Knowledge Objects & Mental Models

M. David Merrill
Professor
Utah State University

Overview

- Knowledge components
- Knowledge Structures
- Schema
- Mental Models
- Conceptual Networks
- Process models (PEA-NETS)
- Meta-Mental Models

Cardinal Principles of Instruction

- **The Cognitive Structure Principle**
  - … the development of that cognitive structure that is most consistent with the desired learned performance.
- **The Elaboration Principle**
  - … incremental elaboration for increased generality and complexity
- **The Learner Guidance Principle**
  - **…** active cognitive processing
- **The Practice Principle**
  - **…** monitored learner performance with feedback

Categories of Knowledge

- **Bloom et al, 1956 Krathwohl et al 1965 Taxonomy**
- **Gagné 1965 - 1985 Conditions**
- **Merrill 1994 Component Display Theory**

Knowledge Structure

- **Knowledge structure is the relationship among knowledge components.**
  - Two questions:
    - What are the components of knowledge?
    - What relationships among these components are important for learning?

Gagné Learning Hierarchy

- **Prerequisite relationship**
  - What capability from prior learning must a learner have to be able to acquire a new capability?
  - What should the learner already know how to do and be able to recall in order to acquire new knowledge or learn a new skill?

Other knowledge Structures

- List
- Learning-Prerequisite
- Parts-Taxonomy
- Kinds-Taxonomy
- Procedural-Prerequisite
- Procedural-Decision
- Causal

- List
- Taxonomies
  - parts
  - kinds
  - properties
  - functions
- Algorithms
  - path
  - decision
- Causal nets
  - event chains
  - causal chains

Knowledge Objects and Structures

A knowledge objects and its components are a precise way to describe the content to be taught.

A knowledge object is uncoupled from the strategies used to present, practice, or test this knowledge.

Knowledge objects can be combined into knowledge structures.

Knowledge structures are external representations of knowledge that are parallel with mental models that are internal (cognitive) representations of models.

Learning Objects vs Knowledge Objects

Learning objects are not the same as knowledge objects.

- Learning Objects are small modules of instruction.
- Knowledge objects are **not** complete modules of instruction.

- Learning objects are usually defined as an objective, some instructional information, and assessment.
- Knowledge objects include **only the content** to be learned but not an objective, presentation, or assessment.

Learning Objects vs Knowledge Objects

- Learning Objects combine the knowledge to be learned with the strategy for presenting, practicing, or assessing this knowledge.
- Knowledge objects are uncoupled from the instructional or information strategies used to present them.
- Learning objects have a given instructional strategy built-in.
- A given knowledge object can be used for a variety of different instructional strategies.
  - Knowledge objects can be used in visualizations and experiential environments.
  - Knowledge objects can be used for practice or assessment.
  - Knowledge objects can be used for simulation, visualization, or experiential environments.

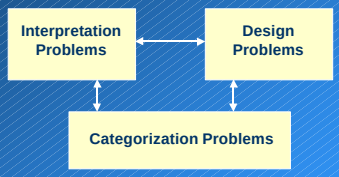
Components of Knowledge Objects

- **Entities -- things, objects**
- **Actions -- activities of the learner**
- **Processes -- events, often consequence of action**
- **Properties -- qualitative or quantitative descriptors**

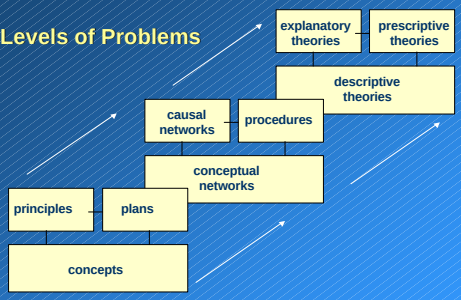
Components of Knowledge Objects

Entity: Name Description Portrayal	**Part:** Name Description Portrayal	**Property:** Name Description Value Value portrayal
Action: Name Description Process trigger	**Process:** Name Description Condition (value of property) Consequence (property value changed) Process trigger	**Kind:** Name Description Definition (list of property values)

Kinds of Problems



Levels of Problems



Concept Knowledge Structure

		Property 1	Property 2	Property 3
Name of super-ordinate class	Coordinate Class A	$Value_1$	$Value_1$	$Value_1$
	Coordinate Class B	$Value_2$	$Value_2$	$Value_2$
	Coordinate Class C	$Value_3$	$Value_3$	$Value_3$

Table 2 Knowledge Structure for Concept.

Example of concept structure

		Shape of leaves	Retains leaves in Autumn	Leaves change color in Autumn
Tree	Deciduous	Broad, flat	No	Yes
	Conifer	Needle like	Yes	No
	?	Broad, flat	Yes	No

Table 3 Instantiation of Knowledge Structure for Concept.

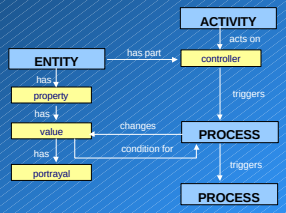
Conceptual Network

	Coordinate concepts	Coordinate concepts	Property 1	Property 2
Superordinate concept I	concept $_{IA}$	Concept $_{IAa}$	V_1	V_1
		Concept $_{IAb}$	V_1	V_2
		Concept $_{IAc}$	V_1	V_3
	concept $_{IB}$	Concept $_{IBa}$	V_2	V_1
		Concept $_{IBb}$	V_2	V_2
		Concept $_{IBc}$	V_2	V_3
	concept $_{IC}$	Concept $_{ICa}$	V_3	V_1
		Concept $_{ICb}$	V_3	V_2
		Concept $_{ICc}$	V_3	V_3

Example Conceptual Network

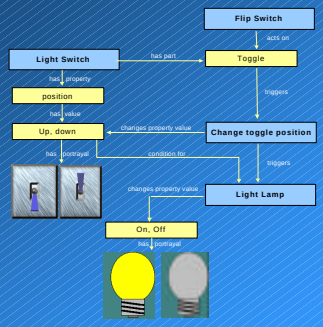
	Coordinate concepts	Coordinate concepts	Locomotion	Source of food
Animal	Bird	Finch	Fly	Plants
		Hawk	Fly	Animals
		Sparrow	Fly	Both
	Insects	Ant ...	Crawl	Plants
		Spider ...	Crawl	Animals
		Bug ...	Crawl	Both
	Mammal	Cow ...	Walk	Plants
		Lion ...	Walk	Animals
		Dog ...	Walk	Both

PEA-NET Structure



A process is knowledge about how something works.

Example of PEA-NET structure



Example of PEA-NET Structure

Property and Legal Values	Portrayal	Property and Legal Values	Portrayal
Mood = Happy		Mood = Angry	
Mood = Sad		Entity = Boss Present = Yes	
Mood = Surprised		Entity = Boss Present = No	

PEA-NET Table Form

Action		Process		Consequence	Condition
Statement "We have a new contract."	*triggers*	Make Mark happy	*changes*	Mood = happy	
Statement "But you don't get to direct the project."	*triggers*	Make Mark sad	*changes*	Mood = sad	
Statement "Jean will direct this project"	*triggers*	Make Mark surprised	*changes*	Mood = surprised	
Statement "You get to work for Jean"	*triggers*	Make Mark angry	*changes*	Mood = surprised	Boss present = yes
				Mood = angry	Boss present = no

Mental Models

- **A mental model is a schema plus a cognitive process.**
- **A knowledge structure is a form of Schema.**
- **Cognitive processes are algorithms or heuristics for manipulating a schema or the components of a knowledge structure.**

Classification

		Shape of leaves	Retains leaves in Autumn	Leaves change color in Autumn
	Deciduous	Broad, flat	No	Yes
Tree	Conifer	Needle like	Yes	No
	?	Broad, flat	Yes	No

- Remember properties and values for each category (definition).
- For each example find portrayal of a property in portrayal of example. Determine its value. Repeat for each property.
- Compare property values with those for class. When match give name.

Generalization

	Coordinate concepts	Coordinate concepts	Locomotion	Source of food
		Finch	Fly	Plants
	Herbivore	Ant	Crawl	Plants
		Cow	Walk	Plants
		Hawk	Fly	Animals
Animal	Carnivore	Spider	Crawl	Animals
		Lion	Walk	Animals
		Warbler	Fly	Both
	Omnivore	Bug	Crawl	Both
		Dog	Walk	Both

A generalization is when classes from different sets of coordinate concepts are seen as coordinate concepts for a new set of coordinate concepts.

Explanation

- Asking a student outline the PEAnet of a given process provides a very precise way to assess the completeness and accuracy of the learner's mental model.

Prediction

- Explanation is level 1 of Dijkstra's levels of problems.
- The algorithm (cognitive process) for prediction involves:
  - find conditions relevant to the consequence -- that is, find portrayal of property(s) and determine current value.
  - Remember the principle in terms of conditions and consequences.
  - Predict change in property(s) value that will occur and the corresponding change in property portrayal.

Trouble Shooting

- **Algorithm for trouble shooting**
  - Shown consequence (change in property value) find condition (property values) that caused this consequence.
  - What property was changed?
  - Recall relevant principle.
  - Match consequence to appropriate principle.
  - Identify conditions that must have been faulted.
  - Find portrayal of potentially faulted condition property
  - Does value match principle, if not this is faulted condition.

Meta-Mental Model

- Models about models.
- Knowledge structures provide meta-mental models that may facilitate learning.

Automated Instructional Design

- The processes identified for manipulating the knowledge objects in a knowledge structure provide the bases for computer algorithms that can emulate some of the processing done by a learner.

Summary

- Knowledge components
- Knowledge Structures
- Schema
- Mental Models
- Conceptual Networks
- Process models (PEA-NETS)
- Meta-Mental Models

Plan Now for

13th Annual
Utah State University
Instructional Technology Institute

August 28 - August 31, 2001

Utah State University Conference Center

Instructional Design, Training and Technology:
Finding Common Ground