# Maryland Cognitive Complexity Framework (MCCF) Background

K-12 science education in Maryland is guided by the Next Generation Science Standards (NGSS). The NGSS advances a vision of science education that requires students to operate at the nexus of three dimensions of learning to demonstrate scientific literacy. The NGSS combines the three dimensions into performance expectations that state what students should be able to do to demonstrate they have met the standards. The dimensions are:

- **Science and Engineering Practices (SEP)** - Actions scientifically literate individuals take to investigate the world around them. There are eight practices identified in the *Framework* showing how students can use their understanding to investigate the natural world through scientific inquiry or solve problems through engineering design.
- **Disciplinary Core Ideas (DCI)** - The key ideas in science that have broad importance within or across multiple science or engineering disciplines. There are four domains: Physical Science, Life Science, Earth and Space Science, and Engineering, Technology, and Applications of Science.
- **Crosscutting Concepts (CCC)** - Overriding concepts that facilitate connecting ideas across domains. There are seven crosscutting concepts identified in the *Framework* to help students develop a coherent and scientifically based view of the world.

To assess the three dimensions of the NGSS on the Maryland Integrated Science Assessment (MISA), it is necessary to use sets of interrelated items, rather than individual, unrelated items. Individual items may focus on two of the three dimensions, but together in a set, all three dimensions can be addressed, resulting in a holistic representation of a student's knowledge, skills, and abilities. Thus, the MISA contains item sets and each item set has a stimulus focused on a specific real-world context or phenomenon.

The commonly used frameworks, Bloom's Taxonomy and Webb's Depth of knowledge, were not well suited for evaluating the cognitive complexity of an assessment aligned to the multidimensional NGSS. Therefore, it was necessary to develop a new approach to evaluate the cognitive complexity of each assessment item. Using Achieve's *Framework to Evaluate Cognitive Complexity in Science* (2019), specifically the Detailed Individual Item Analysis Rubric, the Maryland State Department of Education (MSDE) drafted the Maryland Cognitive Complexity Framework for Science (MCCF) Rubric. The MCCF rubric helps ensure cognitive complexity alignment between MISA items and the NGSS.

# Maryland Cognitive Complexity Framework (MCCF) Cognitive Levels

The MCFF has three cognitive levels:

| Level | Summary |
| --- | --- |
| **High** | Questions at the high cognitive complexity level require critical thinking that goes beyond classroom experiences. These questions have little to no scaffolding and require students to fully demonstrate their skills at using the three NGSS dimensions along with comprehending as well as applying the data and storyline of the stimuli. |
| **Medium** | Questions at the medium cognitive complexity level require some transfer of content or practices. These questions have some scaffolding, which allows students to see connections to their classroom experiences that they can use to answer the question. |
| **Low** | Questions at the low cognitive complexity level require no transfer of content or practices as they are directly connected with student experiences. These questions are heavily scaffolded, which allows students to identify one or more dimensions or the stimuli as an entry point for answering the question. |

It is important to keep in mind that each cognitive complexity level is a range. Items identified at the low cognitive complexity level could be very scripted with a lot of guidance and support, but the low level also includes items with some scaffolding. The medium level starts with items with some scaffolding and continues toward items with little guidance. The high cognitive level starts with items with minimal guidance and moves towards items with the most significant level of student independence as they do not include any support. The difference between levels is based on evaluating the stimuli and the three NGSS dimensions.

# Using the Maryland Cognitive Complexity Framework (MCCF) Rubric

To evaluate the cognitive complexity of NGSS items similar to items found on the MISA, evaluators should follow these steps:

1. **Review the evidence statements for each performance expectation covered in the set that contains the item.** Use the evidence statement documents to review the grade-level expectations for each of the NGSS dimensions before starting the evaluation. Alignment is attained when an item is aligned not only to the title of the dimension, but also to the bulleted explanation statements.

2. **Determine the overall cognitive complexity level of the stimuli.** The stimuli of a MISA set can consist of one or more tabs of information, which need to be evaluated first. This is the one component of the MCCF that will apply to all items in the set. When evaluating the stimuli, it is important to give equal weight to the text and graphics included in each tab.

3. **Determine an item's overall cognitive complexity level by analyzing the cognitive complexity level of each dimension.** Use the MCCF rubric to determine the cognitive level of each dimension as it applies to the given item. Once the cognitive complexity of each NGSS dimension and the stimuli have been determined, analyze the overall pattern of the four components. If all four MCCF components are at the same cognitive level or if there is a clear majority for a specific cognitive complexity level, then that is the cognitive level of the item.

4. **When the stimulus and dimensions are not in alignment or there isn't a clear majority for the cognitive complexity level within the MCCF components, expand the analysis to consider the type of item, text complexity, and the evidence statement to which the item is aligned.** Certain types of items are more cognitively complex than others. For example, inline choice items require additional working memory to complete successfully as compared to other item types. As for text complexity, the evaluator should consider the balance between text and graphics. How easily can students use the information as part of their sensemaking? Lastly, many of the NGSS evidence statements were developed using a hierarchical structure. This does not necessarily mean that the cognitive demand increases from the first to the last level, but it does provide another component to consider.

5. **After determining the cognitive complexity of the item, identify the number of dimensions required to answer the item successfully and label the item accordingly**. The MCCF is used to evaluate the cognitive complexity of an item, while accounting for the number of active NGSS dimensions referenced in the item. If the item is two-dimensional, a two is placed after the cognitive complexity label. If it is three-dimensional, a three is added. The final cognitive complexity label for each item will be low2, low3, medium2, medium3, high2, or high3. (No item should cover only one dimension). The final label conveys the item's cognitive complexity and the number of active NGSS dimensions referenced in that item.

# Maryland Cognitive Complexity Rubric

| Cognitive Complexity | Stimuli | Science and Engineering Practice (SEP) | Disciplinary Core Ideas (DCI) | Crosscutting Concepts (CCC) |
|---|---|---|---|---|
| **High**<br>Little to no Scaffolding<br>Far Transfer | **Emphasis**<br>Addressing a rich and puzzling phenomenon or problem presented with high-degree uncertainty.<br>• The stimuli present A real, authentic, and unique phenomenon or problem that is not immediately explainable by students.<br>• Often involves multiple appropriate ways to engage and pursue the labset items. | **Emphasis**<br>Figuring out a phenomenon or problem using the SEPs in service of authentic sensemaking.<br>• The item requires students to engage with SEP elements in unexpected, unconventional, or unfamiliar ways.<br>• High degree of student agency in the selection and use of SEPs in ambiguous situations with high degrees of uncertainty experienced.<br>• Sensemaking requires the use of multiple SEPs. | **Emphasis**<br>Non-routine use of domain specific science ideas as part of sensemaking.<br>• The item requires students to use and engage in non-typical reasoning with multiple science ideas.<br>• High degree of student agency is needed in selection and use of science ideas [content needed is variable or not immediately obvious]. | **Emphasis**<br>Selection and use of conceptual understanding of crosscutting ideas is necessary and expands students' thinking.<br>• The item requires students to engage in complex sensemaking that leverages the CCCs.<br>• High degree of student agency is needed in selection, use, and application of the CCCs. |
| **Medium**<br>Some Scaffolding<br>Near Transfer | **Emphasis**<br>Addressing phenomenon or problem with some level of uncertainty.<br>• The stimuli present a relatively new phenomenon that students might have some familiarity with, but do not fully understand the specific uncertainty the labset items are focused on.<br>• The stimulus includes multiple facets of information for students to interpret. | **Emphasis**<br>Representation of ideas; use of skills that are relatively complex.<br>• The item requires students to engage in SEPs in expected or well-practiced ways.<br>• Students are required to demonstrate some understanding of how/why to use the SEP.<br>• This may involve the use of multiple SEPs. | **Emphasis**<br>Supported application of science ideas in typical contexts.<br>• The item requires students to use science ideas as part of student reasoning in typical contexts with routine, well-practiced ways.<br>• Addressing the item may require students to connect multiple ideas in routine ways. | **Emphasis**<br>Specific crosscutting concept understanding is needed and is used to focus students' thinking.<br>• The item requires students to engage in CCCs in scaffolded/cued ways to focus students' thinking. |

| Cognitive Complexity | Stimuli | Science and Engineering Practice (SEP) | Disciplinary Core Ideas (DCI) | Crosscutting Concepts (CCC) |
|---|---|---|---|---|
| **Low**<br><br>Heavily Scaffolded<br><br>No Transfer | **Emphasis**<br>Addressing routinely encountered or <u>highly simplified stimulus</u>.<br><br>• The stimuli provide a problem or a phenomenon that students are already familiar with how to explain or solve. | **Emphasis**<br>Using the mechanics, skills, and specific knowledge associated with practices <u>isolated from sensemaking</u>.<br><br>• The item requires students to demonstrate simple, procedural, and mechanical aspects of engaging in SEPs (reading graphs/charts, drawing diagrams, etc.).<br>• Students may be provided with a script/set of defined procedures to follow to engage with the SEP, with limited student thinking required about which, how, or why practices are engaged.<br>• The Performance Expectation's SEP is used but not to the level identified in the SEP foundation box. | **Emphasis**<br>Producing previously learned ideas and conceptual procedures in routine, well-practiced ways.<br><br>• The item requires direct representation of previously learned ideas and concepts, including well-developed procedures related to concepts.<br>• The item does not require relating science ideas to one another, reasoning with ideas or using them in service of sensemaking. | **Emphasis**<br>Crosscutting concepts are <u>implicitly engaged</u> or practiced but are not consciously used by students in service of sensemaking.<br><br>• The item inherently involves the CCCs (e.g., explanation involving a cause and effect) but does not require students to demonstrate that they understand and can use elements of the CCCs.<br>• If CCC is included as part of the DCI. (DCI cognitive level should be identified as either medium or high due to this relationship)<br>• The Performance Expectation's CCC is used but not to the level identified in the CCC foundation box. |

# Definition of terms

| Term | Definition |
|---|---|
| **Item Set** | An item set includes stimuli and an interrelated set of questions or items. There can be one to three stimuli that are focused on a specific phenomenon and are designed to start the student's sensemaking process. Item sets include a mixture of multiple choice, multiple select, and technology enhanced questions. They also include two constructed response questions. |
| **Stimuli** | Text, images, graphs, videos, and other resources that create a complete storyline that students will use to demonstrate their scientific understanding. |
| **Storyline** | An exploration of a scientific phenomenon. |
| **Scaffolding** | The amount of information provided to students to support the sensemaking process. |
| **Transfer** | The ability to transfer scientific understanding across a variety of phenomenon. |