Identifying Cognitively Demanding Science Tasks that Provide Opportunities for Students to Engage in Three-Dimensional Learning

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This is a critical moment for teaching and learning in science classrooms. The release of the Framework for K-12 Science Education (NRC, 2012) has established an overarching vision for science teaching and learning, which then guided the development of the Next Generation Science Standards (NGSS; NGSS Lead States, 2013). The new vision aims to move science teaching away from a focus on many discrete facts to a focus on disciplinary core ideas that can be explored in depth to explain phenomena (Krajcik et al., 2014). This focus on students' making sense of phenomena is argued to be the largest shift within NGSS (Duncan & Cavera, 2015).

Making sense of phenomena to develop a deeper understanding involves three dimensions of the new standards working closely together—crosscutting concepts, disciplinary core ideas, and science and engineering practices (NRC, 2012; Krajcik, 2015a). When asked what they are learning, students should say that they are figuring out how a phenomenon works, such as how water moves into and out of cell (Ambitious Science Teaching, 2014), rather than say that they are learning about a topic like osmosis (Krajcik, 2015a). As they try to explain a phenomenon, students should be designing investigations, asking questions, sharing ideas, building on each other's ideas, developing models, and arguing from evidence; all of these steps will demand new kinds and higher-levels of student thinking than what is currently observed in most science classrooms.

For students to engage in three-dimensional science learning, they must be given worthwhile science tasks in the classroom, ones that involve rigorous intellectual work (Doyle, 1983). But finding such tasks can be a challenge, with many tasks systematically missing critical elements, leading to memorization rather than sensemaking. For example, does having students solve a set of problems about speed provide opportunity for three-dimensional learning and place high levels of cognitive demand on students' thinking? Is researching the effects of air pollution on human health rigorous enough for facilitating students' developing a deeper understanding of air pollution and engaging them in three-dimensional learning? These are just a few examples of the kinds of questions that science teachers may encounter while planning lessons.

What are Instructional "Tasks"?

We define instructional tasks as the classroom-based activities assigned to students that focus their attention on particular science content (*i.e., core and crosscutting concepts*) and/or *scientific practices* (Tekkumru-Kisa, Stein, & Schunn, 2015). A science task (whether part of a lesson or spanning multiple lessons) can be a mini project, a science activity, a lab, a related set of problems or a question to explore—any work that students are given to focus their attention on particular science content and/or practices. Tasks may include formative assessment activities because the distinction between instructional tasks and assessment tasks may be blurred particularly when the assessment is designed to be formative (NRC, 2014).

Tasks are usually situated within larger, multiple-week instructional units focusing on a related set of important science ideas (Ambitious Science Teaching, 2014). Various instructional models such as the 5E instructional model (Bybee, 2015), model-based inquiry (Windschitl, Thomson, & Braaten, 2008), and project-based science units (Krajcik, 2015b) have been productively used for design work at the instructional-unit level. But these models are generally vague about the particular tasks students are assigned. The work of design is not complete, however, without careful thinking about the tasks within the unit. It is the instructional tasks that students are given to work on day-in and day-out that most strongly shape what students come to understand about science (Doyle, 1983). For example, at the "Explore" stage of a 5E instructional unit, a wide variety of tasks could help students to think about different aspects of the topic that they are exploring. Similarly, in a model-based instructional unit focusing on energy storage during phase changes, students can engage in various simple or elaborate model-building tasks such as trying to understand the origins of the water outside of a cold Starbuck's cup (see "Tools for Ambitious Science Teaching"). All in all, while conceptually coherent instructional units (designed around any instructional model) provide important frames for students' experiences as "figuring out a phenomenon," the embedded tasks will maintain students' attention on *figuring out* these phenomena only if they are carefully designed to engage students in cognitively demanding intellectual work. For example, the Starbucks cup task mentioned above can be productively placed in a model-based inquiry unit on the energy story behind phase changes (see "Tools for Ambitious Science Teaching").

Tasks Vary Based on How They Position Students to Learn Science

Instructional tasks form the basis of *students' opportunities to learn* (Doyle, 1983; Hiebert & Grouws, 2007; Stein, Grover, & Henningsen, 1996) by fundamentally shaping student thinking. Studying a task provides a window into *what* science ideas and science practices students are expected to learn. A closer examination will also reveal *how* students are being asked to learn (Blumenfeld et al., 1991; Doyle, 1983): by memorizing?, by following a set of scripted procedures for achieving the right answer?, or by making sense of and developing explanations of the big ideas? Although some memorization is important, students who only memorize (or follow given steps without needing to think about what they are doing and why) will not come to appreciate the real nature of science or learn how to use science knowledge and science practices when needed. For example, common tasks assigned during science labs (e.g., observing seeds sprouting in light and dark conditions) may often lead students to engage in scientific inquiry superficially. While such activities emphasize accurate measument, careful control of variables, and data analysis, they can miss what is integral to science—building knowledge—because students do not need think about knowledge to complete the activities. Such common tasks also limit student thinking about the *how* of science: They make students believe that there is one way to conduct any experiment and that one way will always arrive at the correct answer by carefully following a prescribed set of steps. As such, these common lab tasks do not require students to engage in the kind of thinking required for understanding how scientific knowledge develops, with content understanding fundamentally overshadowing consideration of appropriate science practices (Duncan & Cavera, 2015).

The TAGS: A Tool for Differentiating Between Science Tasks

What are the features of science tasks that are cognitively demanding and can meaningfully engage students in three-dimensional learning? Our recent work with science teachers has shown us that recognizing the kind and level of thinking demanded of students in science tasks can be challenging. Sometimes surface features of tasks can mislead one into thinking that the kind and level of thinking required is NGSS-aligned (e.g., the misconception that connections to daily life events can always position students for three-dimensional learning). Tools have been shown to be an effective way of communicating a standard or developing a shared understanding across communities of educators (Smith, 2014), as well as a powerful means for changing classroom practice (National Academy of Education, 1999). Here, we describe such a tool: Task Analysis Guide in Science (TAGS; Tekkumru-Kisa et al., 2015).

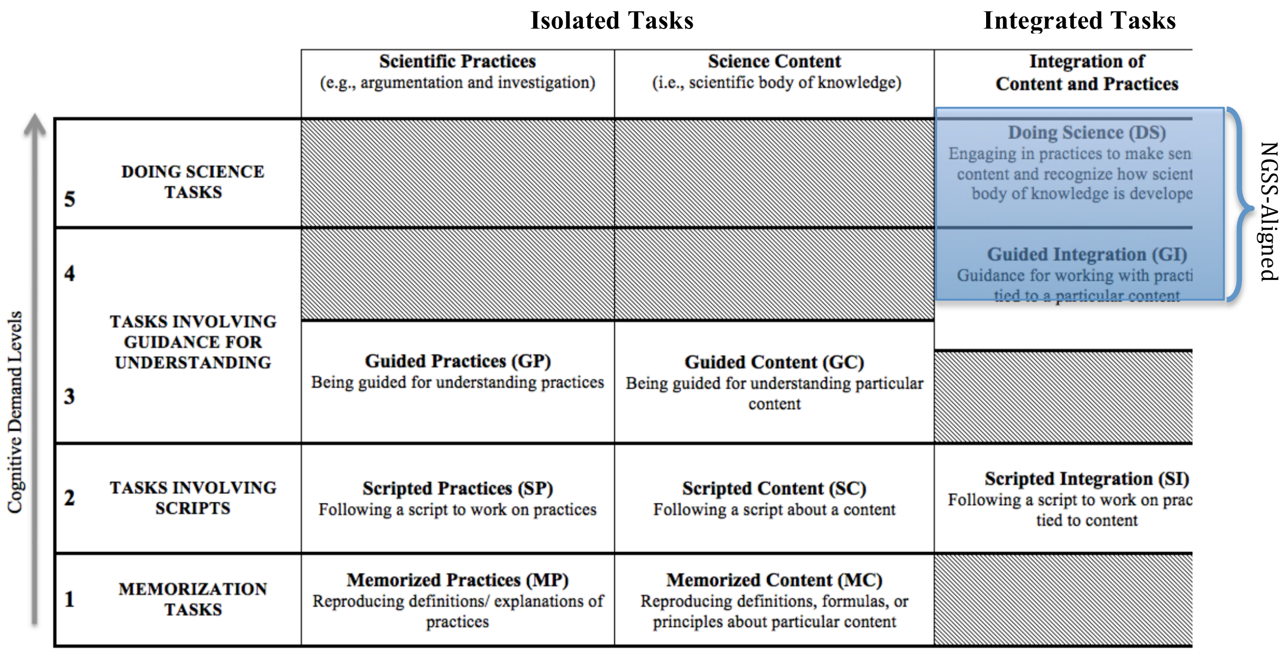

Figure 1. The Task Analysis Guide in Science (Tekkumru-Kisa et al., 2015)

As shown in Figure 1 (and detailed in Appendix A), the columns identify whether or not science content (i.e., core and crosscutting concepts) and scientific practices are integrated or isolated within a task, in other words, whether or not the task has the potential to expose students to *both* scientific practices and science content (which encompasses discipline-specific core ideas and cross-cutting concepts across disciplines). The focus is on the scientific practices to engage students in sensible versions of the actual intellectual work that scientists engage in (Bell et al., 2012). Our conversations with pre-and in-service teachers have made us aware of how difficult it can be to identify the kind of tasks that will engage students in the actual work of scientists. For example, if a task asks students to "explain the phases of mitosis," does this mean that the task requires students to engage in the scientific practice of constructing scientific explanations? As awareness of the Framework for K-12 Science Education and NGSS spreads to larger numbers of classrooms, the number of teachers struggling with similar questions is sure to increase.

In integrated tasks in the TAGS, science content and scientific practices are interwoven, such as an investigation with soda cans aimed at constructing an explanation for why a tanker implodes (see Windschitl and colleagues, 2014). Such tasks require students to develop an understanding of disciplinary core ideas (e.g., gas law, pressure) and think about the cross cutting concepts (e.g., cause and effect) within the context of scientific practices (e.g., developing and using models, constructing explanations) while explaining a phenomenon, as emphasized in the NGSS. On the other hand, isolated tasks (tasks in the first column and the second column) focus students' attention exclusively on science content such as forces and motion or exclusively on terms, meanings or the procedures of various scientific practices such as argumentation or modeling.

The rows of the TAGS indicate the levels of cognitive demand, which is defined as the level of thinking required of students to complete a particular task (Stein et al., 2009). There are five cognitive demand levels, each represented by a row in the matrix, ranging from (1) *memorizing* previously provided terms, definitions, and/or formulas to (2) *following scripts* or well-defined procedures to produce the correct answer, to (3+4) making meaningful choices with some guidance embedded in the (isolated or integrated) task, and finally to (5) *doing science*, which requires engaging in scientific practices to explain a phenomenon in unguided ways.

High cognitive demand tasks provide substantive opportunities for student thinking; they require students to make sense of scientific ideas and/or how to do science, which is a key goal of the NGSS (Huff, 2016). By contrast, low-level tasks provide minimal opportunities for students' thinking by either requiring that they reproduce previously known information or follow scripted procedures that guarantee arriving at the correct answer (see Figure 2 for examples). The tasks at level 4 (i.e., Guided Integration) and level 5 (i.e., Doing Science) in the TAGS under the "integration" column (see Figure 1) can be categorized as NGSS-aligned in that they position students to engage in three-dimensional learning.

Obviously, not every task used in science classrooms needs to be high-level. We would expect productive instances of low-level tasks, alongside high-level ones. It's important to match the goals for students' learning with the tasks that are assigned to students (Tekkumru-Kisa et al., 2015). However, because a dominance of low-level tasks contributes to students' limited understanding, a remedy that is often suggested is the use of more high-level tasks (Blumenfeld, 1999). Moreover, while repetitions and memorization strengthen an initially fragile hold on new skills and knowledge, pure memorization without understanding is less effective for long-term, generative understanding of an idea or concept (Anderson & Schunn, 2000; Tekkumru-Kisa et al., 2015).

Beginning a lesson with a high-level task is essential because students often do not engage in high-level reasoning in classrooms in which low-level tasks are implemented (Kang, Windschitl, Stroupe, &Thompson, 2016; Tekkumru-Kisa et al., 2017). In fact, selecting appropriate tasks "sets the stage" for productive classroom discussions. Commonly recommended methods for a teacher to orchestrate productive discussions in science classrooms (e.g., anticipating student thinking, monitoring student work, selecting student work for discussion, sequencing presentations, connecting strategies and ideas) work best when the teacher has assigned a cognitively demanding task to his/her students (Smith & Stein, 2011) because tasks shape the opportunities that can occur in classroom discourse and interactions. For example, while students are engaging in a procedural activity, monitoring student thinking would be difficult since such tasks would not elicit student thinking, so there would be no student thinking to monitor.

Using the TAGS to Facilitate Teacher Discussion during Professional Development

While the TAGS could be used by teachers working alone during the lesson planning process, it can also serve as a guiding framework for teachers working together to plan or reflect on instruction in professional learning communities. To date, the TAGS has been used in a range of settings with pre-service and in-service teachers, such as professional development programs (e.g., Tekkumru-Kisa & Stein, 2015), workshops and teacher education courses. One of the ways in which the TAGS has been used in professional development settings is to ask teachers to analyze a set of science tasks. Informed by the research-practice work in mathematics education we designed a *task sort activity* (e.g., Arbaugh & Brown, 2006) in which teachers are first asked to sort tasks according to whether the task would place high- or low-level demands on student thinking. This reveals how teachers typically categorize tasks, that is, without being introduced to the TAGS. Then the teachers are asked to re-sort those same tasks using the TAGS and discuss how the framework provides a different lens. In our experience, this activity generates productive conversations among teachers, pressing them to think more critically about the work that they assign to their students.

More recently, we found that the TAGS helps to deepen discussions about different scientific practices and the ways in which tasks facilitate (or constrain) students' productive engagement in these practices (Tekkumru-Kisa et al., 2017b). For example, one of the tasks in the task sort activity that often leads to productive discussions is Task-F in Figure 2. This task requires students to solve a set of problems by identifying the distance and time provided in the problem, and then placing these quantities into the given equation for calculating the speed. Some teachers think that this task positions students to engage in "using mathematics and computational thinking" scientific practice; they place the task into Guided Integration or Scripted Integration categories depending on whether they think that this task is "difficult" or "easy" for their students. Others, however, think that it is procedural and that it does not require students to do anything other than use the same formula in different problems. Such disagreements among the teachers can lead to fruitful discussions. Issues that arise include what it means for students to engage in mathematical thinking within the context of a cognitively demanding task, such as needing to think about the mathematical relationship among the variables to develop a solution for a complex problem. Another issue that often arises is whether difficulty-level and cognitive complexity mean the same thing. For example, in Task-F, calculating the speed might be difficult for students who are struggling with mathematical operations but the task does not necessarily require students to reason about what speed is. These conversations support building a common language among teachers around the critical issues such as scientific practices and what it means for students to explain phenomenon. More importantly, these conversations focus teachers' attention on students' thinking and intellectual engagement in science and how to design experiences to facilitate that. While discussing the cognitive demand of tasks with their colleagues in formal or informal professional development settings, teachers *anticipate* what and how students will think about while working on the task. Thus, the focus and attention of the teachers in these conversations is oriented toward students' thinking and ideas rather than only on what students will *do* in the lesson.

Stepping Back: When, How and Why to Use the TAGS?

We expect that the NGSS and its emphasis on three-dimensional learning will impact science instruction across the country even if it is not adopted by all the states. New curricula are already on their way to being launched in many classroom settings. However, many teachers will still need to make decisions about the kind of work that they should assign to their students to facilitate three-dimensional learning. That is why a tool that provides a common language across teachers about critical aspects of the tasks that they assign to students will help ensure that all students' will have real opportunities to engage in 3-dimensional learning.

Recently, in response to the recognition of a lack of high-quality, NGSS-aligned materials, the Educators Evaluating the Quality of Instructional Products (EQuIP) rubric (2014) was developed by NSTA and Achieve. The EQuIP rubric for science provides criteria by which to measure the degree to which lessons and units are aligned with the NGSS. We can imagine the TAGS working in combination with the EQuIP rubric since the TAGS helps to identify more nuanced information about the task(s) embedded in the lesson or unit. For example, we have used the TAGS in a pre-service teacher education course to support pre-service teachers' learning to design lessons and instructional units that consist of cognitively demanding tasks, with the TAGS guiding task design and the EQUiP criteria guiding overall unit design.

Overall, based on our work with teachers, we envision the TAGS being used in several ways, including identifying instructional activities during lesson planning, modifying textbook and existing activities to become more NGSS-aligned, writing new curriculum materials, and constructing three-dimensional assessments. For example, the TAGS has been used to guide curriculum development efforts among teachers and researchers. It was used by science teachers during their development of curriculum materials as part of a Research Experience for Teachers program. Moreover, we used the TAGS in our curriculum development work to make sure the curricular tasks that we designed were at high cognitive demand levels (Schunn & Stein, 2009).

References

Ambitious Science Teaching (2014). Planning for engagement with important science ideas. Retrieved from http://ambitiousscienceteaching.org/wpcontent/uploads/2014/08/Primer-Plannning-for-Engagement.pdf

Arbaugh, F., & Brown, C. A. (2005). Analyzing mathematical tasks: a catalyst for change? Journal of Mathematics Teacher Education, 8(6), 499-536.

Tekkumru-Kisa, M., Stein, M. K., & Schunn, C. (2015). A framework for analyzing cognitive demand and content-practices integration: Task analysis guide in science. *Journal of Research in Science Teaching, 52*(5), 659–685.

Tekkumru-Kisa, M., & Stein, M. K. (2015). Learning to see teaching in new ways: A foundation for maintaining cognitive demand. *American Educational Research Journal, 52*(1), 105–136.

Tekkumru-Kisa, M., Schunn, C., Stein, M. K., & Reynolds, B. (2017). Change in thinking demands for students across the phases of a science task: An exploratory study. *Research in Science Education*, 1-25.

Bell, P., Bricker, L. A., Tzou, C., Lee, T., & Van Horne, K. (2012). Engaging learners in scientific practices related to obtaining, evaluating, and communicating information. The Science Teacher, 79(8), 31-36, Science Scope, 36(3), 17-22, Science & Children, 50(3), 11-16.

Blumenfeld, P. C., Soloway, E., Marx, R. W., Krajcik, J. S., Guzdial, M., & Palincsar, A. (1991). Motivating project-based learning: Sustaining the doing, supporting the learning. Educational Psychologist, 26(3&4), 369-398.

Bybee, R. (2015). The BSCS 5E instructional model: Creating teachable moments. Arlington: National Science Teachers Association.

Doyle, W. (1983). Academic work. *Review of Educational Research, 53*(2), 159.

Duncan, R., & Cavera, V. (2015). DCIs, SEPs, and CCs, Oh My! Understanding the three dimensions of the NGSS. *Science and Children*, 52(2), 16-20.

Hiebert, J., & Grouws, D. A. (2007). The effects of classroom mathematics teaching on students' learning. In F. K. Lester (Ed.), Second Handbook of Research on Mathematics Teaching and Learning, (371–404). Greenwich, CT: Information Age Publishing.

Huff, K. L. (2016). Addressing Three Common Myths About the Next Generation Science Standards. Science and Children, 53(5), 30.

Krajcik, J., Codere, S., Dahsah, C., Bayer, R., & Mun, K. (2014). Planning instruction to meet the intent of the Next Generation Science Standards. Journal of Science Teacher Education, 25(2), 157-175.

Krajcik, J. (2015). Three-Dimensional Instruction. *The Science Teacher*, *82*(8), 50.

National Academy of Education (1999). Recommendations regarding research priorities: An advisory report to the National Educational Research Policy and Priorities Board. Washington, DC: Author.

National Research Council. (2012). A Framework for K-12 science education: Practices, crosscutting concepts, and core ideas. Committee on Conceptual Framework for New K-12 Science Education Standards. Board on Science Education, Division of Behavioral and Social Sciences and education. Washington, DC: The National Academies Press.

National Research Council. (2014). *Developing Assessments for the Next Generation Science Standards.* Committee on Developing Assessments of Science Proficiency in K-12.

Board on Testing and Assessment and Board on Science Education, J.W. Pellegrino, M.R. Wilson, J.A. Koenig, and A.S. Beatty, *Editors.* Division of Behavioral and Social Sciences and Education. Washington, DC: The National Academies Press.

NGSS Lead States. (2013). Next Generation Science Standards: For States, By States. Achieve, Inc. on behalf of the twenty-six states and partners that collaborated on the NGSS.

Smith, M. S. (2014). Tools as a Catalyst for Practitioners' Thinking. *Mathematics Teacher Educator*, *3*(1), 3-7.

Stein, M. K., Grover, B. W., & Henningsen, M. (1996). Building student capacity for mathematical thinking and reasoning: An analysis of mathematical tasks used in reform classroom. *American Educational Research Journal, 33*(2), 455–488.

Stein, M. K., Smith, M. S., Henningsen, M. A., & Silver, E. A. (2009). Implementing Standards-Based Mathematics Instruction: A Casebook for Professional Development. *Teachers College Press*.

Windschitl, M., Thompson, J., & Braaten, M. (2008). Beyond the scientific method: Model-based inquiry as a new paradigm of preference for school science investigations. *Science education*, *92*(5), 941-967.

Task-A: Doing Science

Acid Rain: Is It In Your Neighborhood?

The National Atmospheric Deposition program has been recording the acidity of rain since 1999. Your local council is concerned that your area may be having problems with acid rain. You work for a local meteorology company and they have hired you to investigate their concerns.

Once you have carried out your investigation you must prepare a presentation to share your analysis and advice.

Task-B: Guided Integration

What happens to properties when I combine substances?

Purpose:

In this investigation, you will make observations of baking soda, road salt, powdered sugar, and water. Then you will combine the four substances, observe what happens and write a scientific explanation.

Safety:

- Wear safety goggles.
- Wash hands after completing this investigation.

Procedure:

1. Put 1 teaspoon of baking soda, 1 teaspoon of powdered sugar, and 2 teaspoons of road salt in separate small containers. Label each container.
2. Measure 10 mL of water with a graduated cylinder. Pour it into a small container.
3. Write your observations of baking soda, powdered sugar, road salt, and water in the table below.
4. Pour the baking soda, powdered sugar, and road salt into a corner of a zip seal bag.
5. Stand the container of water upright in the bag. Be careful not to tip it over.
6. Remove as much air as possible.
7. Zip the bag closed. Be sure the bag is completely sealed. Tip over the container to combine the substances.
8. Write your observations of the four substances combined in the table below.
9. Save your bag with substances until your teacher asks you to throw it away.

Data Collection:

Substances	Observations
Baking Soda	
Powdered Sugar	
Road Salt	
Water	

Scientific Explanation: Look for patterns in your data to write a **scientific explanation** that states whether new substances were formed after combining the baking soda, powdered sugar, road salt, and water.

Claim: (Write a statement that responds to the original question.)

Evidence: (Provide scientific data to support your claim. You should only use appropriate data and include enough data. Appropriate data is relevant for the problem and allows you to figure out your claim. Remember that not all data is appropriate. Enough data refers to providing the pieces of evidence necessary to convince someone of your claim.)

Reasoning: (In your reasoning statement, connect your claim and evidence to show how your data links to your claim. Also, tell why your data counts as evidence to support your claim by using scientific principles. Remember, reasoning is the process where you apply your science knowledge to answer the question.)

What New Questions do you have?

What combination caused the changes?

Purpose:

In this activity, your group will design and carry out an experiment to determine what combination of 3 substances from the last investigation caused new substances to be formed.

What evidence will you look for to determine what caused the changes?

Safety:

- Wear goggles during this investigation.
- Wash hands after completing this investigation.

Procedure:

With your group, discuss what your procedure should be. Record your procedure below. Use numbers or bullet points.

Data Collection:

Create a data table below where you will record your results.

Explanation of what caused the changes?

Write a scientific explanation of what substances caused the changes.

Task-C: Guided Practices

Find the Claim, Evidence, and Reasoning in the following paragraphs. Underline the Claim, CIRCLE the Evidence; and HIGHLIGHT the Reasoning.

1. Life Science: A common type of asexual reproduction found in nature is called Mitosis. Mitosis requires less energy than sexual reproduction does. Mitosis can occur in seconds and does not require a mate to reproduce. Sexual reproduction requires two compatible parents. It also requires time to produce the egg and sperm cells and then for fertilization to occur. Energy is required to find a compatible mate, produce sex cells, and for fertilization. Therefore Mitosis requires less energy than sexual reproduction does.

Task-D: Guided Content

Analogy of the Cell Project

Your goal is to create an analogy that related to a eukaryote cell. Your final product is a story about something that has similarities to a cell structure. Each paragraph should be about one of the parts of a cell. Your paragraphs should clearly lay out the details and function of the cell structures, a comparison of the cell part to the analogy and your reasoning for the analogy. You must write using complete sentences and the story that you create should reflect your understanding of the cell structure.

2. Physical Science: Cold air weighs more than hot air. When I filled a 9 cm diameter balloon with cold air it weighed 1 gram and when I weighed the same size balloon with hot air it weighed 0.5 grams. When molecules are cooled they move closer together and when they are heated up they move farther apart. Because of this more molecules can fit into a balloon when the air going in is cold than when the air going in is warm.

Now see if you can make your own claim, evidence, and reasoning using what you know about these topics.

3. Brianna wanted to compare the densities of two different solids of the same size $6cm^3$ (same volume) to see which one was more dense. Solid A had a mass of 2 grams and Solid B had a mass of 0.5 grams. (Density = Mass/volume)

Task-E: Scripted Practices

Mass of an Object

Tools: Electronic scale or balance

1. Determine the mass (in grams) of the 3 marbles: ___
2. Determine the mass of 20 mil of water. To do this you will need to weigh an empty graduated cylinder, then add the water and find the difference.

Mass of graduated cylinder ________
Graduated cylinder and 20 ml of water ______
Mass of 20 mil of water ______

3. Use the same technique to determine the mass of 50 ml of water

Task-F: Scripted Content

Speed Equation

$$\text{Speed} = \frac{\text{Distance}}{\text{Time}}$$

Note: The SI unit for speed is meters per second (m/s).

Example

Problem: What is the speed of a sailboat that is traveling 100 meters in 120 seconds?

Step-1: Write down the equation you need to solve the problem.

$$Speed = \frac{Distance}{Time}$$

Step-2: Place the known information into the equation.

$$Speed = \frac{100m}{120s}$$

Step-3: Solve. Carefully enter the numbers into your calculator. Remember that this is a division problem. Check to make sure that your solution contains the correct SI unit.

The sailboat has a speed of .83 m/s.

Practice Problems

1. Calculate the speed of a dog running through a field if he is covering 23.7 meters in 54 seconds.
2. If a cross-country runner covers a distance of 347 meters in 134 seconds what is her speed?
3. What is the speed of a baseball that travels 49 meters in 2.4 seconds?

Task-G: Scripted Integration

Conductivity

Materials: conductivity, pH, and temperature probes, table salt, sugar, isopropyl alcohol, vinegar, 10% bleach, bell wire with 2-3 cm stripped at each end, 9V batteries, flashlight bulbs, receptacles

Background information: Characteristics such as boiling point and melting point are determined by the forces that hold a molecule together. Bonds are created through the transfer or sharing of electrons. Molecular and ionic bonds determine the characteristics such as conductivity of compounds. Differentiate among conductors, semiconductors, and insulators.

Procedure:

1. Write a hypothesis to answer the following question: What determines the conductivity of a substance?
2. Make a data table to record observations and pH of water.
3. Fill a beaker half full with water. Measure pH.
4. Connect bell wire to two 9-volt batteries.
5. Attach the end of one wire to a receptacle-mounted flashlight bulb. Tape the receptacle to your desk.
6. Attach a third piece of wire to the bulb receptacle with the other end placed in the beaker liquid.
7. Does the light glow? Record.
8. Slowly add salt to the beaker while stirring. Measure pH while adding salt. Does the light glow? How does the amount of salt affect your results? Record.
9. Remove wires from beaker and empty beaker. Rinse.
10. Repeat procedures with sugar, vinegar, isopropyl alcohol, and bleach. Slowly add sugar to the beaker, like you did with the salt. Record observations and results.
11. Place electrodes in a small pile of dry salt. Record results.
12. Take apart and clean apparatus and beaker.

Conclusion: Which of the solutions conducted electricity? How did the changing concentration of salt and sugar affect the light? What relationship is there between pH and conductivity?

Task-H: Memorized Practices

Draw a line to match these scientific method terms with their definitions.

Experiment	Facts contained in reference sources that support the data in an experiment
Data	The problem that needs to be resolved through an experiment
Research	A test done to check if a hypothesis is correct or not.
Question	The results of an experiment in the form of visuals like graph, etc.
Conclusion	A possible answer to the problem/question
Hypothesis	The result of the experiment that states whether the hypothesis was correct or incorrect.

Task-I: Memorized Content

Elements Poster

Now that you have determined several ways to identify elements, you will be assigned an element to make an advertisement poster on its everyday use. You want to make this poster as appealing as possible for your immediate classmates and school community, so that people will take the time to read and learn about the everyday use of several elements found on the Periodic Table. Your poster needs to include:

(1) a Catchy Title and Atomic Model and the Electronic Configuration

(2) a Listing of physical and chemical properties of your assigned element (at least two each)

(3) a picture of where this element is found and how is it used; in other words, its everyday application; (This picture should either be drawn, taken from the internet, a magazine, or a copy from a book)

(4) a one-paragraph typed caption for the above picture telling where the element is found and how it is used. Give the element's atomic symbol. This information must be factual and written in your own words. If you choose to do so, your one-paragraph caption can be written as a poem or jingle.

Resources:

Task-A revised from a teaching unit designed for the high school mathematics teacher that examines global change created by: Lisa Lesser, Pinckney High School, 10255 Dexter Pinckney Road, Pinckney, Michigan 48169, 810-225-5730, llesser@pcs.k12.mi.us

Task B: received from http://achieve.org/presentations/how-we-learn-now-science-education-next-generation-webinar-powerpoint

Task C adapted from https://d3jc3ahdjad7x7.cloudfront.net/UAwkd8DcsG7SelCyVMmVpvt5jNQ8Pso74yaROmiYfVpvYOUP.pdf

Task E from Author (2015)

Task F from Author (2015)

Task G: Adapted from http://www.cpalms.org/Public/PreviewResourceLesson/Preview/29449

Task H from Author (2015)

Task-I adapted from http://imagine.gsfc.nasa.gov/educators/lessons/xray_spectra/student-wsheet-poster.html

<table>
<tr><th></th><th colspan="2">ISOLATED TASKS</th><th>INTEGRATED TASKS</th></tr>
<tr><td>COGNITIVE DEMAND LEVEL-5</td><td></td><td></td><td>Doing Science
• Require students to work like a scientist: students need to engage in various scientific practices and deepen their understanding of scientific ideas as they explain a natural phenomenon
• Require students to work on mostly authentic problems
• Are often very ambiguous without a clear pathway to follow and may involve some level of anxiety for the students due to unpredictable nature of the process
• Involves no single solution and correctness of the solution depends on consistency with available evidence
• Helps to develop better understanding of how scientific knowledge is produced
• Demands self monitoring and self-regulation of one's own cognitive processes</td></tr>
<tr><td>LEVEL-4</td><td></td><td></td><td rowspan="2">Guided Integration
• Even though students are positioned to engage in engage in the kind of reasoning processes employed in real scientific inquiry, it is often through scaffolding offered by the teacher or by supports contained within the written task
• Helps to get a sense/experience of how scientific knowledge is produced but through guidance
• Lower level GI tasks could include well-designed verification labs that can deepen students' understanding of scientific ideas</td></tr>
<tr><td>COGNITIVE DEMAND LEVEL-3</td><td>Guided Practices
• Help students understand how scientists engage in certain practices often by having students engage in those practices with some guidance
• Do NOT intent to develop students' understanding of a particular scientific idea/concepts</td><td>Guided Content
• In general, require students to engage in high-level cognitive processes (such as finding relations, analyzing information, generalizing to a broader conceptual idea) but these processes are NOT scientific practices
• Often come in the form of application activities: students are introduced to an idea and then work on a task to deepen their understanding of that idea/concepts</td></tr>
<tr><td></td><td colspan="3">All three types of guided tasks:
• Require some degree of cognitive effort for successful completion of the task. Although a pathway to solve the task is suggested (explicitly or implicitly), they cannot be followed mindlessly
• Have SOME ambiguity about what to do and how to do it. Tasks guides students about what they should do but students need to understand what they are doing and why</td></tr>
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<tr><th></th><th colspan="2">ISOLATED TASKS</th><th>INTEGRATED TASKS</th></tr>
<tr><td rowspan="2">COGNITIVE DEMAND LEVEL-2</td><td>Scripted Practices
• Require students following a procedure/script relevant to scientific practices
• Are not about a particular scientific content because the goal is not to teach scientific ideas/concepts
• Are commonly associated with lab skills
• Focus on successful completion without requiring students to think about the reasons for when and why these procedures or these lab skills are needed</td><td>Scripted Content
• Require using a procedure related to a particular scientific formula or principle, to which students have been introduced.
• Do not require any engagement or exposure to scientific practices
• Often procedure can be repeated to solve similar kind of problems/questions
• Commonly require students to solve generic problems following a well-defined formula
• Focus on successful completion without requiring students to make sense of the underlying scientific ideas, why the concepts apply here and what they mean</td><td>Scripted Integration
• Require students following a procedure/script as they superficially engage in scientific practices within the context of a particular science content
• Do not require students to make sense of the disciplinary ideas or develop an understanding of how scientific ideas are developed even though the task focuses on a particular science content
• Fail to engage students in the kind of reasoning processes employed in real scientific inquiry
• Often require illustrating or confirming science ideas/concepts without really understanding what they really mean</td></tr>
<tr><td colspan="3">All three types scripted tasks:
• Are distinctive because of the scripted nature of the work that students do: A script is a provided, well-defined set of actions or procedures a student needs to take, usually in a given order, to complete a given task
• Require students to follow a set of actions/procedures that lead them to that answer without knowing (or needing to know) why and how the script lead to that answer
• Use of the procedure is either specifically called for or its use is evident based on prior instruction, experience, or placement of the task
• Require limited cognitive demand for successful completion. There is little ambiguity about what needs to be done and how to do it because students are often told what to do.
• Are focused on producing the correct answer to artificial questions rather than producing meaning
• Often, some of the questions involved in the task require students to reproduce previously learned definitions, rules, formulas and/or solely describing the procedure that they followed to complete the task.</td></tr>
<tr><td rowspan="2">COGNITIVE DEMAND LEVEL-1</td><td>Memorized Practices
• Require students to reproduce definitions relevant to scientific practices to which they were already exposed to OR commit definitions to memory
• Do not require exposure to scientific ideas/concepts</td><td>Memorized Content
• Require students to reproduce aspects of previously learned “scientific body of knowledge” (e.g., rules, formulas, and definitions of scientific terms) OR commit facts, rules, formula, and definitions to memory
• Do not require exposure to/engagement in scientific practices</td><td rowspan="2"></td></tr>
<tr><td colspan="2">Both types of memorized tasks:
• Cannot be completed by following some procedures because a procedure does not exist
• Are not ambiguous- such tasks involve exact reproduction of previously seen material and what is to be produced is clearly and directly stated; they have clear and correct answers
• Do not require making connections to meaning underlying facts, rules, formula, or definitions being learned or reproduced: No understanding required</td></tr>
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