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