Review of QuarkNet Activities
May 2017

<u>Criteria Used at Instructional Design Stage – Annotated</u>

In line with the NGSS Framework

1 – Includes a question to address and/or problem to solve; could be developing a model to explain a phenomenon or test a model
2 – Students gather data and/or test solutions; provide claims, evidence and reasoning.
3 – Students use science and engineering practices (p. 3)*.
3 – Address crosscutting concept(s) and core idea((p. 3)*.

**A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas*, National Research Council, 2012.

Macro Design

1 – A 'big idea' (core idea) is addressed; sub-ideas support the big idea (can be concepts and/or principles).

Often, this is the same as or similar to the enduring understanding. A core idea can be as basic as "calibration," a classic physics concept such as "momentum," or a principle (law) such as $E = MC^2$. Research indicates that students come away from a well-structured lesson/activity with an understanding that they maintain even through life (it "endures"). Over time they lose the details, but not the enduring understanding.

2 – Students apply science process skills and/or design technology.

There are a variety of skills that students learn in *doing* science. These include all the ways student use data as well as thinking/reasoning skills such as compare/contrast, infer/predict. Design technology means the process of design-develop-test-redesign-redevelop-retest . . . i.e., engineering.

3 – Format is guided inquiry.

Over the years, QuarkNetters have developed the understanding that in doing particle physics, students, and even teachers, can learn best facilitated by guided, not open, inquiry. While leading/facilitating is important, such as asking clarifying questions, learning particle physics depends on difficult concepts, principles and procedures that need more guidance than some other science fields.

4 – Is compatible with the conceptual framework (follows one level of the framework—if a second level is an 'enrichment' or follow-on section of the activity).

The conceptual framework is embodied in the Data Portfolio. The DP organizes activities by data strand and level of student engagement. Activities differ in complexity and sophistication—tasks in Level 1 are simpler than those in Levels 2 and 3. While each level can be explored individually, students who start in one level and progress to more complex levels experience increasingly challenging tasks. Teachers select activities to offer a learning experience of an appropriate length and level for their students.

Level Definitions

Level 0 – The student builds background skill and knowledge needed to do a Level 1 activity. Students analyze one variable; they determine patterns, organize into a table or graphical representation and perform simple calculations. <u>Example</u> in statistics—Number of times a rolled die returns a particular number

Level 1 – Students analyze two variables; they calculate descriptive statistics, seek patterns, identify outliers, confounding variables and perform calculations to reach findings; they may also create graphical representations of the data. Data set used are small in size ~1 – 10 events. Example in oceanography – temperature measure at various ocean depths – determine thermocline

Level 2 – Students analyze two or more variables; they calculate descriptive statistics, seek patterns, identify outliers, confounding variables and perform calculations to reach findings; they may also create graphical representations of the data. Data sets used are medium in size ~100 events. Example in climate change – CO_2 data correlated with ice core data over time

Level 3 – Students analyze two or more variables through guided inquiry; correlations; they transform provided data into usable form; they calibrate or determine useful data. Data sets used are large in size ~1000 events or more. Example in biology: determine the "carrying capacity" of a population given density and density-independent factors.

Level 4 - This is TBD, but may involve students writing or modifying code.

Micro Design

1 - There are behavioral objectives.

The objectives start with a verb (what you want students to know and be able to do) and/or the action (behavior) is implicit in the objective. The objectives should ALL be measurable since they will drive what is in the assessment. (Did students learn what you wanted them to know? Did they exhibit the skill you wanted them to learn?)

2 – There are connections to the real world such as actual scientific exploration (modern physics), skills that scientists use, and promoting scientific literacy.

Since one of the QuarkNet goals is for students to become more scientifically literate, it is important that the activities help them better understand what doing science actually is as practiced by scientists. This may include something like this is what they do at CERN or this is how scientists do . . . such as make sure their data are useable/reliable/accurate.

3 – Students analyze data to come up with a hypothesis/solution/explanation; they are asked to apply reasoning including critiquing their ideas (e.g., identify flaws in their argument).

A main focus of the NGSS, as well as common core, is for students to be able to make a claim and follow it up with evidence. Often, the final "reasoning" part is missing; i.e., they can describe the evidence, but can they back it up with *why* and evaluate the extent to which their data is "good" evidence?

4 – Evaluation/assessment is based on whether or not the objectives are achieved; questions asked directly refer to the objectives. (There are no distractions such as extraneous ideas.)

Several of the activities will have a student report sheet. This could be the summative assessment if the objectives are aligned with the report sheet—which most currently "published" activities are. Learning a skill, such as developing a histogram, can be more of a formative assessment that may or may not become part of the report sheet but is nonetheless assessed, maybe just through checking student work informally. If there is more that can be added to the activity, there might be an enrichment section. By adding extra ideas at the assessment stage confuses what you want them to know and be able to do (distractions and extraneous ideas).

TITLE
TEACHER NOTES

DESCRIPTION

Briefly provide an overview and purpose of the activity. *For example:* From where do cosmic rays come? Can they be from the sun? Or are they from elsewhere but blocked by the sun? Students search for a specific data file in the Cosmic Ray e-Lab and look for evidence of the passage of the sun in the flux measurements derived from this file. Many people new to studying cosmic rays initially *think* that cosmic rays originate in our sun. This activity allows students to investigate this idea and study evidence that can confirm or refute their original understanding. An e-Lab user collected data with the detector in a configuration that allowed the detector's axis to sweep across the sun at local solar noon including data before and after the sun's transit. Data collected at the beginning and end of the sweep provide the "control" or no effect from the sun, while solar noon provides data on effect of the sun.

STANDARDS ADDRESSED (FILL IN AS APPROPRIATE. THIS LIST SHOWS FORMAT.)

Next Generation Science Standards

Science and Engineering Practices

4. Analyzing and interpreting data
5. Using mathematics and analytical thinking

Crosscutting Concepts

1. Observed patterns

Common Core Literacy Standards

Reading

9-12.4 Determine the meaning of symbols, key terms . . .

9-12.7 Translate quantitative or technical information . . .

Common Core Mathematics Standards

MP2. Reason abstractly and quantitatively.

ENDURING UNDERSTANDINGS

- One EU per activity

Enduring understandings with regard to data include:

- Data are collected using careful measurement and/or observation; instruments are calibrated to ensure accuracy. (Instrument calibration can also include observation such as several people observing a phenomenon.)
- Data are organized in charts, tables, and/or graphs for data analysis that often includes recognition of patterns in the data.
- Claims are made based on data collected, which comprises the evidence for the claim; relation to a scientific principle is often included.
- Reasoning is provided when presenting the claim based on evidence that may include caveats, flaws, and possible alternative explanations based on the data; further research may be indicated for clarification, particularly in relation to the associated scientific principle.

See other activities for examples of content-related enduring understandings, such as:

- Well-understood particle masses provide data to calibrate detectors.
- Indirect evidence provides data to study particles too small and fleeting to see.

LEARNING OBJECTIVES (BEGIN WITH VERB THAT CAN BE MEASURED.)

As a result of this activity, students will know and be able to:

- xxx

BACKGROUND MATERIAL

This is content information for the teacher, often including links for where to get more information.

PRIOR KNOWLEDGE

What students should probably know before they engage in this activity

RESOURCES/MATERIALS

IMPLEMENTATION

Guidelines for the teachers, activity sequence; basically, write-up of the activity - procedure

ASSESSMENT

Formative assessment such as discussions, questions to ask students to increase conceptual understanding. Summative assessment such as tests, quizzes, oral and/or written report (including the activity report that focuses on claims, evidence and reasoning). Note: Any assessment should address the learning objectives. (Assess what you want them to know and be able to do.) Just indicating that students will write a report is insufficient. If a report is the best option, include some idea of what the report would be about. For example, an assessment about cosmic rays (as in the sample description) might be: This activity is suitable for assessment via a formal or informal lab report. What would you tell people who believe that cosmic rays originate from our sun? What evidence and reasoning would you provide to support your claim?

NOTE: WE PROVIDE TWO TEMPLATES FOR STUDENT PAGES.

GUIDELINES FOR WHICH TEMPLATE TO USE:

- For a level two or three activity, use a student report sheet and template two.
- For complex activities that require students to make a claim and provide evidence and reasoning, use a student report sheet and template two.
- An activity that addresses a claim based on observed data, such as "Solar Cosmics," does not need a student report sheet because it is not complex. Contrast this with the "Data Express" activities. Could be template one or two.
- For an activity that focuses on learning a skill and/or exploring a model, a report page may be the only thing necessary, e.g., "Quark Workbench"; students make "rules" and have to back them up with reasoning, but not in the context of a scientific investigation. The activity, "Dice, Histograms and Probability," explores histograms so does not need a student report sheet: template one.

Clearly these guidelines are not hard and fast rules. Authors will have to decide for themselves which template to use. Luckily there are several people in the review process who can act as consultants. NOTE: Some activities do not even need a student page. (See, e.g., Dice, Histograms & Probability.)

TITLE

STUDENT GUIDE

Template One:

Question(s), problem to solve, model to create and/or explore; overall purpose

Steps/guidelines; supporting content, materials, resources (including websites)

Claims, Evidence, Conclusions
For example, when the students have finished the activity, project on the screen the Elementary Particles chart again. Discuss the fact that they have investigated a small part of the Standard Model—one that describes formation of baryons and mesons. There is more to learn about the Standard Model— both for the students and for physicists.

- What rules did you discover that determine the composition of baryons? Mesons? What is the evidence for the rules? (Hint: Describe quark properties.)
- What role did quarks play in forming the mesons and baryons?
- In addition to quarks, what other particles are "fundamental"?
- What do physicists call the current theoretical framework for our understanding of matter?

The learning objectives were: As a result of this activity, students will know and be able to:

- Identify the fundamental particles in the Standard Model chart.
- Describe properties of quarks, including color, spin, and charge.
- Describe the role of quarks in forming particles that are part of the Standard Model.
- State the rules for combining quarks to make mesons and baryons.

Template Two:

Question(s), problem to solve; overall purpose of doing the activity - INTRODUCTION

Objectives: Could be as simple as what is their task; does not have to be the learning objectives, but could be.

Student pages currently include (after a brief overview of the activity):

- What do we know?
- What tools do we need for our analysis?
- What do we do?
- What are our claims? What is our evidence?

Assessment is a student report.

Title
Student Report

Research question:
____

Reason: ____

Physics principles:
____

Hypothesis and reasoning:
____
____
____

Claim:

Evaluate the accuracy of your hypothesis as an answer to the research question.

Evidence:

2-3 pieces of evidence (data, observations, calculations) that support the claim

Questions to consider: How did we test the hypothesis? What data supports the claim?

Reasoning:

Justify how and why the evidence backs up the claim. Use scientific principles to explain ***why*** you got this data. Use and explain relevant scientific terms.

Questions to consider: Why does the data compel this claim? Is anything left out?

Sources of Uncertainty in Measurement:

Question to consider: Why and to what extent can we trust your results?

How much do results vary in calculation of the Z mass? Why? Are their outliers? Why?

Practical Applications:

Questions to consider: How might this information be useful to the ATLAS and/or CMS collaborations? To the future runs of the LHC?

What is the value of what you learned?

Now, write your formal scientific conclusion statement. Combine your ideas from the previous pages into two or three well-constructed paragraphs that include the research question, your hypothesis, your evaluation of the hypothesis (claim, evidence and reasoning), possible sources of uncertainty (specific to your data) and practical applications for your discovery. Spelling and grammar do count; be thorough and persuasive!