Race & Associates, Ltd.

University of Oklahoma/ Oklahoma State University 2023-2025

Implementation Plans

Implementation plans proposed by participating teachers during workshops held during 2023, 2024 and 2025 workshops are presented. Within each workshop year, plans are numbered to protect the identity of the teachers who proposed them.

August 2026

OU Implementation 2023

Please enter the implementation plans for your group to the appropriate slide. If you need more space, add a slide!

Group 1

For Biology and ACT using histograms to graph and synthesize data.

AP Physics - use the Case of the Missing Neutrino event data as an addendum to a two-dimensional collisions lab.

AP Research - utilizing the History of Science Collection at OU to investigate the history of research in science.

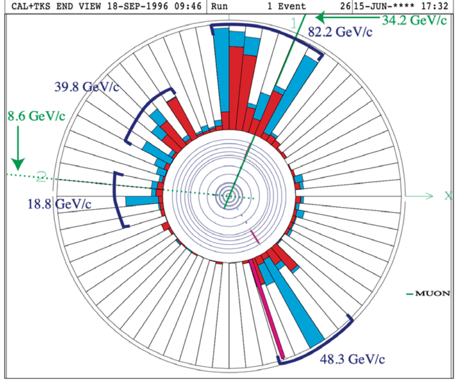
Science club - utilization of masterclass

Physical Science-exposure to scientific thinking and graphing, Dice, histograms

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



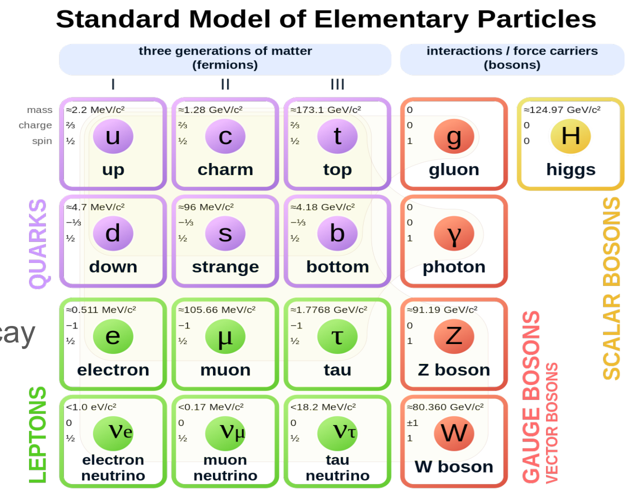
<u>What are you looking to do?</u>

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)



<u>What class?</u>

Physical Science, Chemistry, Physics

<u>What unit?</u>

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

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.

Group 5

Teacher #1 - I plan on using the muon detector to collect data and show to my astronomy students. For my Physical Science students, I will use the data collected from the detector for basic graphing of information. It was also very helpful to get the latest information on Neutrino experiments as well as updates on Dark Matter research. I learned a lot about Dark Photons this meeting.

Teacher #2 - I am going to start making use of the stuff in the quarknet data activities portfolio. The dice and histograms and probability activity will be really useful for helping physics students understand how averages work out over time.

Teacher #3 - The physics students will use a dice roller to show the distribution of data. I also liked the use Replit in place of some of the software that is available to me at my school. This was shown to me by Jessica.

Implementation Plans

QuarkNet, Oklahoma State University, July 2024

Name: Teacher #1 School: High School

Ideas Particle Physics Unit (Goal 2 weeks):

-Quark Puzzle Workbench→Particle Deck (Standard Model)

-New Part*Special Relativity*****

Postulates of Special Relativity, Derivation of Time Dilation, Derivation of Length Contraction, Basic Problems Practice Carefully Setting Up Reference Frames and Choosing Proper Time and Proper Length, Twin Problem and Ladder Going Through Barn Problem with Space-time diagram summarizing, Mean Lifetime Part 1(Dice) and Mean Lifetime Part 2 (Half-Life and Meaning of Lifetime) Muon Detection Video with video calculating time dilation and length contraction, and Post Additional Optional Videos About Special Relativity, Want to mention curvature of spacetime and general relativity, but time may prevent. I want to at least mention experiment where time between pulses increased from ground floor to top of tall building.

-Particle Adventure Website→Rutherford Experiment →Mass of Z Boson (applying conservation of energy and momentum)-->Mass of Top Quark (inferring neutrino)

When and where in school year:

2nd Semester:

…→Impulse→Conservation of Momentum in 1 and 2 Dimensions→Particle Physics→Conservation of Energy→Conservation of Energy and Momentum Together→…

Want to have students attend physics journal club and masterclass.

Name: Teacher #2

School: HS

Ideas:

Particle Cards (Deck)

PH.PS1.8

Dice Lifetime - Data Analysis

PH.PS1.8

Z-Mass - Conservation of Momentum

PH.PS.3.1

When and where in school year:

Unit 2: Energy and Thermodynamics

October 23rd to Dec 01

Name: Teacher #3

School:HS

Ideas:

- Rolling with Rutherford
- Shuffle the Particle Deck
- Histograms (basics)
- Signal vs. Noise
- Mean Lifetime I: Dice
- Linearization of Data

When and where in school year:

- ❑ Chemistry–atomic structure
- ❑ Advanced PS-atomic structure
- ❑ Physical Science-graphing, NOS
- ❑ Advanced PS–NOS
- ❑ Chemistry–NOS and/or nuclear
- ❑ APS or Chemistry–NOS

Name: Teacher #4 School: **HS**

Ideas:

#1: I like using the Z-mass calculation activity to sneak some particle physics into vector addition work.

#2: The linearization help sheet/activity is awesome and I will use it .

#3:Journal Club- OSU

#4: Atlas Master Class

When and where in school year:

#1: I would start this in 2-d motion in my AP physics class and Honors Physics class, around mid September.

#2: During week 0, when I am practicing math skills for AP Physics.

#3: Will hang up flyer in classroom

#4: try to bring kids to the Atlas master class

Name: Teacher #5

School: High School

Ideas:

Using the Mean Lifetime Part 1 dice activity

- **Visualization**

Radioactive Decay of Muons activity

- **Conservation of mass**

Calculate Z mass

- **Protractor use**
- **Discuss various results**

When and where in school year:

Chemistry:

- **Nuclear unit**
- **Stoichiometry unit**
- **Law of Conservation of Mass and of Energy ideas throughout the year**

Teacer #6 High School

Cosmic rays:

- Introduce particle concepts in workgroups using:
  - Particle Cards?
  - Dice (particle lifetime)
- Muon speed as it relates to relativity (c as “the speed limit of the universe”)

  Have students Plot energy levels of particle acceleration data Relativity vs. Newton

Neutrinos *(Last year’s Quarknet)*

- Star life cycle (neutrinos)

Balloon Lab

Additional Items:

- Tuesdays or Thursdays - “More with Mr. B” & P&A Journal Club
- **Cosmic Ray Detector!**
- **Master class?**

When and where in school year:

Astronomy I (first semester)

Unit 2 (How the universe works)

Standard model

Unit 3 (Gravity, Relativity, Spacetime)

Cosmic rays

Unit 4 (Stars & Galaxies)

Star life cycle (neutrinos)

Teacher #7

High School

Ideas: Introduction - 1 week.

Introducing the Standard Model to the students and the different types of fundamental particles and force carriers.

Explain cosmic rays and the types of radiation/particles that interacts with us on earth.

Use of vector addition to determine the mass of Z bosons using the 2-D (transverse plane) of muon events

Mean lifetime/half-life Dice game to gain an appreciation of exponential decay.

Continue to Update students in regards to

Promote Journal Club/Questions for the Physics Journal Club to my students to encourage participation..

When discussing gravity, introduce what gravity waves are, what causes them, and how they are detected.

The balloon lab and measuring distance on curved surfaces vs. planar surfaces.

When and where in school year:

In Chemistry/Physical Science after presentation of the structure of the atom and discussion of radioactive decay.

Chemistry - would be in the first semester.

Physical Science - sometime in the second semester after learning the general structure of the atom/nuclear forces.

Physical Science - vector addition practice to determine the mass of the Z boson.

Name: Teacher #8 School: Preparatory School

Ideas: Energy, momentum, and mass activity as a linearization activity

Have students derive a relationship between energy and momentum using their knowledge of classical physics and compare their models to the experimental results.

Students can then explore the “corrections” that have to be made to classical mechanics for fast moving object. Students can review a selection of videos on the implications of relativity on classical mechanics.

I will also encourage students to attend journal club activities

When and where in school year:

AP Physics C - at the end of first semester after studying energy and momentum from a classical perspective.

This would be a skill review/extension activity before semester exams

Name : Teacher #9 *(AP Chem)* **School :** HS

Dice activity (Chemical Kinetics)

This activity would be easy to modify slightly and approach it from the perspective of chemical reactions. The reaction would be a 1st order reaction. The amount of numbers on the dice corresponding to a successful reaction would be related to collision theory and the kinetic molecular model. Repeat with different “rates” by getting more sides of the dice resulting in successful reaction.

When and where in school year:

This lesson would be part of Unit 5: Chemical Kinetics. This unit is typically the first unit completed at the beginning of the spring semester .

Implementation Plans

Wednesday 10 July 2025

Teacher(s): Teacher #1

Class: Physical Science (Chemistry Fall 2025, *Physics Spring 2026***)**

When to present: Unit 1.1 The Periodic Table and Properties of the Elements

CH.PS1.1, CH.PS1.8

Description:

Half life of radioactive isotopes

Modified Mean Lifetime of Dice

- How does the lifetime of D6 compare to D8, D10, D12, D20?

What is the “Half-life” of 100D6 vs 100D20?

- What does the difference in half life tell us?

What does it mean that some isotopes have longer half lives than others?

Teacher(s): Teache #1 (con’t.)

Class: Physical Science (Chemistry Fall 2025, *Physics Spring 2026***)**

When to present: Unit 1.1 The Periodic Table and Properties of the Elements

Description:

Research Applications - Muons

- Data Analysis E-Lab

What is the mean lifetime of muons?

- Do all muons only live ≈ 2.2 microseconds?
- Do all dice roll 1s at 5 rolls?

Quantum Chaos!

Teacher #2

Astronomy Class:

- 2025 First Semester, in-class, as part of the unit on the sun
    - I will use the muon detector that I have on loan

Astronomy Club & Tuesday “extra” (Extracurricular):

- Provide a designated area in my classroom where the detector will reside
- Have several activities all year long:
    - Basic Standard Model overview
    - Mean Lifetime - Dice
    - Mean Lifetime - Muon detector
    - Shuffling Particle Deck

Two Teachers #3 and #4

Class: Chemistry

When to present: Fall Sem, early October, during the radioactivity unit

Description: Using the Mean Lifetime Part 1 Dice. We have used a different variation in the past using coins, but the students did 100 coins in each group and collected their own data. However, with the entire class coming up with data together, it went faster. Our class periods are decreasing in length next year and this will work better. This will also give more accurate data for the students to present on their graphs. This relatively simple data will also allow the students to learn to use graphing in a graphing program (Excel, Sheets, etc…). We may also use the coins and the dice to compare the difference when you have less or more sides.

Teacher(s)#5

Class: Physics

When to present: Beginning of the year

Description: Careers in Physics at beginning of year. Study particle physics, half-life study with dice. Also figure out a way to introduce muon detectors without access to a muon detector.

Class: Chemistry

When to present: Beginning of year or study of atom development. (Add Muons to timeline) Periodic table review of the elements with half-life of radioactive elements.

Description: Particles in an atom, introduce the primary particles, expand the students knowledge level of the particles that make up the atom.

Teacher #6

Class: Physical Science/Chemistry

When to present: Towards the end of the year for both chemistry and 2nd quarter for physical science

Description:

Standards: PS.PS1.8 , PS.PS1.7, CH.PS 1.7, CH.PS1.6

Model ionization in gases, relate to nuclear reactions,half-life, Indirect observation of things we can’t see, discussions about the nature of evidence in science, Mini cosmic rays lesson.

Teacher: #7

Class: Earth Science

When to present: I would like to do the mean lifetime dice activity for me students when we talk about radiometric dating.

Description: Since I teach virtually I won’t be able to give each group of students some dice, but I was thinking that I would roll like 100 D6 dice on a document camera and have the students use the die results to generate a data table. This is a good activity to get them to understand that while we don’t know when a single atom might decay, the decay does happen at a steady rate just like how we don’t have a way of knowing which dice might roll a 1 at any given time.

Teacher #7 (con't.)

Class: Astronomy

When to present: In Unit 4 when we cover the Sun. However, I also plan to run the experiment throughout the year.

Description: We'll use the Muon Detector to talk about cosmic rays coming from the Sun. We'll use this as an anchor phenomenon throughout the unit and the rest of the semester.

Teacher #8

Class: AP Physics, Digital Electronic, SWENext club

When to present: right before big breaks,may embed a few activities that overlap with course learning objectives, May after AP test

Description: STEP Up Careers with physics students (activity 1), and also with SWENext (activity 2) Data Activities Portfolio(TOTEM1 etc)

Dice activity, e labs on Quarknet website (Lifetime Study)

If resources allow, masterclass at OSU with interested students

Teacher #9

Class: Physical Science/Chemistry

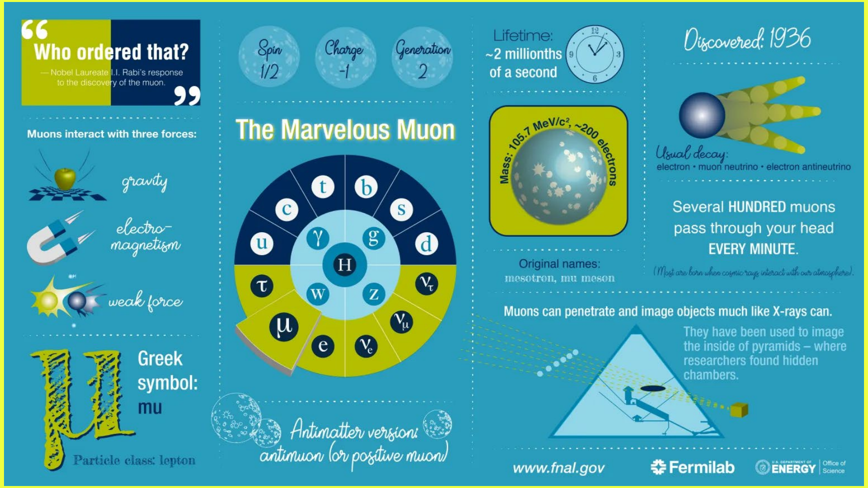
When to present: Towards the end of the semester when we are covering half-life of radioactive elements, radioactive decay, and lifetimes of radioactive elements

Description: Radioactive decay involves introducing the students to beta decay via the electron and positron. Thisa great time to describe the standard model and introduce the additional fundamental units that make up matter. Could incorporate the dice project to illustrate how decay occurs naturally as a function of time and use different-sided die to illustrate how there may be different rates of decay for different elements/particles.

Teacher #10

Class: Physics (or Science Club as a year-long exploration)

- When to present: early in semester to coincide with graphing skills
- Description: Mean lifetime part 1: Dice
    - When to present: prior to Master Class
    - Description: Mean lifetime part 2: Cosmic Muons
        - When to present: after Master class
        - Description: Cosmic Ray e-lab (analysis)



Teacher #11

Class: Honors Physics (i.e. "Pre-AP")

When to present: Dice activities in August to understand data, randomness, noise. Quarks and energy in January, when returning from Xmas break. (I end the fall semester with work and conservation of mechanical energy).

Description: Where does energy come from? $E=mc^2$; Big Bang is source of all energy; quarks and leptons; quark structure of proton and neutron; strong, weak, EM force; α, β, γ decay explained via quarks and weak force; energy release via decay, fusion, fission

OK Standards: **PH-PS1-8 Matter and Its Interactions -** Develop models to illustrate the changes in the composition in the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

PH-PS3-2 Energy - Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as either motions of particles or energy stored in fields.

Teacher #12

Class: AP Research

When to present: During the first month of classes when we are learning about the appropriate use and evaluation of primary sources.

Description: Machine Learning - I would like to integrate the information learned from Mr. Waits presentation into my current lesson on appropriate and inappropriate uses of generative AI. Examples of new information that I might use: AI easily inherits biases from training data and is rarely conservative in predictions. It is limited in its ability to recognize outlying data and can overfit on the data given to it, which might limit its ability to make predictions based on new data.

Teacher #13 - Marine Biology September 2025

1. Dice Activity - Introduction to Halflife
2. Introduce the concept of how Cosmic Rays modify elements creating isotopes.
   a. Radioisotope Production and Deposition into the Oceans.
   b. Influence on Ocean Chemistry and Evolution.

3. Introduce the concept of how Cosmic Rays trigger lightning.
   a. Effects of lightning on the Environment - Climate Change via Polution and Atmospheric cleansing
4. How Cosmic Rays can cause Mutation on lifeforms
   a. Mutations can be beneficial or harmful to life.
   b. How these mutations can trigger extinctions in biota
5. Run Cosmic Ray Detector to show how we collect the Data.
   a. Look at studies, what the data means.
   b. Create and run an experiment. Explain the results

Teacher #14 - Chemistry and Physics

When to present:

- CH.PS1.8 Develop models to illustrate the changes in composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.
- PH.PS1.8 Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay

Description:

Half life of radioactive isotopes

Modified Mean Lifetime of Dice

Elementary introduction to Quarks et al.

Teacher #15 – HS Chemistry

Mass of US Pennies - Unit Zero

DCI: **Structure and Properties of Matter**

- Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it.

I am planning to use this as an intro to chemistry (review of matter) as well as intro to using classroom technology for students to submit their assignments and check their own grades.

Teacher #16 Honors Chemistry

Class: Honors Chemistry (i.e. “Pre-AP”)

When to present: January after students return from Xmas break, at beginning of atomic structure unit

Description: $E=mc^2$; intro to quarks and leptons; quark structure of proton and neutron; strong, weak, EM force; α, β, γ decay explained via quarks and weak force; segue into wave/particle duality, probability & uncertainty, structure of the atom and electric charge

OK Standards: ***CH-PS1-8 Matter and Its Interactions* -** Develop models to illustrate the changes in the composition in the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay
***CH-PS4-3 Waves and Their Applications in Technologies for Information Transfer* -** Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model may be more useful than the other.