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DOK: Categories of Cognitive Engagement for Science

This tool supports educators, educational content developers, assessment writers, and other stakeholders in interpreting, evaluating, operationalizing, and communicating about shared goals related to the types of complex cognitive engagement expected within current science standards, including NGSS and other Framework-influenced standards. This tool can be used to differentiate between and among the different types of complexity of cognitive engagement required by learning expectations along with corresponding questions, prompts, and tasks used within curriculum, instruction, and assessments.

*The four broad DOK Categories of Cognitive Engagement for science are described in this document. These categories **do not** represent a progression or sequence in terms of learning. Students may engage directly with a higher complexity task and later incorporate tasks of lower complexity–that all together contribute to an overall learning goal. Verbs should not be relied upon to determine task complexity; complexity is dependent on the way(s) in which students are required to interact with or engage with science ideas, practices, and concepts.*

Importantly, this tool differentiates the complexity of cognitive engagement from difficulty, from cognitive load, and from sophistication of thinking as well as from other important but distinct factors and considerations, including the dimensionality of the NGSS and other Framework-influenced standards. This is consistent with the NGSS, which includes three-dimensional performance expectations requiring cognitive engagement at DOK Categories 2, 3, and 4. The standards expect "deeper understanding of content," "application of content," "putting…knowledge to use," greater depth and rigor," "conceptual understanding," "engage[ment] in scientific investigations and argumentation," etc. These expectations for complexity of cognitive engagement apply across grades with "increasing sophistication of student thinking" developing as students move through the grade bands (Appendices A, C, E; The Framework).

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Using DOK to Interpret the Complexity of Cognitive Engagement Represented within the NGSS PEs:

A Framework for K-12 Science Education and the resulting NGSS both emphasize a conceptual shift in science standards, related to the **complexity** of student engagement with science ideas, concepts, and practices (NGSS Appendix A, Conceptual Shift #4). As one of the central conceptual shifts specified in the standards, attention must be given to determine if and in what ways different types of student cognitive engagement (i.e. cognitive complexity) are being interpreted in the expectations, in curriculum / learning opportunities, and in assessments (of all types). Use of Webb's DOK – Categories of Engagement helps educators interpret, communicate about, and evaluate the **complexity** of cognitive engagement required by learning expectations, along with the corresponding questions, tasks, and prompts used in curriculum and assessment.

Use of DOK helps all stakeholders to work purposefully to attain our existing goals of an aligned system. As a reflective lens, DOK is used to foster intentionality in teachers' and in content writers' practices, to help ensure that the complexity of expected learning outcomes are clearly understood, that (formative/summative/etc.) assessments provide opportunities to make reasonable inferences about attainment of the intended learning outcomes, and that appropriate educational opportunities are provided to allow students to engage at the level(s) of complexity intended. The critical role of alignment in the success of Framework-influenced science standards, including but not limited to the NGSS, was called out in the very first chapter of A Framework for K-12 Science Education:

> *"The committee recognizes that the framework and subsequent standards will not lead to improvements in K-12 science education unless the other components of the system – curriculum, instruction, PD, and assessment – also change so they are aligned with the framework's vision."* (NRC, 2012)

In other words, in order to achieve the shift in the complexity of student engagement with science–an explicit goal of the standards–students must be provided with learning opportunities that are as cognitively complex as what students are expected to know and do as stated in the corresponding standards. Similarly, what is elicited from students on assessments must be as cognitively complex as what students are expected to know and do as stated in the corresponding standards.
The Framework and NGSS documentation specify that DOK Category 1 type expectations are not intended as summative assessment targets. Because

“[p]erformance expectations are the assessable statements of what students should know and be able to do” and are intended to “to make clear the intent of the assessments” (p. 1, NGSS Release and p. 2, Appendix A, April 2013) it can be inferred that no PE should be considered to expect only DOK Category 1 type work. Although DOK Category 1 expectations are not intended as summative assessment targets, they *are* expected to be necessary and included in curriculum and instruction. One example given is that although “[n]o part of the NGSS specifies the student outcome of defining a gene – it is…implicit that in order to demonstrate proficiency on MS-LS3-1, students will have to be introduced to the concept of a gene through curriculum and instruction” (NGSS, Appendix B, p. 6).

Individual PEs are used by some and/or in some cases as curriculum and assessment targets. Bundles of PEs are used by some and/or in some cases as curriculum and assessment targets. When bundled, dimensions may be shuffled and regrouped, affecting the complexity of the expectation(s) and corresponding curriculum and assessment tasks. No matter the approach, meeting the goals of the NGSS to effect a conceptual shift in science standards, related to the **complexity** of student engagement with science concepts and scientific thinking (NGSS Appendix A, Conceptual Shift #4) means that it is necessary to differentiate between and among the different types of student cognitive engagement (i.e. cognitive complexity) explicit in the standards. Use of DOK – Categories of Cognitive Engagement allows stakeholders in all parts of the system to identify and name the referents for complexity, adding clarity to the interpretation and operationalization of the standards, and informing instructional, curricular, and assessment choices and design.

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Science – DOK – Category 1

Category 1 is defined by the recall of information, such as a discrete fact, definition, or term, as well as performance of a clearly defined process, scripted series of steps, or set procedure (e.g. use a balance, read information from a Periodic Table, follow a protocol). Category 1 tasks may require a rote response or use of a well-known formula. Finding a particular point on a graph or otherwise directly reading information from graphs, charts, diagrams, or maps is considered Category 1 work. In the context of multidimensional science standards, Category 1 tasks are, by definition, unidimensional—for example, requiring recall of a particular disciplinary core idea or widely accepted “fact.” Category 1 expectations and tasks, by definition, do not require students to engage in sense-making and do not require knowledge-in-use. If working with NGSS or other Framework-based standards, it is important to note that while performance of Category 1 tasks are expected as a part of curriculum and instruction (NGSS Appendix B), an explicit goal of Framework-based standards is to promote a shift away from Category 1 tasks as ultimate learning expectations and, correspondingly, as summative assessment targets. Students will, however, engage in Category 1 tasks in the classroom in the context of broader work to make sense of a phenomenon. Across all grades, for example, students are expected to properly use measurement tools, recognize specific structures or relationships, recall appropriate safety protocols, and learn relevant terminology. Students may be expected to develop fluency with Category 1 expectations. Although not complex, Category 1 expectations can be difficult, and may require time and effort to learn.

Importantly, Category 1 expectations do **not** necessarily need to be mastered before engaging in more complex expectations. For example, it is possible to plan and conduct an investigation to provide evidence that feedback mechanisms maintain homeostasis (HS-LS1-3) without first memorizing vocabulary terms for the structures involved in the feedback system and without first determining the atomic composition of molecules involved in the feedback system. In fact, engaging in complex tasks can promote, motivate, and facilitate mastery of DOK 1 learning expectations because they are encountered in a relevant and meaningful context.

Some examples that represent (but do not constitute all of) Category 1 expectations and tasks:

- Recall or recognize a fact, term, relationship, structure, or property.
- Reproduce in words or diagrams a typical or routinely used representation or model of a scientific concept or relationship, such as labeling a diagram of a life cycle or labeling a diagram of the water cycle with the correct terms.
- Provide or recognize a standard scientific representation for common phenomena or relationships, such as reading directly from or adding arrows to a food web diagram.
- Perform a (grade-level-appropriate) routine procedure, such as measuring length or completing a basic Punnett square.

Science – DOK – Category 2

Category 2 expectations and tasks require knowledge-in-use rather than in isolation of purpose or context. In general, Category 2 tasks require application of underlying conceptual understanding and therefore engagement in mental processing beyond recalling or reproducing a response. In other words, Category 2 tasks require students to interact with and make use of science ideas and concepts. Students may need to make some decisions about how to approach a question or problem, including applying knowledge and making connections between and among related ideas and concepts. Category 2 tasks require students to use observations, data, and/or other information to make sense of a phenomenon. Sense-making within Category 2 involves fairly straightforward or routine relationships or interactions between and among ideas and concepts. Using one's own observations to make original comparisons or to draw connections between and among science ideas and concepts are tasks that are typically Category 2. Tasks that require purposeful interpreting, organizing, and displaying of data in tables, graphs, and charts are also considered Category 2. Students may represent ideas mathematically or use routine mathematical and statistical concepts and processes to represent relationships between variables. At Category 2, students use evidence in the context of tasks such as explaining relationships in terms of observations or science concepts. A task requiring a rationale equivalent to an explanation grounded in conceptual understanding would be Category 2.

Some examples that represent (but do not constitute all of) Category 2 expectations and tasks:

- Specify and explain in one's own words the relationship between ideas, concepts, properties, or variables; draw meaning from observing, describing, and/or comparing patterns.
- Differentiate between and among ideas that are considered scientific fact, reasoned hypothesis, and speculation.
- Engage in sense-making related to the relationships between and among ideas and concepts in the context of a fairly routine phenomenon or problem, given data and conditions.
- Organize and represent data to show basic patterns or relationships relevant to making sense of a phenomenon.
- Interpret data to make sense of concrete relationships or to inform an explanation or design solution relevant to a phenomenon.
- Interpret or explain phenomena in terms of science ideas and concepts.
- Develop a fairly basic model that demonstrates underlying conceptual understanding and/or use a model that is a common representation of a phenomenon or concept to solve a problem, make sense of a relationship, etc.
- Apply conceptual understanding of disciplinary ideas to identify limitations of models.
- Make predictions for cause-and-effect relationships that are fairly direct but that require some consideration of the factors that influence outcomes.

Science – DOK – Category 3

Well-designed Category 3 tasks are likely to promote productive struggle as students may need to grapple with the context and information provided to figure out how to even begin to make sense of a phenomenon or problem. The complexity does not result only from the fact that there could be multiple approaches and solutions to a problem (also a possibility for both Category 1 and 2) but because the task requires more demanding, thorough, and abstract reasoning grounded in evidence. Category 3 tasks require planning with consideration of purpose and constraints. Students must use robust evidence to make original arguments. Tasks that require students to provide an evidence-based rationale for a novel solution or engage in scientific argumentation that involves heavy reasoning grounded in appropriate evidence are Category 3. An authentic science or engineering problem that has more than one possible solution and requires students to justify the response with appropriate evidence would most likely be a Category 3. Work may require application of ideas across diverse concepts, contexts, and disciplines. Category 3 expectations and tasks typically involve the use of science and engineering practices to solve non-routine problems. Conceptual understanding of science ideas and concepts may be applied to hypothetical contexts or used to support design solutions, claims, and arguments. Category 3 tasks include a scope of work that can be completed in a discrete period of time (i.e. “in one sitting”).

Some examples that represent, but do not constitute all of Category 3 expectations and tasks:

- Identify appropriate research questions and design brief investigations to help make sense of a phenomenon or science/engineering problem.
- Engage in abstract sense-making related to a complex and non-routine phenomenon or problem, given data and conditions, to develop hypotheses, logical conclusions, or original scientific arguments grounded in evidence.
- Develop and/or use a model (likely novel to the student) to describe a complex, non-routine phenomenon or concept.
- Conduct critical analyses of models, requiring the synthesis of disciplinary ideas.
- Form robust and defensible conclusions about non-routine problems or phenomena based on experimental data.
- Evaluate the bias, credibility, or accuracy of a scientific claim expressed in a text.
- Critically analyze causes for different conclusions based on scientific investigations of or reports about the same phenomenon.
- Evaluate alternative design solutions to an engineering problem.
- Propose revisions for aspects of experimental design grounded in evaluative review.
- Define authentic constraints and incorporate considerations for these constraints into problem-solving work.
- Analyze data to inform revisions to a proposed process or system.
- Develop a mathematical or computational simulation of a phenomenon.

Science – DOK – Category 4

Category 4 demands are at least as complex as those of Category 3, but a main factor that distinguishes the two categories is the need to perform activities over days or weeks (Category 4) rather than in one sitting (Category 3). The extended time that accompanies this type of task allows for more extensive planning and consideration of potentially intricate contingencies (dependent and interacting pieces) within and across systems. Category 4 tasks likely require thinking about implications of choices across time and require sustained metacognitive awareness. Category 4 science tasks parallel the types of extended iterative and non-linear engagement involved in authentic science inquiry and engineering design processes. Broad and abstract thinking is likely required to synthesize diverse ideas, concepts, contexts, and disciplines.

Note that an extended time period is not a distinguishing factor if the required work is only repetitive and does not require applying significant higher-order thinking. For example, if a student is expected to measure the water temperature from a river each day for a month and then construct a graph, this would be considered to fit within Category 2. However, if the student is engaged not only in the data collection and representation but in all aspects of planning and carrying out an authentic scientific investigation or design solution, then the overall task would be Category 4. While some science standards expect students to engage at Category 4, on-demand assessment instruments are inappropriate tools for judging student proficiency as relates to the full scope of Category 4 expectations; these are most appropriate for classroom assessment.

The scope of a Category 4 task requires demonstration of multiple Category 1, 2, and 3 expectations in the service of the larger goal. Note that educators may choose to design Category 4 tasks that promote, motivate, and facilitate Category 1, 2, and 3 work. These Category 4 tasks may be grounded in PE bundles or other groupings of learning goals. Phenomenon-based learning, problem-based learning, and the 5E Model, are some examples of common pedagogical strategies that may be used to support this approach.

Some examples that represent, but do not constitute all of, Category 4 expectations and tasks:

- Plan and carry out an authentic scientific investigation that will yield appropriate data that could be used as evidence to answer scientific questions related to real-world problems.
- Plan, test, and revise a design solution for a real-world problem.
- Analyze the results of multiple studies on a particular science topic or design solution to form an original conclusion about the subject.
- Use trials of a scientific investigation or design solution to evaluate strengths and weaknesses of an experimental design and develop a revised and more optimized approach.
- Conduct broad-scope, systems-level analyses of non-routine problems.

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