of it, maybe they didn't) can be applied to their organization.
    e) Possible Extensions:
        i) Parking Lot the rules, see how many they can apply simultaneously.
        ii) Gamify the cards, like Pokemon, what characteristics of each particle could be used as mechanics for a game. (You could even have students propose a card game)
3) Quark Workbench
    a) Similarly to the Particle Deck, have students determine the "rules" that dictate the quarks that combine to create baryons and mesons.
4) Rolling with Rutherford
    a) Using probabilities to determine the diameter of a marble to build the foundation of particle physics experimentation methodology
5) Making Tracks
    a) To confirm to students the concept of the "unseen" but very real particles
6) Mass of US Pennies

a) This is a great foundation for building histograms, to show the relative masses of pennies - students submit a Google form, which complies a large data set and builds out the histogram with very large bin widths on the projector as they collect data.
b) We then begin to analyze the histogram, and make the bin widths smaller and smaller to show how histograms can be used to make observations/predictions about the “true mass” of the US penny

7) CRMD Introduction Slides
8) How Speedy are these Muons

Possible Coding Incorporation?

Implementation Plan #2
I found a way to introduce elementary students to the idea of particle physics through a lab. The activity I have used in the past with the 5th grade class is the Mass of the U.S. Pennies. This was a great way for the students to learn accuracy in measurement and how to make hypotheses of why the groups do not have the same mass when the number is the same. It is a great way to introduce the students to subatomic particles because all pennies may look the same, but the inside is different. So there has to be something different on the inside according to the mass. Then the students can work on histograms, that also apply to the math curriculum.

[Mass of the U.S. Pennies]

Science & Math Standards for 5th Grade

2	Science investigations use a variety of methods, tools, and techniques.
4	Scientists use tools and technologies to make accurate measurements and observations.
5-PS1-1	Develop a model to describe that matter is made of particles too small to be seen.
5.G.A.2	Represent real world and mathematical problems by graphing points in the first quadrant of the coordinate plane, and interpret coordinate values of points in the context of the situation.
6	Science theories are based on a body of evidence and many tests.
CC.K-12.MP.1	Make sense of problems and persevere in solving them.
PS1.A.3-5.1	Matter of any type can be subdivided into particles that are too small to see, but even then the matter still exists and can be detected by other means. A model shows that gases are made from matter particles that are too small to see and are moving freely around in space can explain many observations, including

	the inflation and shape of a balloon; the effects of air on larger particles or objects. (5-PS1-1)
PS1.A.3-5.3	Measurements of a variety of properties can be used to identify materials. (Boundary: At this grade level, mass and weight are not distinguished, and no attempt is made to define the unseen particles or explain the atomic-scale mechanism of evaporation and condensation.) (5-PS1-3)
SEP 1.3	Ask questions that can be investigated and predict reasonable outcomes based on patterns such as cause and effect relationships.

Implementation Plan #3

- CRMD Plans:
  - Get both detectors up and plateaued over the summer
  - Start uploading data
  - Try to recruit some students interested in independent study
    - Do a short introduction to APP 2 class using presentation created during QuarkNet https://docs.google.com/presentation/d/106AmaDmOP_-caVBI6nvVAXfo_DpWqIFXigUhwQQGK3E/edit?usp=sharing
    - Email previous students
    - Try to recruit some robotics students to be involved
- Fall Semester Week 5: General Physics Class How speedy are these muons? Activity-
  - Canvas Commons template shared
    - https://lor.instructure.com/resources/c8862fc33272448285520cc552c80fae?shared
  - Incorporates CRMD Intro Presentation created during summer Workshop
    - https://docs.google.com/presentation/d/106AmaDmOP_-caVBI6nvVAXfo_DpWqIFXigUhwQQGK3E/edit?usp=sharing
  - Demonstrate with the CRMD detector how data was collected
  - Hopefully recruit some students interested in Independent Study with CRMD
- Spring Semester March - Masterclass Prep
  - Shuffling the Particle Deck https://drive.google.com/file/d/10Alhok1fRBMXC-hV2HDtz1X8_K_S3Wjd/view?usp=sharing
  - Rolling With Rutherford
    - Adapted for sharing with students on Canvas lesson: https://docs.google.com/document/d/1zvFh3eyB8jUilwwF3BJ4kEchbEvbxDpZGjJiohiEKxY/edit?usp=sharing
- Spring Semester April - Masterclass

Implementation Plan #4
High School
QuarkNet Implementation Plan

Data Activities: Chemistry
Mass of US Pennies Fall (fall 2026 Unit 1 Mass)
Histograms “the Basics” (fall 2026, Unit 1 Data)
Cloud Chambers
Rolling with Rutherford (atomic structure Unit 10 April 2026 Chemistry)

Data Activities: Physics
How Speedy are these muons (fall 2025) kinematics
Sorting the Particle Deck (Spring 2026)
Rolling with Rutherford (Spring 2026)

Spring 2026 Master Class (in person/remote) Physics class

CRMD
Collaboration with Jack Maseberg at FHSU/KAMS on Cosmic Ray Muon Detector data collection and experimentation.
Set up a detector at TCHS in the spring of 2026.

QuarkNet Implementation Plan 25-26 School year

Implementation Plan #5

Cosmic Ray Muon Detector - Set up, collect, and upload data at Junction City High School. Recruit students to conduct research using CRMD data.

Neutrino Masterclass - Recruit students from Junction City High School to attend masterclass at KSU in the spring of 2026. Complete the following activities prior to masterclass day.

- Shuffling the particle deck
- Case of the missing neutrino
- Coding exercise
- Neutrino master class activity part 1

Additional Activities for Medical Innovations class to introduce students to electromagnetism at the beginning of the Diagnostic Medicine unit.

- Mapping the poles
- Making it around the bend

Implementation Plan #6

The QuarkNet organization has opened up a vast area of Physics to my students and myself. It has been a great opportunity for me to learn about the Physics that is done today at no cost to myself, but time and focus. If not for QuarkNet, I would not be nearly as likely to teach about Modern Physics and certainly not with the knowledge base I have gained through lectures, and field trips.

As a result of my QuarkNet experiences, I begin the school year each year in General Physics with a particle physics unit. The very first day of school, I have an introductory coding assignment to engage them with a little coding. I include some of the Data Portfolio activities such as Shuffling the Particle Deck, Rolling with Rutherford, Quark Workbench. I use a cloud chamber so students can see the tracks of some of these mysterious particles during the unit. This year, I am adding “How speedy are these muons activity, early as we begin kinematics. Also, I give a survey of work done at the national laboratories I have visited through QuarkNet. We watch several Fermilab videos throughout this unit. I also use one of the Fermilab videos during Chemistry class. The biggest accomplishment for my students has been the authentic research they have performed with data collected from cosmic ray muon detectors. The chance to investigate something real, as my students put it, in High Energy Physics is very exciting. So much so, that it has inspired many of my students to choose STEM careers, some specifically in Physics.

Before our Nova Masterclass that happens at KSU, we do the Case of the Hidden Neutrino to focus on neutrino characteristics. My use of histograms and all sorts of questioning techniques have come directly from my experiences with QuarkNet. In addition to all the opportunities available, it is also a place to network with other Physics and Chemistry teachers. We each gain support, friendships and ideas from these interactions.

Implementation for 2025-26- Implementation Plan #7

1. Classroom Activities:

In past years, students participated in the "Rolling with Rutherford" activity and completed "The Particle Adventure" by visiting the website and answering the questions. Practiced the standard model by watching a video and completing a worksheet just to get a basic understanding of the elementary particles.

Students also completed the "Shuffling the Particle Deck" activity before the masterclass and conducted the NOVA analysis in class. Later, they participated in coding analysis at K-State master class at the University. These activities were conducted in the second semester prior to the masterclass to prepare students.

- Generally, AP Physics students don't have time to participate in QuarkNet activities. At the beginning of the semester, students do an introductory lab where they plot a graph, draw a line of best fit, and find the slope. The teacher plans to replace this lab in upcoming years and is interested in using the **"How Speedy Are These Muons?"** activity. The teacher prefers using Method 3, which aligns well with the skills needed by AP students.

- In the General Physics class, students perform labs at the beginning of the semester to gain practice in data collection and graphing skills. The teacher would like to incorporate the **"How Speedy Are These Muons?"** activity during the first semester.

- In the second semester, the teacher intends to include two activities before the masterclass:

    - Rolling with Rutherford

    - Shuffling the Particle Deck

    - NoVA Far Detector Events

    - NoVA Near Detector Events

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2. Cosmic Ray Detector:

- Recruit students to participate in the CRD data analysis.

- Upload CRD data twice a month, or at least once a month.
- Based on student participation, assign different research topics to student groups.