

Contents

1	Introduction	1
2	Model-Based Reasoning	9
2.1	Scientific Models	9
2.2	The Inquiry Cycle	12
2.3	Some Relevant Results from Psychology	14
2.3.1	Experiential Aspects of Model-Based Reasoning	14
2.3.2	Reflective Aspects of Model-Based Reasoning	15
2.3.3	Higher-Level Skills	16
2.3.4	Implications for Assessment Use Cases	17
3	Evidence-Centered Assessment Design	19
3.1	Assessment Arguments	20
3.2	Design Patterns	22
4	Design Patterns for Model-Based Reasoning	25
5	Model Formation	31
5.1	Rationale, Focal KSAs, and Characteristic Task Features	31
5.2	Additional KSAs	36
5.3	Variable Task Features	39
5.4	Potential Work Products and Potential Observations	42
5.5	Considerations for Larger Investigations	46
5.6	Some Connections to Other Design Patterns	47
6	Model Use	49
6.1	Rationale, Focal KSAs, and Characteristic Task Features	49
6.2	Additional KSAs	53
6.3	Variable Task Features	55
6.4	Potential Work Products and Potential Observations	55
6.5	Some Connections with Other Design Patterns	57

7	Model Elaboration	59
7.1	Rationale, Focal KSAs, and Characteristic Task Features	59
7.2	Additional KSAs	61
7.3	Variable Task Features	61
7.4	Potential Work Products and Potential Observations	63
7.5	Some Connections with Other Design Patterns	64
8	Model Articulation	65
8.1	Rationale, Focal KSAs, and Characteristic Task Features	66
8.2	Additional KSAs	67
8.3	Variable Task Features	67
8.4	Potential Work Products and Potential Observations	68
8.5	Some Connections with Other Design Patterns	69
9	Model Evaluation	71
9.1	Rationale, Focal KSAs, and Characteristic Task Features	71
9.2	Additional KSAs	76
9.3	Variable Task Features	77
9.4	Potential Work Products and Potential Observations	78
9.5	Some Connections with Other Design Patterns	79
10	Model Revision	81
10.1	Rationale, Focal KSAs, and Characteristic Task Features	81
10.2	Additional KSAs	84
10.3	Variable Task Features	85
10.4	Potential Work Products and Potential Observations	86
10.5	Some Connections with Other Design Patterns	86
11	Model-Based Inquiry	89
11.1	Rationale, Focal KSAs, and Characteristic Task Features	90
11.2	Additional KSAs	92
11.3	Variable Task Features	92
11.4	Potential Work Products and Potential Observations	94
11.5	Some Connections with Other Design Patterns	97
12	Conclusion	99
12.1	Standards-Based Assessment	99
12.2	Classroom Assessment	100
12.3	Large-Scale Accountability Testing	101
12.4	Simulation- and Game-Based Assessment	102
12.5	Closing Comments	103
Appendix: Summary Form of Design Patterns for Model-Based Reasoning		105
References		121
Index		129

- Rumelhart, D. E., & Norman D. A. (1977). Accretion, tuning and restructuring: Three modes of learning. In J. W. Cotton & R. L. Klatzky (Eds.), *Semantic factors in cognition* (pp. 37–54). Hillsdale, NJ: Erlbaum.
- Rupp, A. A., Levy, R., DiCerbo, K. E., Sweet, S., Crawford, A. V., Caliço, T., et al. (2012). Putting ECD into practice: The interplay of theory and data in evidence models within a digital learning environment. *Journal of Educational Data Mining*, 4, 49–110.
- Scalise, K., & Gifford, B. (2006). Computer-based in E-Learning: A framework for constructing “Intermediate Constraint” questions and for technology platforms. *Journal of Technology, Learning, and Assessment*, 4(6). Retrieved July 17, 2009, from <http://www.jtla.org>
- Schunn, C. D., & Anderson, J. R. (1999). The generality/specificity of expertise in scientific reasoning. *Cognitive Science*, 23, 337–370.
- Schwarz, C. V., Reiser, B. J., Davis, E. A., Kenyon, L., Achér, A., Fortus, D., ... & Krajcik, J. (2009). Developing a learning progression for scientific modeling: Making scientific modeling accessible and meaningful for learners. *Journal of Research in Science Teaching*, 46(6), 632–654.
- Seibert, G., Hamel, L., Haynie, K., Mislevy, R., & Bao, H. (2006). *Mystery powders: An application of the PADI Design System using the Four-Process Delivery System (PADI Technical Report 15)*. Menlo Park, CA: SRI International.
- Shute, V. J., Masduki, I., Donmez, O., Dennen, V. P., Kim, Y. J., Jeong, A. C., Wang, C. (2010). Modeling, assessing, and supporting key competencies within game environments. In D. Ifenthaler, P. Pirnay-Dummer, & N. M. Seel (Eds.), *Computer-based diagnostics and systematic analysis of knowledge* (pp. 281–309). New York: Springer.
- Shute, V. J., Ventura, M., Bauer, M., & Zapata-Rivera, D. (2009). Melding the power of serious games and embedded to monitor and foster learning. In U. Ritterfeld, M. Cody, & P. Vorderer (Eds.), *Serious games: Mechanisms and effects* (pp. 295–321). New York: Routledge.
- Simon, H. A. (1996). *The sciences of the artificial*. Cambridge, MA: MIT Press.
- Snir, J., Smith, C. L., & Raz, G. (2003). Linking with competing underlying models: A software tool for introducing students to the particulate nature of matter. *Science Education*, 87, 794–830.
- Songer, N. B., Kelcey, B., & Gotwals, A. W. (2009). How and when does complex reasoning occur? Empirically driven development of a learning progression focused on complex reasoning about biodiversity. *Journal of Research in Science Teaching*, 46, 610–631.
- Spitulnik, M. W., Krajcik, J., & Soloway, E. (1999). Construction of models to promote scientific understanding. In W. Feurzeig & N. Roberts (Eds.), *Modeling and simulation in science and mathematics education* (pp. 70–94). New York: Springer-Verlag.
- Steinberg, L. S., & Gitomer, D. G. (1996). Intelligent tutoring and built on an understanding of a technical problem-solving task. *Instructional Science*, 24, 223–258.
- Steinberg, L. S., Mislevy, R. J., Almond, R. G., Baird, A. B., Cahallan, C., Dibello, L. V., ... Kindfield, A. C. (2003). *Introduction to the biomass project: An illustration of evidence-centered assessment design and delivery capability (CSE Technical Report 609)*. Los Angeles: The National Center for Research on Evaluation, Standards, Student Testing (CRESST), Center for Studies in Education, UCLA.
- Stewart, J., & Hafner, R. (1991). Extending the conception of “problem” in problem-solving research. *Science Education*, 75(1), 105–120.
- Stewart, J., & Hafner, R. (1994). Research on problem solving: Genetics. In D. Gabel (Ed.), *Handbook of research on science teaching and learning* (pp. 284–300). New York: MacMillan.
- Stewart, J., Hafner, R., Johnson, S., & Finkel, E. (1992). Science as model-building: Computers and high school genetics. *Educational Psychologist*, 27(3), 317–336.
- Stewart, J., Passmore, C., Cartier, J., Rudolph, J., & Donovan, S. (2005). Modeling for understanding science education. In T. Romberg, T. Carpenter, & F. Dremock (Eds.), *Understanding mathematics and science matters* (pp. 159–184). Mahwah, N.J.: Lawrence Erlbaum.