Developing and Assessing Knowledge and Skills in Complex Domains

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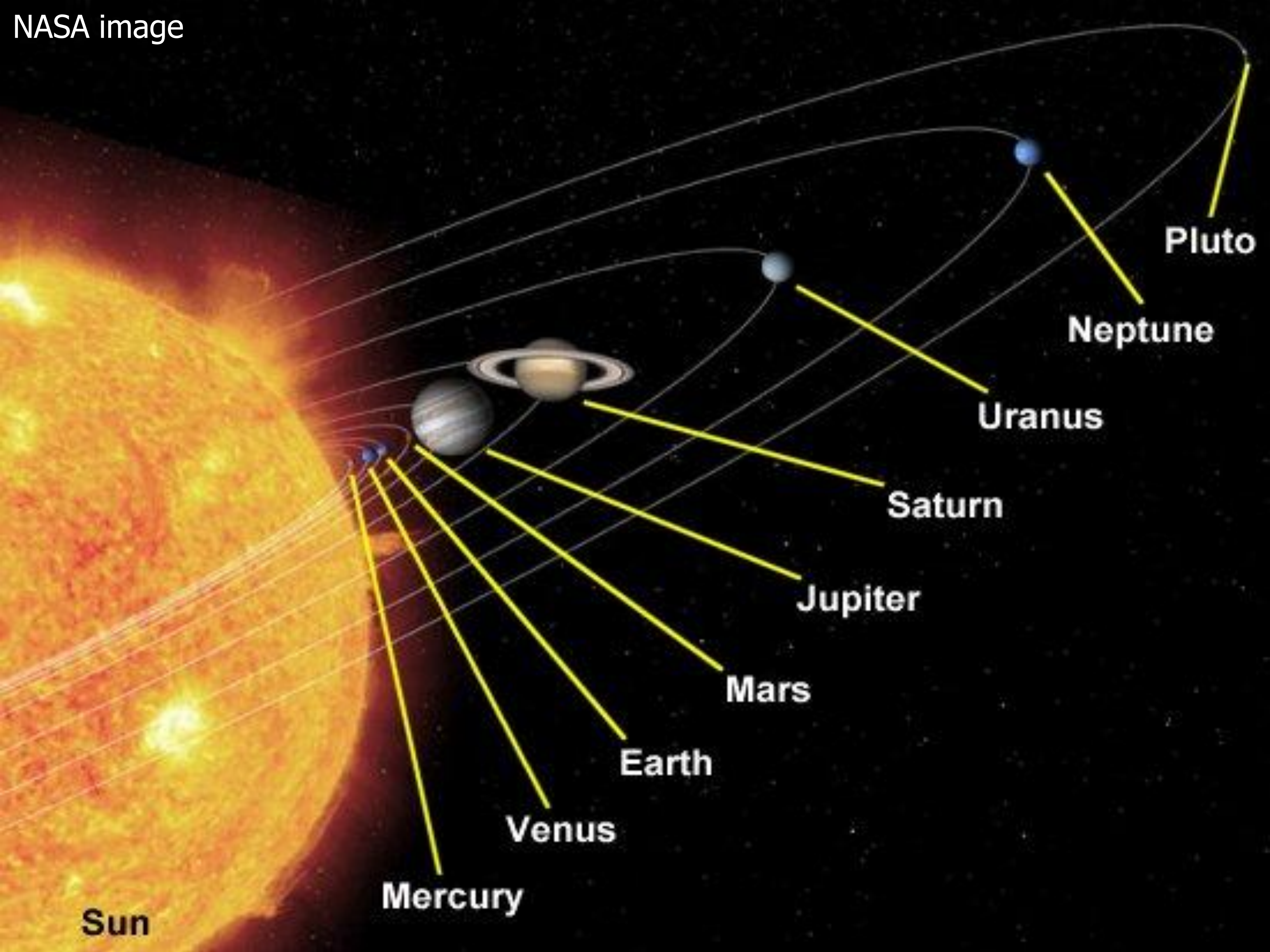

NASA image
Pluto
Neptune
Uranus
Saturn
Jupiter
Mars
Earth
Venus
Mercury
Sun

The Context and the Problem

- Learning → observable, persistent change(s) in abilities, attitudes, beliefs, knowledge, and skills
- Complex ,dynamic and ill-structured problem solving → few standard problems, multiple solutions
- Detecting relevant changes and measuring growth and progress→ **How?**

Instructional Assessment

- Timely, informative, personally meaningful feedback promotes learning
- Two types of assessment
  - Summative
  - Formative
- Formative assessment is critical in developing knowledge and expertise

The Logic of Assessment

- To measure growth and progress, there should be a target
  - Better than past performance
  - Consistent with established standards
  - Approaching competent performance or expert-like performance
- A performance standard should be linked with the kind(s) of things being learned

What Makes Tasks Complex?

- Unfamiliar task domain
- Lack of appropriate background
- Many interrelated aspects involved
- Non-recurrent aspects (van Merriënboer, 1997)
- Dynamic aspects (Sterman, 1994)
- Ill-structured aspects (Newell & Simon, 1972)
- Uncertain aspects (Rittel & Webber, 1973)

Learning Goals for Complex Tasks

- *Deep understanding*
  - Capacity to manage dynamic aspects
  - Able to transfer knowledge from less similar tasks and develop an appropriate solution approach quickly
  - Capable of working with others with different backgrounds in developing and implementing solution

The Development of Expertise

- Expertise is developed through
  - Experience (Dewey, 1938)
  - Practice with feedback (Gagné, 1985)
  - Failure (Schank, 1989)
  - Reflective practice (Ericcson, 2001)
- Experience results in
  - Mental model development (Johnson-Laird, 1983)
  - Automaticity, schema and scripts (Seel, 2003)
  - Speed in developing appropriate responses
  - Flexibility in modifying solution approaches

Problem Focus

- Matching instructional approach with types of problem-solving tasks and learner characteristics
- Linking objectives to learning activities and assessments
- Tools and technologies to support design, development, delivery, and assessment and evaluation

A Dilemma

- Internal representations are critical for reasoning, development, and learning
- However, internal representations are not directly observed
- One way to improve learning is to facilitate the development of meaningful and useful mental models
- One way to assess understanding is to examine mental models and look for productive developments
- But making such observations is necessarily indirect and inferential

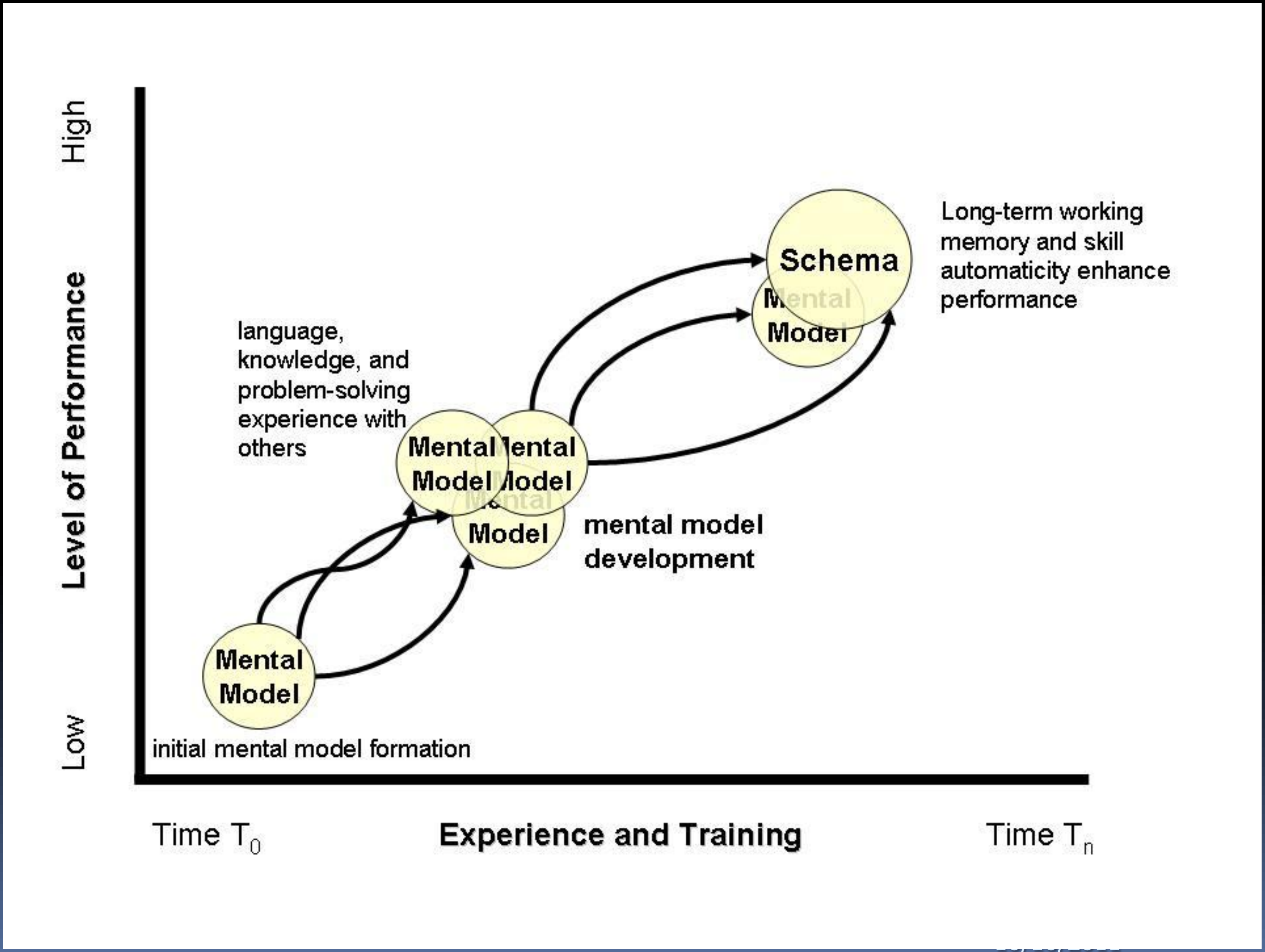
Right on Target, So Direct

- Be as direct as possible in examining mental models
- Behavior is two steps away – one step in terms of a time delay, and a second step in terms of the relationship to an underlying mental model
- The traditional way out of this dilemma was to say that what was important was the behavior or the performance
- From an instructional design perspective, the traditional way out is deficient because it does not inform the learner of how or what to improve

What is a Mental Model?

- A hypothetical or inferred entity
- Used to explain certain phenomena, such as differences in responding to highly familiar situations and unfamiliar situations and various problem solving behaviors
- Created just when needed – transient
- May develop into automated response mechanisms called schema
- Not a schematic diagram nor a concept map – those are external representations of mental models, but they may share critical attributes of mental models

Mental Model Development



Talk Aloud Protocols

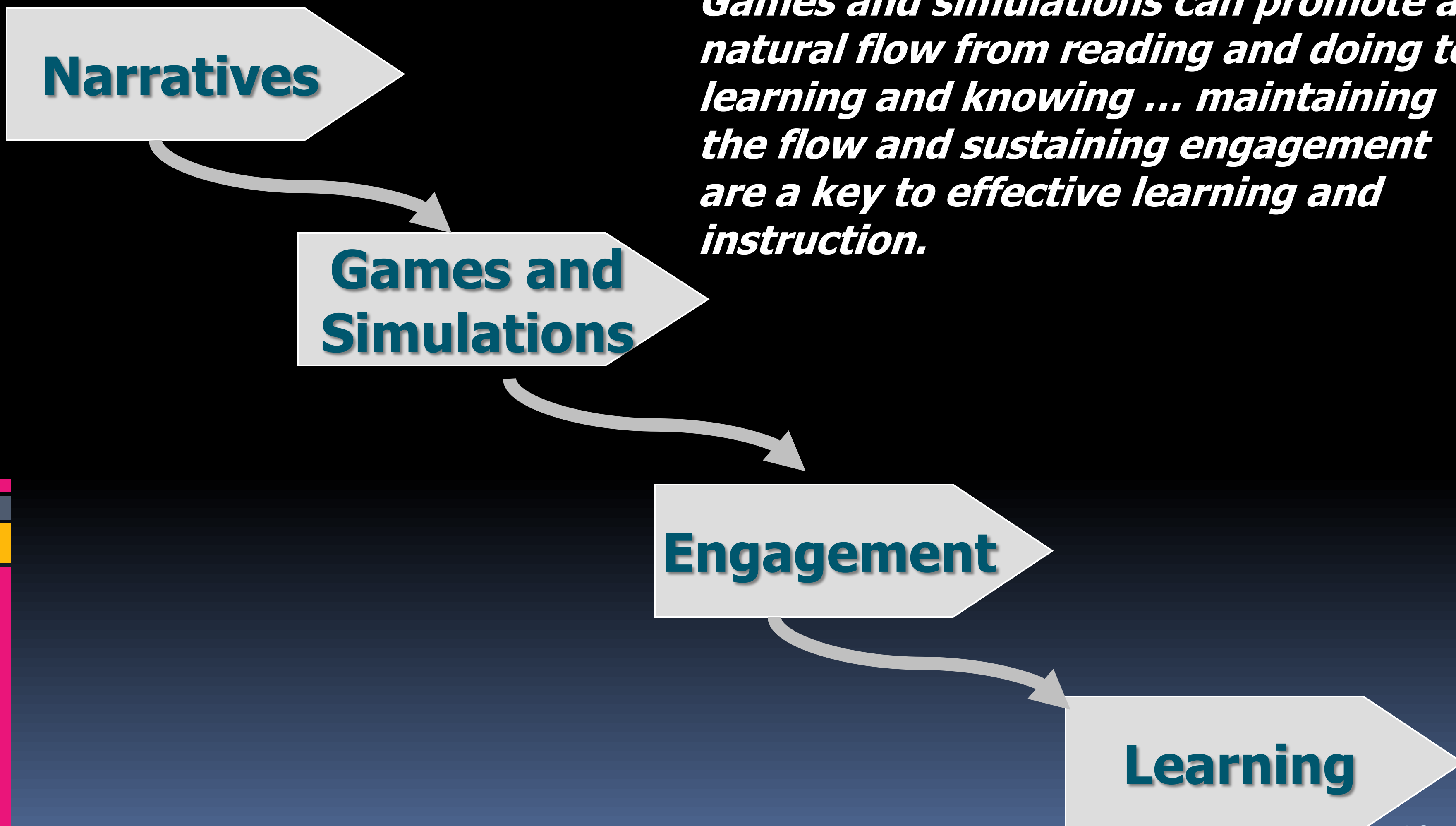
- Ericsson used the talk aloud protocol method – have the person simply say out loud what he/she was doing (primarily descriptive but could include simple explanations and elaborations)
- Believed by many to closely reflect the mental models and other internal, hidden mechanisms involved in solving problems
- But, not easily analyzed and not a scalable methodology

The Role of Narrative

- Ericsson used narratives – talking aloud – to gain insight into human thinking and problem solving
- Narratives are a natural part of both formal and informal learning situations
- However, narratives may not be close in form to internal, hidden models and it is difficult to provide timely, informative feedback when many narratives are involved – at least that was the case until recently

Narrative Approaches

Games and simulations can promote a natural flow from reading and doing to learning and knowing … maintaining the flow and sustaining engagement are a key to effective learning and instruction.



A Tale of Three Tools

- DEEP – to elicit problem conceptualizations (visually based, annotated causal concept maps)
- MITOCAR – to generate concept maps from narratives
- SMD – to compare two concept maps and indicate similarity

HIMATT is the integrated set – Highly Interactive Model-Based Assessment Tools and Technology

Dynamic Evaluation of Problem Solving Abilities

- **Model problem-conceptualizations of highly experienced persons**

- **Metrics to assess progress towards expert-like problem conceptualizations**
    - surface analysis
    - structural analysis
    - semantic analysis

Relevant Research

- Expert Performance
  - Ericsson: think-aloud protocol analysis; deliberate practice (2001)
- Concept Mapping Analysis
  - Herl & O'Neil: semantic nets in well-structured domains (1999)
  - Taricani & Clariana: concept map metrics
- Levels of Analysis
  - Davidsen, Christensen & Spector: University of Bergen (2000)
  - Seel: University of Freiburg (2001)

Development Challenges

- Differences across domains and within domains
- Representing thinking and linking to performance
- Scalable methods for use in classroom settings– think-aloud protocol analysis is not scalable

Problem Conceptualization Models

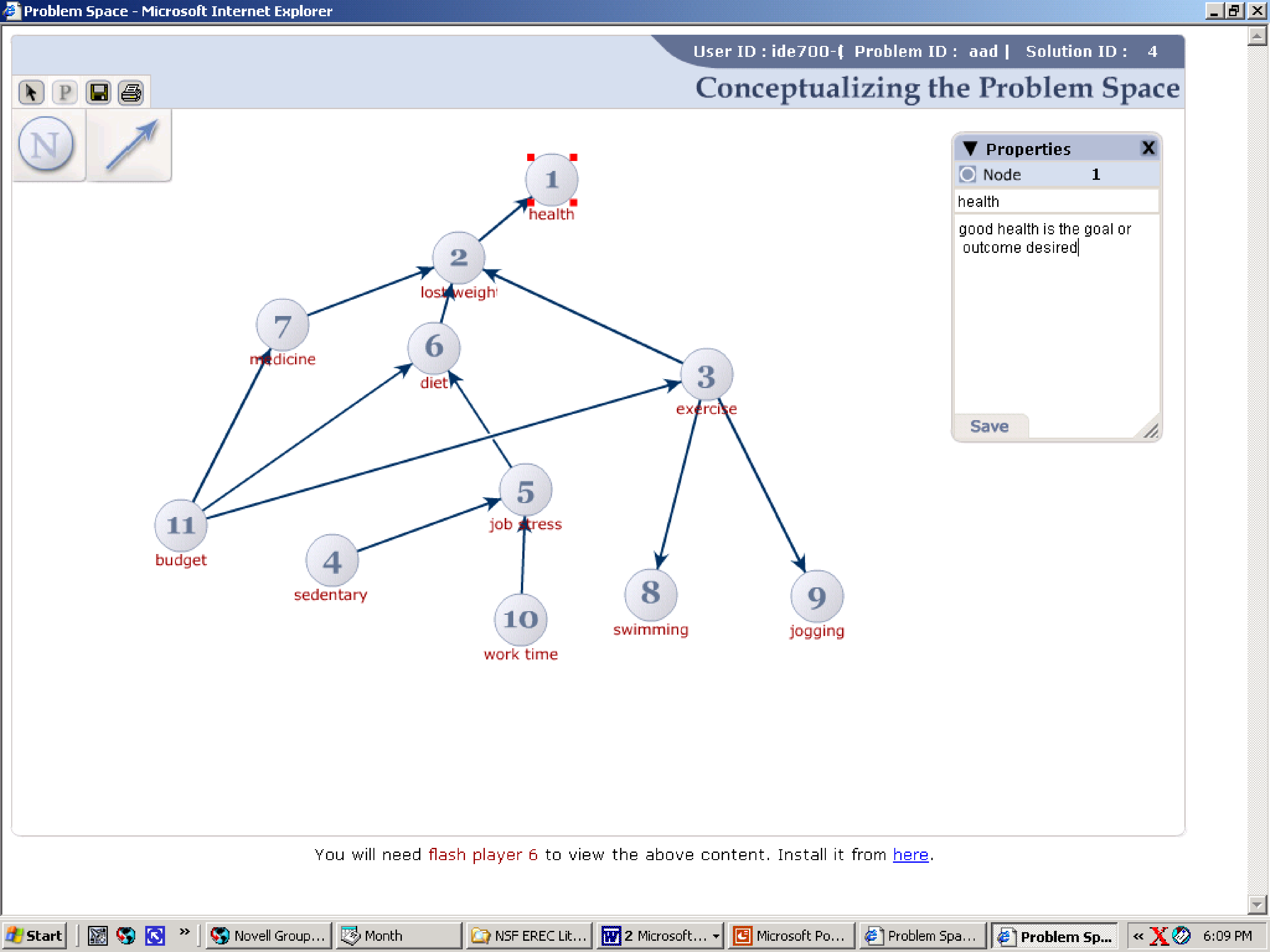
- To detect changes in understanding
- To detect improved understanding
- To determine optimal instructional approach
- To provide meaningful personalized feedback
- To facilitate collaborative learning

Dynamic Enhanced Evaluation of Problem Solving (DEEP)

- Different domains
- Experts and non-experts
- Representative problems in each domain
- Annotated causal concept maps
  - Related to Seel's (2001, 2003) work and that of Milrad et al. (2000, 2002)

Conceptualizing the Problem Space

- Present problem situation, scenario, story
- Identify 5 to 10 key factors influencing resolution of the problem situation
- Describe each factor
- Identify critical relationships among these factors
- Describe the relationships
- THEN, two reflective questions: What else needs to be known to actually resolve the problem, and what assumptions have been made in answering the previous questions


Problem Space - Microsoft Internet Explorer
User ID : ide700-(Problem ID : aad | Solution ID : 4
Conceptualizing the Problem Space
N
1
health
2
lost weight
3
exercise
4
sedentary
5
job stress
6
diet
7
medicine
8
swimming
9
jogging
10
work time
11
budget
Properties
Node 1
health
good health is the goal or outcome desired
Save
You will need flash player 6 to view the above content. Install it from here.
Start
Novell Group...
Month
NSF EREC Lit...
2 Microsoft...
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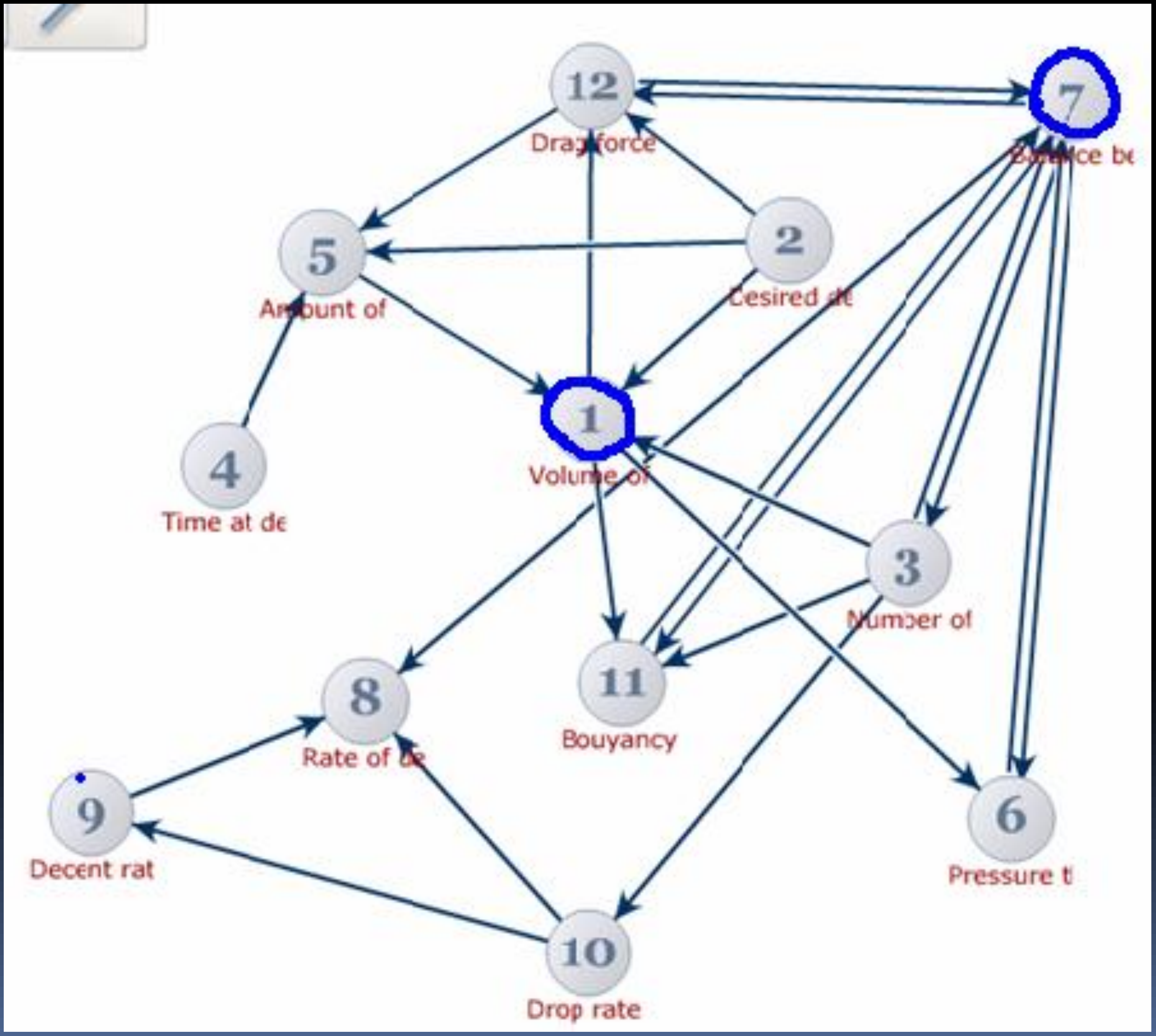
Surface Analysis – Scenario 1

Scenario #	Domain	Group	Avg. # nodes	Avg. one-way links	Avg. two-way links	Avg. words-node	Avg. word-node-name	Avg. words-link
Scenario 1	Medical							
		Novices	13.07	16	6.86	15.86	1.83	11.57
		Experts	10.6	17.6	4	26.6	2.24	21.2
	Engineering							
		Novices	9	12	2	22.9	2.6	7.25
		Experts	8	8	1.5	11.15	2.55	16
	Biology							
		Novices	7.36	10.29	1.14	39	2	24.86
		Experts	16	20.6	0.6	12.8	1.8	8.8

Structural & Semantic Analysis

- Intertwined and interdependent in the initial study
- Protocols for semantic analysis based on expert reviews
- Similarities and differences among and between experts and non-experts

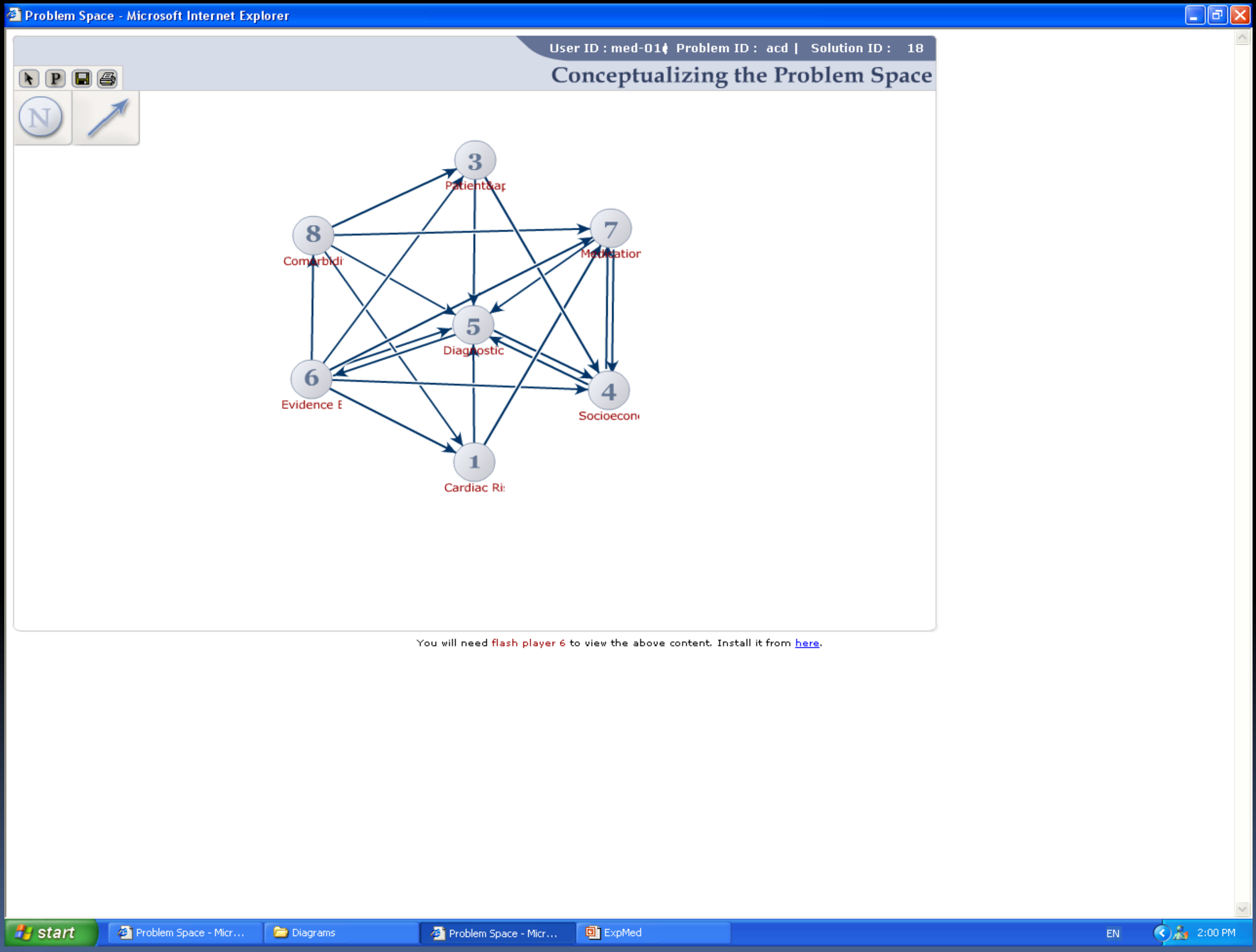
Node-Link Clusters



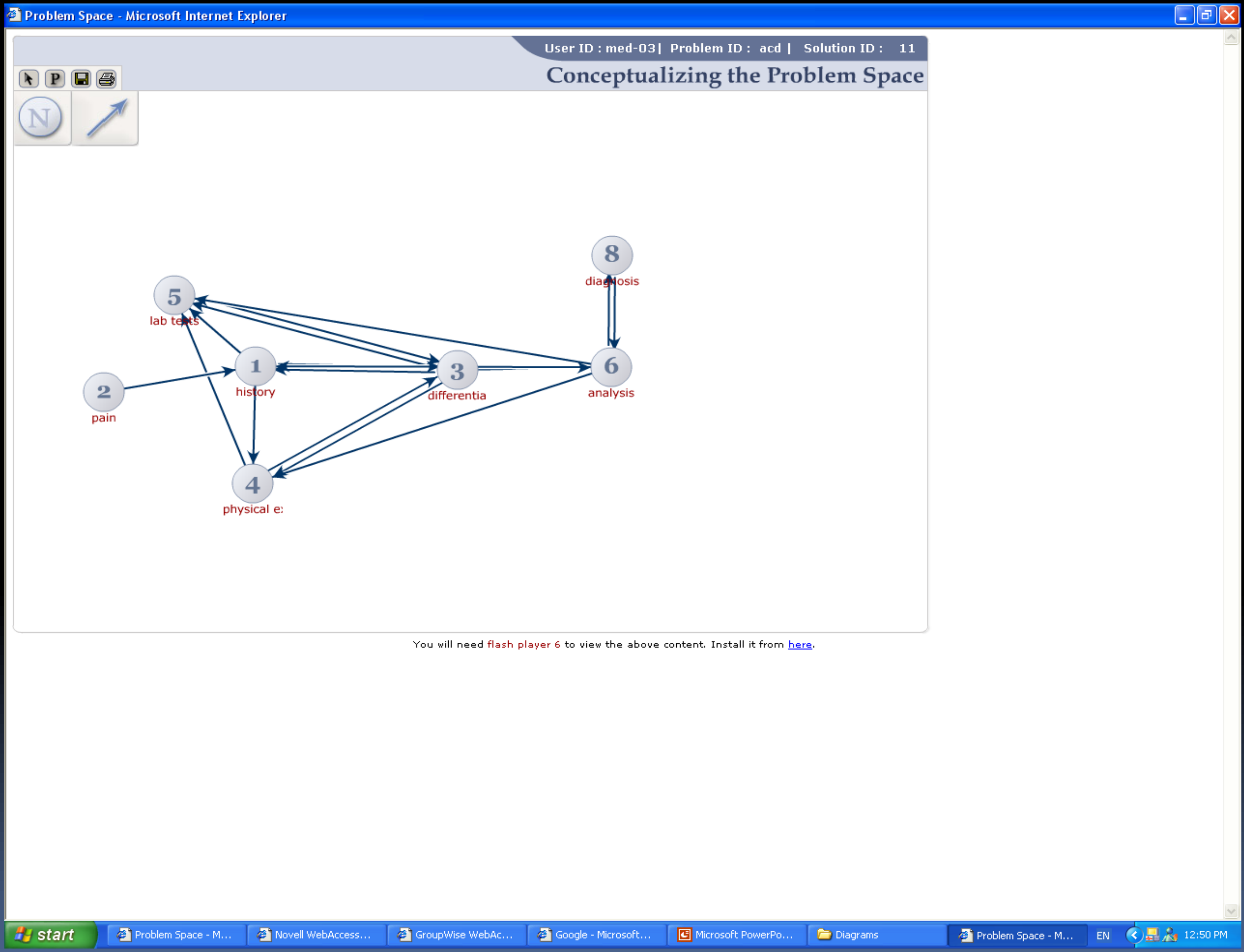
A Similarity & Analysis Metric

- Hypothesis: experts will tend to think more systemically than non-experts
- Indicators of systemic thinking:
  - Internal feedback (links to other parts of the system; two-way links)
  - One possible measure – ratio of unreachable pairs to all possible ordered pairs of nodes in the problem conceptualization

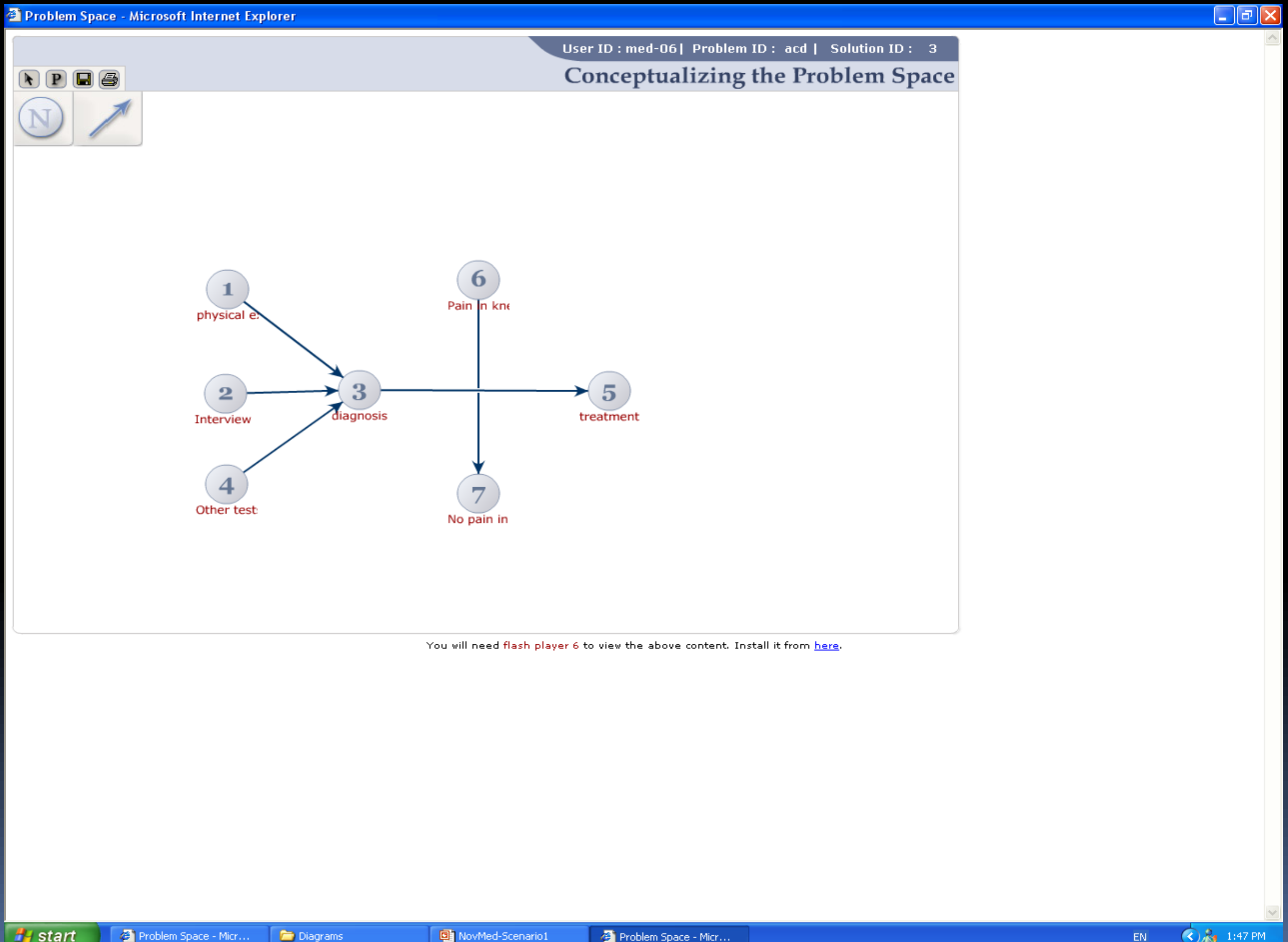
Orphan Nodes



An Expert Example



A Novice Example



Comparing Experts & Novices: Key Nodes / Clusters

Biology Experts – Scenario 2 (N = 5; Links = 128).

	Nodes	*Links*	*From / To*	*Percentage*
1	Analyze the mercury concentrations	16	9 / 7	12.5%
2	Possible solutions	14	7 / 7	10.93%
3	Food chain	12	7 / 5	9.37%
3	Source of mercury contamination	12	8 / 4	9.37%
4	Limit consumption	11	7 / 4	8.59%

Biology Novices – Scenario 2 (N = 16; Links = 147).

	Nodes	*Links*	*From / To*	*Percentage*
1	Biological effects of mercury on fish	41	21 / 20	27.89%
1	Source of mercury contamination	41	24 / 17	27.89%
2	Human interaction	29	12 / 17	19.72%
3	Social awareness	28	13 / 15	19.04%
4	Analyze the mercury concentrations	24	17 / 7	16.32%

Implications for Learning and Instruction

- Provide feedback based on comparative analyses of causal concept maps
- Identify distractions - factors contributing to unnecessary cognitive load

Collaborative Learning and Concept Mapping

- Exposure to alternative paths and points of view
- Support for focusing activities
- Effective, efficient way to assess understanding in complex domains
- Expert models can support novice learning processes
- Engage learners in collaborative processes
  - Group map construction requires negotiation of knowledge
  - Individual maps stimulate group conversation and subsequent concept map development

Questions?

To have a question is to be in a state of uncertainty **AND** to be engaged in a search for knowledge.

We may know less than we are generally inclined to believe.

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