1 ❑ *Cognitive and Instructional Issues in System Modeling*


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2 ❑ **MS in System Management,** College of Notre Dame, Belmont CA

- Exploit similarities among systems
- Transfer analysis and problem-solving from one management context to another
- Managers apply systems thinking in technologically oriented industries
- Students come from aerospace, biotechnology, materials science, telecommunications, computer hardware, and software industries

3 ❑ **Metaphors and Analogies**

- Concrete, memorable, and resonant with students' prior knowledge
- More complexity, more difficult to understand and predict
- Need refinement to mathematical models
- Example of early 20th Century physics: Rhodes, *Making of the Atomic Bomb*

4 ❑ **Modeling Tools for Organizations**

- Bridge from metaphor (jungle, machine, team, family, community, rational individual, learner) to data
- Represent systems accurately without representing them completely
- Organize & interpret data
- Visualize, communicate with a group

5 ❑ **Cognitive research on problem solving and reasoning**

- Rule-based expertise
- Solving puzzles, algebra, geometry, and computer programming
- Metaphor or mental models
- Misconceptions in physics, computer systems, medicine, probability
- Explanation of error patterns

6 ❑ **Rule-based Expertise**

- Knowledge from past problem-solving experiences
- Rules to define legal moves through problem-space
- Low memory load
- Well-defined problems

## 7 ❑ Metaphor & Analogy in Problem Solving

- Structure problem-space, control search
- Progress within memory capacity
- Plans remembered long enough to be implemented
- Insufficient for real system

## 8 ❑ From Metaphor to Mental Models

- More variables, more interactions
- From logic to troubleshooting
- Heuristic rules supplemented by models
- Progression from novice to expert
- Physics, economics, human-automation
- Instructional software using carefully designed sequences of models

## 9 ❑ Mental Models in Problem Solving

- Useful but insufficient
- Mental models operationalized different ways
- Can't analyze real systems mentally
- System complexity limits data collection
- Not extensible

## 10 ❑ Management Students

- Need to develop problem-solving skills
- Analyzing novel situations, creating new solutions, transfer of learning
- Work in business settings constrained by
- Rapid decision making
- No experimentation

## 11 ❑ System Modeling in Problem Solving

- Establish correct mental models
- Supplement limited human memory
- Organize and interpret data
- Encourage testing and refining business processes
- Support thinking about new possibilities
- Flexible, extensible, refinable

## 12 ❑ Rule-based Analysis

- Linear programming, forecasting, inventory, queuing analysis
- Recognition of types, matching of structures
- Limited in scope
- Artificially simplified problems

13 ❑ **Modeling with *iThink***

- Simple, graphical, affordable tool
- Solves problems in ordinary differential equations
- Draw relationships among components
- Output numeric, graphical, and animation

14 ❑ **Goals for Model-Based Instruction - 1**

- Identify components of the system
- Partially describe functions
- Verbalize relations and interactions among system components
- Describe qualitative causation, expectations, and interpretations of the performance of the system

15 ❑ **Goals for Model-Based Instruction - 2**

- Predict and explain step-by-step system performance
- "Think-aloud" during problem-solving
- Develop plan for problem approach
- Groups discuss conclusions from results

16 ❑ **Goals for Model-Based Instruction - 3**

- Show how model solves different problems
- Identify metaphorical or analogical explanations
- Integrate several model versions

17 ❑ **Students' Initial Modeling Efforts**

- System, model, and tool are overwhelming to the student
- "As-is" defined, not "what must be"
- Process vs. system: trace path of individual person or object, rather than showing system
- Extensible: How to add elements/relations?
- Sensitivity analyses: do not lead to questioning structure of model

18 ❑ **Problem of Resources**

- How many resources should be used?
- Pick just one, or too many
- "Mix up units"
- "What is perceived quality?"
- "Where do I plug in the data?"

19 ❑ **Problem of Feedback**

- Linear flows with no feedback
- Do not anticipate time-lag
- Feedback in process control

- "Everything I expected came out different"
- "Why didn't a change have immediate impact?"

20 ❑ **Problem of Levels**

- Fundamental to controlling complexity (nested subroutines in computer programming)
- Students: flat models with no hierarchy
- Need at least three modeling levels, with easy movement

21 ❑ **Summary of Student Problems**

- Student problems mirror properties of mental models
- Small models, due to working memory limits
- Diagrammatic, not dynamic, models
- Concrete situations represented

22 ❑ **Instructional Solution**

- Analogy/Metaphor
- Rules What is the policy? But what if ?
- Mental Models some degree of coherence
- Multiple Mental Models coverage
- Integrated Models require *iThink*

23 ❑ **Communication**

- *iThink* as a mechanism for modeling and communicating
- Students capture features of real life
- Brain-storming and problem-solving tool

24 ❑ **Selected Research on Mental Models**

- Gentner & Gentner'83: metaphors
- Johnson-Laird & Byrne'91: logic
- White & Frederiksen'85: physics
- Gott, Bennett, Gillet'86: troubleshooting
- Salter (n.d.): macro-economics
- Feltovich, Spiro, Coulson'89: medicine
- Jonassen'96: methodology