# Mathematical Modeling: A Structured Process

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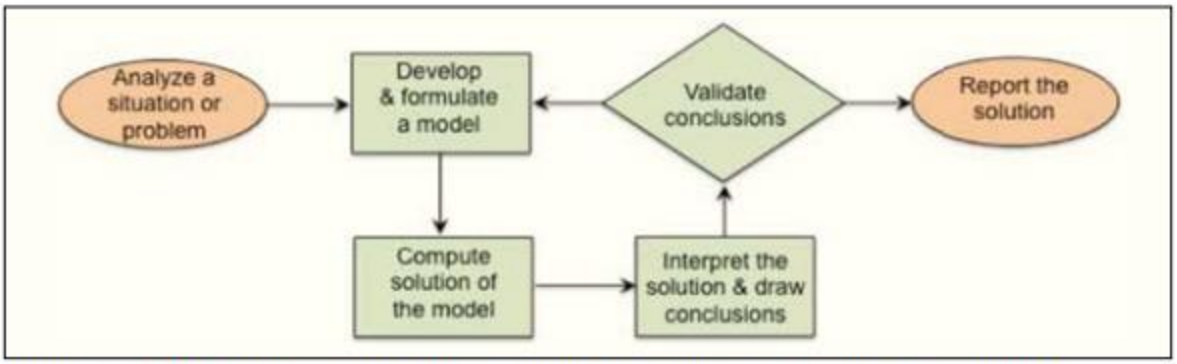


**Fig. 1** Element titles within the modeling cycle (CCSSI 2010, p. 72) have been expanded to be more descriptive.

**Table 1 Elements of Mathematical Modeling and Description of the Work That They Entail**

| Modeling Element | What It Entails |
|---|---|
| 1. Analyze the situation or problem | • Identify a problem taken from an external context (often from an everyday life context) that must be solved or a situation that must be understood and explained.<br>• Do background research if necessary.<br>• Make sense of the situation or problem and understand the question. |
| 2. Develop and formulate a model | • Determine all given information.<br>• Determine what assumptions are necessary.<br>• Translate the information given in the problem together with the assumptions into a mathematical problem that can be solved.<br>• Use mathematics appropriate for the information given and assumed as well as the students' expertise. |
| 3. Compute a solution of the model | • Solve the mathematical problem stated in the model.<br>• Analyze and perform operations in the model.<br>• Check for correctness. |
| 4. Interpret the solution and draw conclusions | • Interpret the mathematical solution in terms of the original situation.<br>• Draw conclusions that the solution implies about the original situation. |
| 5. Validate conclusions | • Reflect on whether the mathematical answer makes sense in terms of the original situation (e.g., is the answer within a valid range of values?).<br>• If the conclusions are satisfactory with regard to the accuracy needed, report the solution. If the conclusions are not satisfactory or need to be improved, go back to stage 2 ("Develop and formulate a model"). |
| 6. Develop and formulate a new or modified model | • Revise the assumptions made according to what was learned in the first solution and translate them into a new or modified mathematical problem that can be solved.<br>• The type of mathematics in the current model may be different from the previous one.<br>• Go through these stages again: Compute, Interpret, and Validate. |
| Report the solution | • Share your conclusions and the reasoning behind them. |

**Table 2 Mathematical Modeling Task Categories for Evaluating**

| Categories for Scoring | Score | Observations and Comments |
|---|---|---|
| Reasonable and relevant assumptions | | |
| Formulation of a model based on assumptions | | |
| Solution of the model | | |
| Interpretation of solution | | |
| Validation of conclusions | | |
| Modeling cycle—revised assumptions and model | | |
| Reflection on thought process as the model was created and the modeling cycle considered | | |
| Reflection on other ways to model this problem besides the approach taken | | |
| | **Total** | |

**Table 3 A General Rubric for Assessment of Modeling Problems**

| | 5 | 4 | 3 | 2 | 1 | 0 |
|---|---|---|---|---|---|---|
| Explanations | Demonstrates full understanding and provides full explanations: justifications and explanations demonstrate understanding of concepts | Demonstrates basic understanding and provides minimal explanations | Demonstrates some understanding but has some gaps, brief explanations | Demonstrates little understanding, gaps in thinking, little to no explanations | Demonstrates some partial understanding with no explanation | Shows no evidence of understanding |
| Connections | Shows ideas that are well-connected: uses more than one concept and shows understanding of their connection | Shows ideas that are well connected | Shows ideas that are partially connected, missing points, or unclear | Shows ideas that are not well connected | Shows ideas that are not well connected | |
| Work | Provides complete work: includes assumptions and solutions that follow them | Provides complete work | Provides incomplete work but includes essential information | Provides incomplete work, missing some essential information | Provides incomplete work, missing essential information | Shows no evidence of work |
| Reasoning | Shows evidence of thoughtfulness and reasoning | Shows evidence of reasoning | Shows evidence of partial reasoning | Shows little evidence any reasoning | Shows evidence of faulty reasoning | |
| Concepts | Displays correct conceptual mathematical ideas: uses appropriate and multiple representations, uses appropriate concepts for the given problem | Displays correct conceptual mathematical ideas | Displays partial correct conceptual mathematical ideas | Displays incorrect conceptual mathematical ideas | Displays incorrect conceptual mathematical ideas | |
| Calculations | Presents correct calculations (possibly one minor error): numerical calculations are correct, appropriate units are used | Presents minor errors in calculations | Presents consequential errors in calculations | Presents significant errors in calculations | Presents significant errors in calculations | |