Unpacking Practices: Scientific Explanation

Scientific Explanation

A written or oral response to a question about how or why a phenomenon occurs that is supported by evidence. Hypotheses are "plausible explanations for an observed phenomenon that can predict what will happen in a given situation." (NRC, 2012, p. 67).

Constructing explanations involves articulating a claim responding to a question about how or why a phenomenon occurs, describing or citing appropriate evidence supporting the claim, and providing reasoning that describes how or why the evidence supports the claim using appropriate scientific principles.

Intersections with other Practices

- Results of **data analysis** and output from **models** can be used as evidence for explanations or hypotheses
- **Investigations** can inform the construction of explanations
- **Scientific arguments** critique or defend the strength/validity of explanations

Component descriptions and evidence of high performance

Component	Description	Evidence of high performance
Claim	**Articulate** a testable statement or conclusion that answers a question about how or why	Student makes a testable statement or conclusion that **correctly** answers a question about how or why in a way that is consistent with available evidence
Evidence	**Describe** or **provide** scientific data that support the claim Sources of data include (but are not limited to) student-conducted investigations, everyday observations, reading material, numerical data, and model outputs	Student describes or provides **appropriate** and **sufficient** scientific data that support the claim
Reasoning	**Describe** how or why the data support the claim using scientific ideas/principles	Student describes how or why the evidence support the claim using **appropriate** and **valid** scientific ideas/principles

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Unpacking Practices: Developing and Using Models

Developing and Using Models

A scientific model is an abstract, simplified, representation of an object, phenomenon, or system of phenomena that makes its central features explicit and visible. Models can be used to communicate information about objects and phenomena and generate explanations and predictions. They include diagrams, physical replicas, mathematical representations, analogies, and computer simulations.

Developing models involves generating a representation having elements and relationships that communicate information about a target object, explain a target phenomenon, representing the correspondence between these elements and the real world, and specifying the limitations of the model. **Using models** involves applying a previously developed model to answering a scientific question and can include generating explanations based on the model.

Intersections with other practices

- Output from models can be used as evidence for **explanations** and **arguments**
- **Scientific arguments** critique or defend the quality or appropriateness of models
- Models are developed based on results of **data analysis**
- **Investigations** may inform the development of models or involve the use of models
- Models **communicate information** about objects to intended audiences

Component descriptions and evidence of high performance

Component	Description	Evidence of high performance
Model elements	**Specify/identify** elements of the model (and their attributes)	Student specifies/Identifies **only the appropriate and necessary** elements (and their attributes) in the model **needed to explain the target phenomenon or communicate the desired information**
Relationships among elements	**Represent/describe** the relationships or interactions among model elements	Student represents/describes **only the appropriate and necessary** relationships and/or interactions among model elements **needed to explain the target phenomenon or communicate the desired information**
Correspondence	**Represent/describe** the correspondence between the model and the target phenomenon	Student **correctly** represents/describes the correspondence between model elements/relationships and the real world object or phenomenon
Limitations	**Specify/identify** the limitations of the model	Student specifies/identifies **the appropriate** limitations of the model **with respect to explaining the target phenomenon or communicating the desired information**
Explanation/ prediction	**Explain or predict** phenomena using the model	Student constructs **a correct and complete** explanation or prediction of the phenomenon using the model

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Unpacking Practices: Analyzing and Interpreting Data

Analyzing and Interpreting Data

Analyzing and interpreting data involves organizing and/or displaying collected data in order to identify patterns that can be used as evidence.

Intersections with other practices

- Patterns uncovered by data analysis and interpretation may constitute evidence for **explanations**
- **Models** should be consistent with available real world data. **Models** can produce data for interpretation and analysis.
- **Scientific arguments** evaluate the appropriateness/completeness of data analyses, the consistency of data analysis with a hypothesis, theory, or model, or the strength of a conclusion that can be inferred from data.
- Methods of data analysis and interpretation are appropriate to specific **scientific questions.**
- Scientists **communicate scientific information** using descriptions and visual displays of analyzed data
- Scientists use **mathematical and computational** approaches to interpret and analyze data

Component descriptions and evidence of high performance

Component	Description	Evidence of high performance
Organization	**Organize** data to highlight patterns and relationships	Student organizes data **in a clear way** that highlights patterns **that are relevant or meaningful to a scientific question**
Visual displays	**Generate** visual displays of data (e.g. tables, graphs, flowcharts, illustrations)	Generates interpretable/clear visual displays that are appropriate to the data (e.g. tables, graphs, flowcharts, illustrations)
Summarizing	**Summarize** data using descriptive statistics	Student uses **appropriate** descriptive statistics to summarize data in a way **that addresses a scientific question**
Patterns	**Identify** patterns (e.g. similarities and differences, causal and correlational, linear and nonlinear)	Student identifies **relevant or meaningful** patterns that **address a scientific question**
Sources of measurement variation	**Identify** relevant sources of measurement variation and **determine** how to address them	Student identifies **relevant** sources of measurement error that **limit interpretations of the data**
Outlying data	**Identify** outlying data and **determine** how to address them	Student **appropriately** identifies data as outlying and describes how those outlying data should be appropriately addressed in the analysis

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Unpacking Practices: Planning and Carrying Out investigations

Scientific Investigation
A scientific investigation is a systematic procedure developed and conducted in order to answer a scientific question. Though the nature and form of scientific investigations may vary, investigations often aim to determine relationships among system variables. Certain components of the practice are therefore specific to these types of investigations.

Intersections with other practices

- **Construct an argument** about the validity of an investigation that was planned/carried out
- Plan/carry out an investigation to test the strength of **scientific explanation** (hypothesis)
- Plan/carry out an investigation to test the strength of a **model** (hypothesis)
- **Analyze data** produced/collected by the investigation
- Plan/carry out an investigation to answer **asked questions**

Component descriptions and evidence of high performance

Component	Description	Evidence for a high level of performance
Tools and instruments	**Identify, set up, and use** tools required to gather data	Correctly identifies, sets up, and uses the appropriate tools required to gather data relevant to the question being addressed and describes why the tools are appropriate
Measurement procedure	**Determine** what measurement methods are needed	Describes how measurements will be made using specific tools/instruments and why these procedures should be used, including specifying how much data are required
Sources of measurement variation	**Identify** potential sources of measurement variation	Identifies potential sources of measurement variation that are relevant to the question being addressed and describes why these sources of variation exist
Step-by-step procedure	**Describe and execute** an investigation procedure	Completely describes and executes a step-by-step procedure for carrying out the investigation and describes why the procedure is appropriate for the investigation
Components specific to investigating variable relationships		
Identifying variables	**Identify** relevant variables	Correctly identifies system variables relevant to the scientific question and describes why they are relevant
Dependent/ independent variables	**Identify** dependent and independent variables	Correctly identifies the dependent and independent system variables relative to the scientific question and describes why they are dependent or independent
Controlled/ varied variables	**Identify** controlled/ varied variables	Correctly identifies what variables must be controlled/varied across multiple trials in order to address the scientific question and describes why they must be controlled/varied
Confounding variables	**Identify** confounding variables	Correctly identifies potentially confounding variables relative to the scientific question and describes why they are confounding

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Unpacking of Crosscutting Concepts – Cause and Effect: Mechanism and Prediction

Cause and Effect

Cause and effect addresses the identification of mechanisms, causal relationships, and chains of events and interactions that govern scientific phenomena. Knowledge about causal relationships is often necessary to make predictions about new situations and develop engineering solutions.

Intersections with Practices

- **Explanations** articulate conditions, mechanisms, and evidence.
- **Arguments** evaluate statements about causal mechanisms and evidence.
- Patterns from **data analysis** provide evidence of causal relationships
- **Investigations** are planned and carried out to generate evidence of causal relationships
- **Models** are developed to test hypothesized causal mechanisms and used to make predictions.
- Scientists **ask questions** about underlying causal mechanisms underlying phenomena

Component descriptions and evidence of high performance

Component	Description	Evidence of a high level of performance
Causes	**Identify** or **describe** the cause(s) that lead to the given effect(s) under various conditions	Correctly identifies or describes the cause(s) that lead to the given effect(s) under various conditions
Effects	**Identify** or **describe** the effect(s) that result from the given cause(s) under various conditions	Correctly identifies the effect(s) that result from the given cause(s) under various conditions Correctly describes multiple possible effects probabilistically and specifies their relative probabilities of occurrence
Conditions	**Identify** or **describe** the conditions under which causal relationships occur	Correctly identifies or describes the conditions under which specific causal relationships occur using an appropriate qualitative description or numerical range
Mechanism/ Intermediate events	**Identify** or **describe** the intermediate events or scientific principles that link cause and effect	Correctly identifies or describes a sequence of intermediate events that explain how cause and effect are linked Correctly identifies or articulates specific disciplinary concepts or underlying models/theories that justify how/why cause and effect are linked
Evidence	**Describe** or **provide** observations/data that constitute evidence for the causal relationships	Describes or provides appropriate and sufficient observations/data that constitute evidence for the causal relationships
Predictions	**Articulate** predictions that are based on an identified causal mechanism	Articulates appropriate or correct predictions consistent with an identified causal mechanism

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Unpacking of Crosscutting Concepts – Patterns

Patterns are regularly occurring shapes or structures and repeated events, or relationships that can be used to classify objects or behaviors. The idea that observed patterns can be explained is fundamental to the nature of science (NRC, 2012).

Intersections with practices

- **Construct explanations** about how and why particular patterns occur
- **Develop and use models** to describe observed patterns or predict patterns
- **Analyze data** to identify or characterize patterns
- **Plan and conduct investigations** to discover patterns
- **Ask questions** about how/why patterns occur

General components of performance

- **Identification**: Identifying patterns in phenomena or data
- **Characterization**: Characterizing the strength, direction, or nature of patterns
- **Categorization:** Categorizing objects or relationships according to similarities or differences

Pattern types

- Repeating occurrences (in space or time)
- Correlations and trends
- Similarities, differences, comparisons, and categories

Component descriptions and evidence of high performance

Component	Description	Evidence of a high level of performance
Repeating occurrences		
Identification	**Identify** the occurrence of spatially or temporally repeating phenomena	Correctly identifies the occurrence of repeating phenomena and describes why they repeat
Characterization	**Characterize** the frequency and nature of spatially or temporally repeating phenomena	Correctly characterizes the frequency and/or nature repeating phenomena and describes why the phenomenon exhibits these characteristics
Correlations and trends		
Identification	**Identify** correlative relationships between variables	Correctly identifies correlative relationships and describes why the variables are correlated
Characterization	**Characterize** the direction, strength, and nature of a correlative relationship	Correctly characterizes a correlative relationship and describes why the relationship exhibits these characteristics
Similarities, differences, comparisons, and categories		
Identification	**Identify** similarities or differences across two or more quantities or properties	Correctly identifies similarities or differences and describes why the similarity or difference exists
Characterization	**Characterize** the amount or degree of difference among two or more quantities or properties	Correctly characterizes the amount or degree of difference and describes why this degree of difference is important
Categorization	**Categorize** objects or entities based on similarities and differences	Correctly categorizes objects or entities and describes why the categories are meaningful relative to a scientific question

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