INSTITUTE for SCIENTIST & ENGINEER EDUCATORS

# Examples of STEM Practice Rubrics

Institute for Scientist and Engineer Educators (ISEE)

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This paper was written and produced by the developers of the Professional Development Program (PDP) at the Institute for Scientist & Engineer Educators (ISEE) at University of California, Santa Cruz. The PDP was a flexible, multi-year program which trained participants to teach STEM effectively and inclusively at the post-secondary level. Participants were primarily graduate students and postdocs pursuing a broad range of science and engineering careers. Participants received training through two in-person multi-day workshops, worked on a team to collaboratively design an authentic, inclusive STEM learning experience (an "inquiry" lab), and then put their new teaching skills into practice in programs or courses, mostly at the college level. Throughout their experience, PDP participants used an array of online tools and received coaching and feedback from PDP instructors. The overall PDP experience was approximately 90 hours and was framed around three major themes: inquiry, assessment, and equity & inclusion. Leadership emerged as a fourth theme to support PDP teams, which were each led by a participant returning to the PDP for a second or third time, who gained training and a practical experience in team leadership. ISEE ran the PDP from 2001-2020, and there are more than 600 alumni.

**CONTEXT FOR THIS PAPER WITHIN THE PDP**

This resource includes STEM practice rubrics which were used as examples in the PDP. Each rubric contains a couple of dimensions (or "quality definitions"), which are meant to be examples and are not comprehensive. The rubrics are meant to be representative of what an instructor might produce for their own teaching purposes, not a highly refined and validated rubric that might be used in a rigorous assessment study. Participants revised these rubrics based on their experience and teaching goals. During PDP sessions, these rubric examples were often presented to participants with one dimension missing so that they had an opportunity to think through and discuss how they would define the dimension.

The PDP was a national program led by the UC Santa Cruz Institute for Scientist & Engineer Educators. The PDP was originally developed by the Center for Adaptive Optics with funding from the National Science Foundation (NSF) (PI: J. Nelson: AST#9876783), and was further developed with funding from the NSF (PI: L. Hunter: AST#0836053, DUE#0816754, DUE#1226140, AST#1347767, AST#1643390, AST#1743117) and University of California, Santa Cruz through funding to ISEE.

## 1. Core STEM Practice: Using models to develop explanations

| Dimensions of core practice: | What it looks like when a learner needs to work more on the practice | What it looks like when a learner is proficient with the practice |
|---|---|---|
| **Useful models have components that represent relevant aspects of phenomenon** | • Does not identify one or more important model components<br>• Does not identify contradictions within proposed model | • Identifies all relevant model components<br>• Identifies which components do not correspond to any of the observables provided |
| **Models reflect the relationship between inputs and outputs** | • Does not define inputs (parameter values in the model) and outputs (values of observable quantities)<br>• Does not describe expected behavior in output given a set of inputs | • Identifies specific inputs and outputs<br>• Describes expected behavior in output given a set of inputs |
| **Models have limitations and assumptions** | • Does not explicitly state assumptions posed when constructing the model<br>• Does not state ways in which the model can fail<br>• Does not state unphysical situations which the model could represent | • Explicitly states the assumptions behind the model<br>• Identifies scenarios where the model would not apply |

## 2. Core STEM Practice: Designing investigations

| Dimensions of practice | What it looks like when a learner needs to work more on the practice | | What it looks like when a learner is proficient with the practice |
|---|---|---|---|
| An experiment is the measurement of a predicted variable. | Does not identify a measurable variable. | Identifies a measurable variable without connecting it to a hypothesis. | Identifies the predicted variable and its connection to the hypothesis being tested. |
| Predictor variables are hypothesized to account for variation in predicted variables. | Mis-identifies the predictor and predicted variables. | Successfully identifies both predictor and predicted variables. | Identifies both predicted and predictor variables and demonstrates their connection to the hypothesis. |
| Confounding variables are hypothesized to affect both predicted and predictor variables. | Neglects to consider variation in the predicted variable from sources other than the predictor variables. | Considers possible variation in the predicted variable due to confounding variables. | Attempts to control for the effect of confounding variables in the experimental design. |

### 3. Core STEM Practice: Designing solutions within requirements

| Dimensions of core practice: | What it looks like when a learner needs to work more on the practice | What it looks like when a learner is proficient with the practice |
|---|---|---|
| Requirements define what a solution must do | Does not mention the requirements<br><br>Loosely-defined requirements - broad ideas, not verifiable (e.g. "good signal")<br><br>Identifies constraints instead of requirements | Identifies what solution must do (to be a solution at all)<br><br>Requirements stated in a verifiable (measurable when possible) way<br><br>Differentiates from constraints |
| A solution meets requirements, | States evidence but it does not fulfill the "must do" requirements<br><br>Solution seems separated from the requirements<br><br>No evidence of meeting requirements provided | States evidence (result of tests- quantitative when possible) that indicates that solution fulfills requirements<br><br>Uses evidence to show that solution does not meet all requirements, and how their solution could be modified to meet requirements |
| Solution is supported with evidence indicating why it is better than other solutions | Does not relate solution back to science goal<br><br>Does not acknowledge alternative solutions<br><br>Does not have any verifiable way to compare alternative solutions (uses "better" etc.) | Articulates how solution achieves science goal<br><br>Acknowledges alternative solutions<br><br>Uses trade study or other systematic way to show tradeoffs made and justify solution |

**4. Core STEM Practice: Building algorithms (coding)**

| Dimensions of core practice: | What it looks like when a learner needs to work more on the practice | What it looks like when a learner is proficient with the practice |
|---|---|---|
| Definition of relevant variables is built in early and with consistency | ● Variables are defined sporadically.<br>● Naming conventions are unclear and inconsistent.<br>● Doesn't identify when code errors are related to poor choices of variable type.<br>● Declaration of non-necessary variables. | ● Defines all relevant global variables clearly and at beginning of algorithm.<br>● Temporary/intermediate variables are defined and used as needed.<br>● Uses clear and concise variable names.<br>● Identifies variable types and uses the appropriate types when needed. |
| Algorithms are built with compartmental-ization of functions | ● Does not partitioned code into consistent groups (e.g. functions written between i/o).<br>● Uses irrelevant functions.<br>● Reuses an identical piece of code multiple times in different places. | ● Partitions code into logical groups (e.g. functions, initialization, data i/o, and main program)<br>● Uses functions to serve a specific purpose (e.g. repetitive code) and tries to make functions generalized (i.e. capable of serving more than one purpose) |
| Algorithms are built to have efficient flow | ● Overwrites important variables, leading to errors.<br>● Uses unnecessary loops or repetitive code. | ● Flow has minimum number of loops<br>● Repetitive coding is minimized |

**5. Core STEM Practice: Revising a hypothesis based on observations**

| Dimensions of core practice: | What it looks like when a learner needs to work more on the practice | What it looks like when a learner is proficient with the practice |
|---|---|---|
| A hypothesis makes a testable claim | • Hypothesis is vague/incomplete<br>• Not testable | • Hypothesis generates *specific predictions* that can be *validated (or invalidated)* with data that can be *reasonably acquired* |
| Hypotheses are revised based new data or observations | • Uses incomplete data or data inconsistent with hypothesis<br>• Uses anecdotes | • Uses *relevant* data on hand and knows what data to leave out. |
| Hypotheses are based on a scientific principle or reasoning | • Logic (regardless of how correct it is) *linking data or observations to hypothesis* is missing.<br>• Hypothesis is a guess. | • States a scientific principle or reasoning<br>• Relates principle or reasoning to data or observations to hypothesis Demonstrates the *logic* of how the model system produces the data. |

## 6. Core STEM Practice: Constructing explanations

| **Dimensions of core practice:**<br><br>**A complete explanation includes:** | What it looks like when a learner needs to work more on the practice | | **What it looks like when a learner is proficient with the practice** |
|---|---|---|---|
| **Claim:**<br>A claim that addresses the original question | Does NOT make a discernable claim statement | Makes a claim that:<br>does not specifically address the question OR is vague | Makes a specific claim that addresses the question |
| **Evidence:**<br>Relevant data or observations are used to support a claim | Does NOT provide evidence or data<br><br>Repeats data but does not use as evidence | Uses data as evidence but does not account for all data<br><br>makes a vague or insufficient statement about the data | Accounts for and uses all relevant data as evidence |
| **Reasoning:**<br><br>Reasoning the links evidence to claim | Does NOT provide reasoning | Only repeats evidence and/or claim<br><br>Implies scientific principle, but does not explicitly state it<br><br>References a scientific principle but doesn't link this principle to the evidence and claim | Includes a statement of a general principle, how evidence relates to it, and specifically how it links the evidence to the claim |