

Preface

Model-based reasoning is essential to navigating the complexities of the real world. Though the literature on model-based reasoning has been available for many years, the advent of the Next Generation Science Standards (NGSS) has increased interest in how students can effectively develop model-based reasoning abilities. The vision of these standards originated with “The Science Framework for K-12 Education” (NRC Framework, 2012), which advocates for the deep integration of the practices of science with the understanding of core ideas and crosscutting concepts (NRC, 2014). The Framework identifies eight practices of science and engineering that are essential for all students:¹

1. Asking questions (for science) and defining problems (for engineering);
2. Developing and using models;
3. Planning and carrying out investigations;
4. Analyzing and interpreting data;
5. Using mathematics and computational thinking;
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence; and
8. Obtaining, evaluating, and communicating information.

Developing assessments that target these practices will require tasks that elicit evidence about how students integrate their knowledge of disciplinary core ideas, apply scientific practices, and build connections across ideas (NRC, 2012). In this manuscript, we focus on model-based reasoning as related to the NGSS practice of developing and using models. The National Science Teachers’ Association (NSTA) describes developing and using models as “a practice of both science and engineering ... to use and construct models as helpful tools for representing ideas and explanations. These tools include diagrams, drawings, physical replicas,

¹*Next Generation Science Standards: For States, By States* (2013) Chapter: Appendix F: Science and Engineering Practices in the Next Generation Science Standards

mathematical representations, analogies, and computer simulations” (NSTA, 2016). The practices of defining problems and designing solutions for engineering present new opportunities to engage learners in aspects of model-based reasoning, in both instruction and assessment.

In these sections, we describe an approach to designing assessments of model-based reasoning that draws on recent developments in several areas. The first is research on science learning, and, in particular, learning to reason with and through models. A second is cognitive psychology, which highlights both cognitive and social aspects of how people, as individuals and as communities develop models and use them to solve problems and extend their knowledge. The third area is developments in technology, which enable us to build interactive simulations for students, for both learning and assessment, and to make sense of the rich data that can be captured.

The fourth area, the center of this brief, is advances in assessment theory. The first three developments mentioned above expand our knowledge base, widen our vision of what assessment can be, and give us technologies to create richer and more valid assessments. The challenge is how to effectively realize the potential of these advances in practice.

Educational assessment is itself experiencing a renaissance of sorts. Although technological developments have provided improved task environments and psychometric methods, the key development has been to recognize assessment not as a simple exercise in measurement, but as the construction of an argument: What do the particular, situated, noisy observations in a task tell us about students’ understandings? About the knowledge structures and activity patterns they can marshal to address what kinds of situations? How does their performance depend on their previous experiences, and how can we sort out the meanings of complex performances in complex tasks? How can we manage task design when multiple aspects of knowledge and skill are involved, and when they may interact differently with different students? How can we design tasks that integrate the broad array of new insights about learning, about the nature of science, and about the technologies that are available for new forms of assessment?

The framework of this brief is a particular approach to these questions, called evidence-centered assessment design. We describe and illustrate a support tool for task development called an assessment design pattern. The suite of design patterns presented here integrate design issues and design choices for seven aspects of building and working with models in science and engineering: Model Formation, Model Use, Model Elaboration, Model Articulation, Model Evaluation, Model Revision, and Model-Based Inquiry. They can be used as stand-alone patterns, or in combinations for in-depth investigations. The key is to organize them as assessment arguments, to enable clear and coherent reasoning about what students know and can do. Assessment arguments provide much-needed structure for coordinating the moving parts of models, cognition, performances, and technology to render integrated and valid insights into student learning. These are tools to help us do it better.

Our goal for this work is to generate a reference that provides insights on design decisions that must be addressed to develop assessments of model based reasoning. We hope these *de-sign patterns* and the framework they are created in can support the design of model-based reasoning in NGSS-inspired assessments, and assessments to come as long as model-based reasoning remains integral to science.

Princeton, USA
Menlo Park, USA
Redwood City, USA
Menlo Park, USA
Menlo Park, USA

Robert J. Mislevy
Geneva Haertel
Michelle Riconscente
Daisy Wise Rutstein
Cindy Ziker

Assessing Model-Based Reasoning using Evidence-Centered Design

A Suite of Research-Based Design Patterns

Mislevy, R.; Haertel, G.; Riconscente, M.; Wise Rutstein, D.; Ziker, C.

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