Authoring Tools, Complexity, Epistemic Forms, and Cognitive Development:

"What works for authors?"

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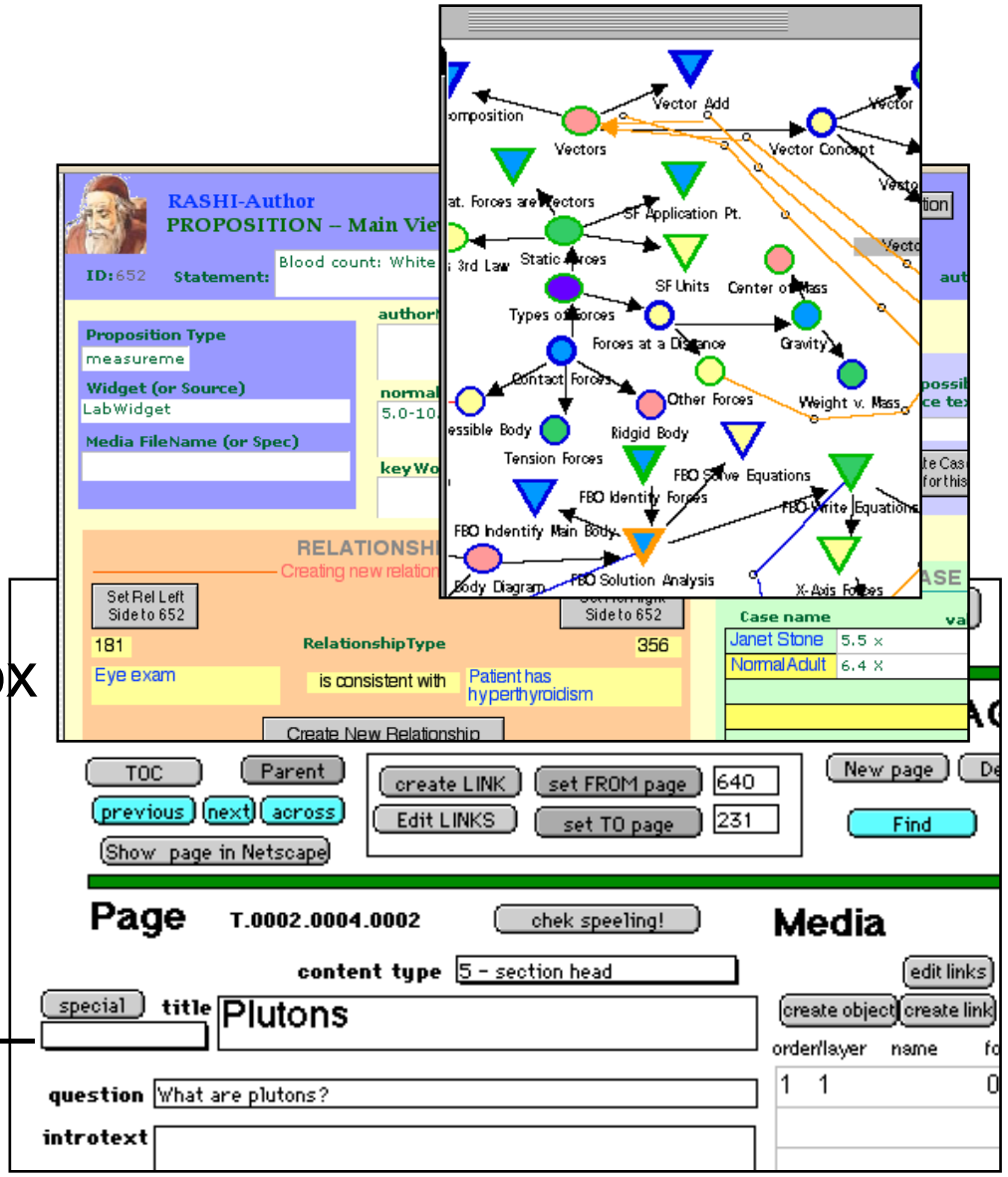
ITS 2014 Workshop:
Intelligent Tutoring System Authoring Tools

Authoring Tool Projects

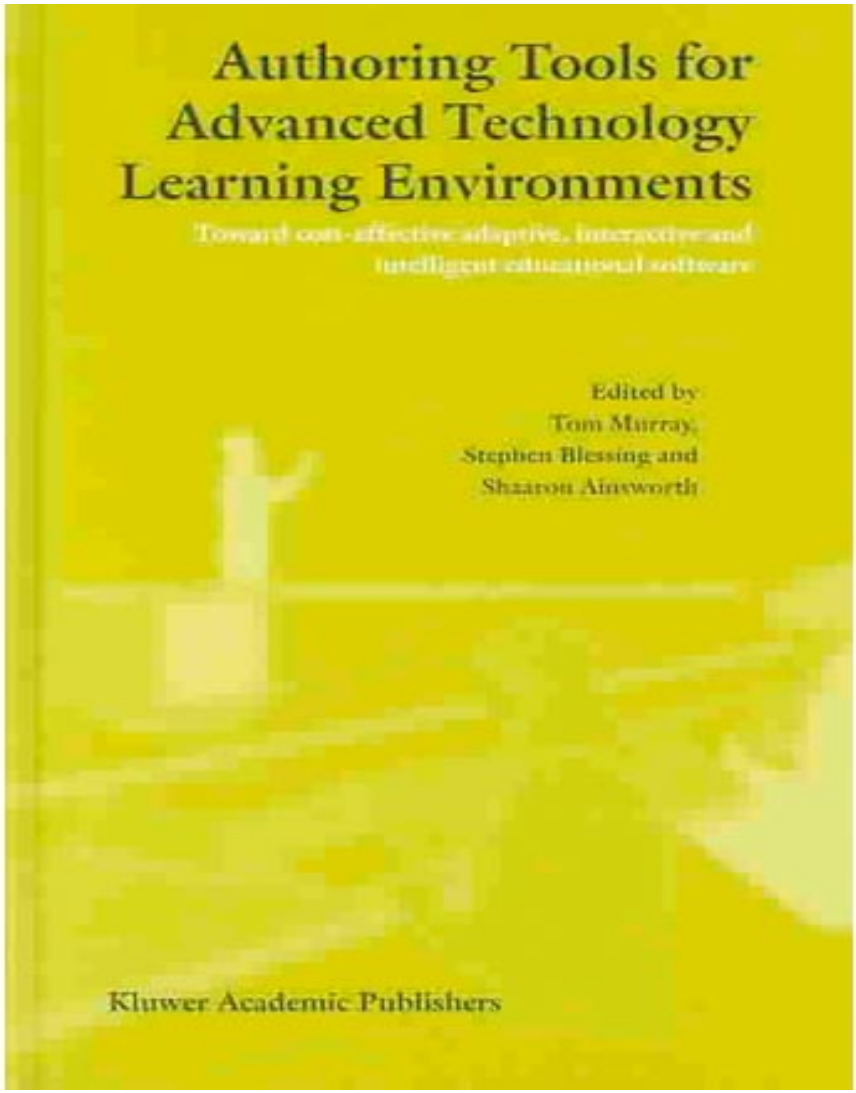
- SETS – (1991) Equipment maintenance training
- Eon - ITS authoring for domain, student, teaching models, and interface
- MetaLinks - hyperbook authoring tool
- SimForest-G - Glass box simulation authoring
- Rashi - Coached inquiry learning environment w/ authoring tool
- Wayang/MathSprings – (2014) teacher tools



Authoring Tools for Advanced Technology Learning Environments

Murray, Blessing, Ainsworth (Eds)

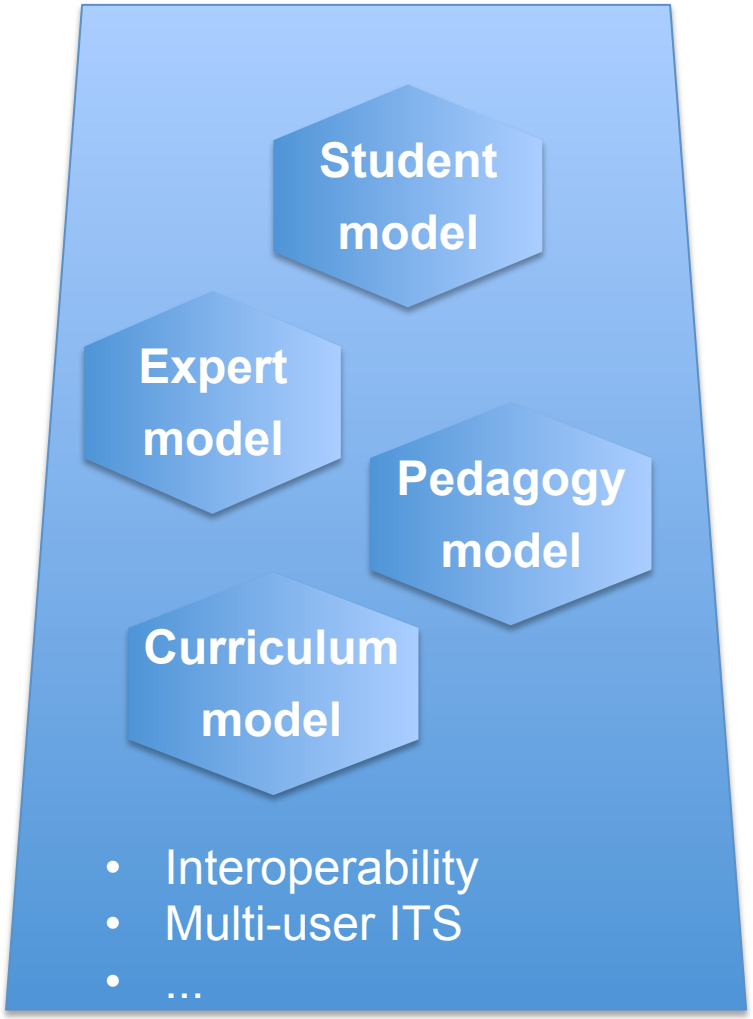
(2003)

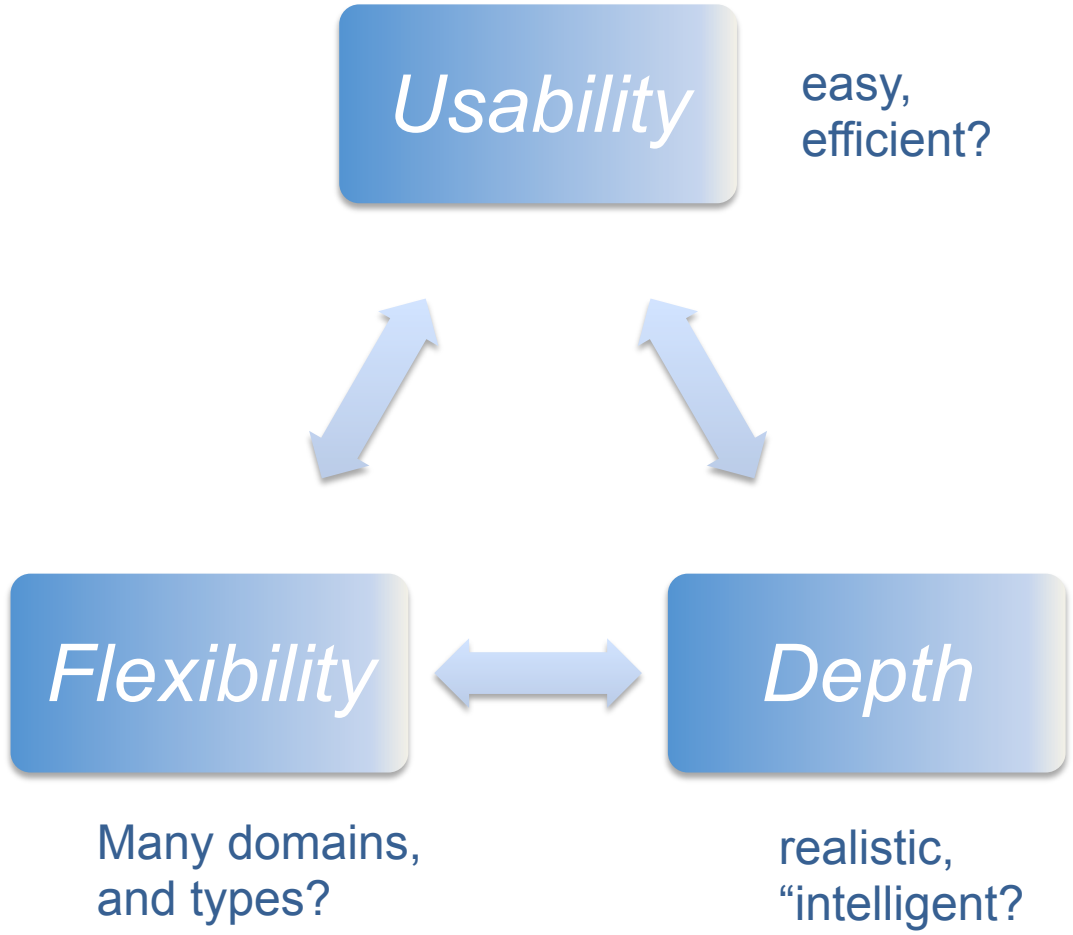


Recent interests applied to ITS authoring -- Theory

- User Roles vs Tools: Matching **Complexity**
- **Activity Theory**: Tools, Tasks, Users, Community
- **Epistemic Forms**/Games
- **Developmental** Theory (of complexity)

ITS Authoring Tool Design Tradeoffs





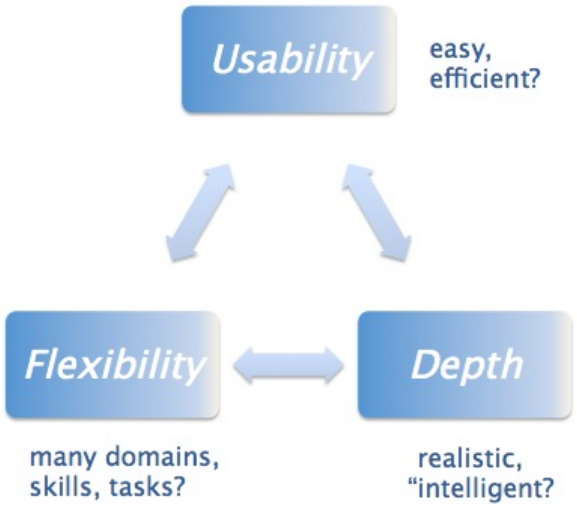
Authoring Tool Users

Roles (tool use roles)	**Benefits** (of that role)	**Problems** (of that role)
Teachers PRACTICAL	Practical experience	Not good at articulating or abstracting expertise
Domain Experts & Content Developers PARTIAL	Auth. tool infers the instructional methods	A fixed instructional method
Instructional Designers & Learning Theorists THEORETICAL	Know learning theories & research	Rare; not trained in knowledge engineering
Knowledge Engineers and ITS Developers EXPERIENCED	Know the tools; Are sometimes also plugged into user testing	May not know what it is like to teach or learn the material
Computer scientists & Software developers (ACTUAL?!)	Complexity capacity. Don't have to build to a real user base.	"its intuitively obvious to the casual observer…"

Matching Complexity— Tools vs. User capacity

Tools

Users



Complexity?

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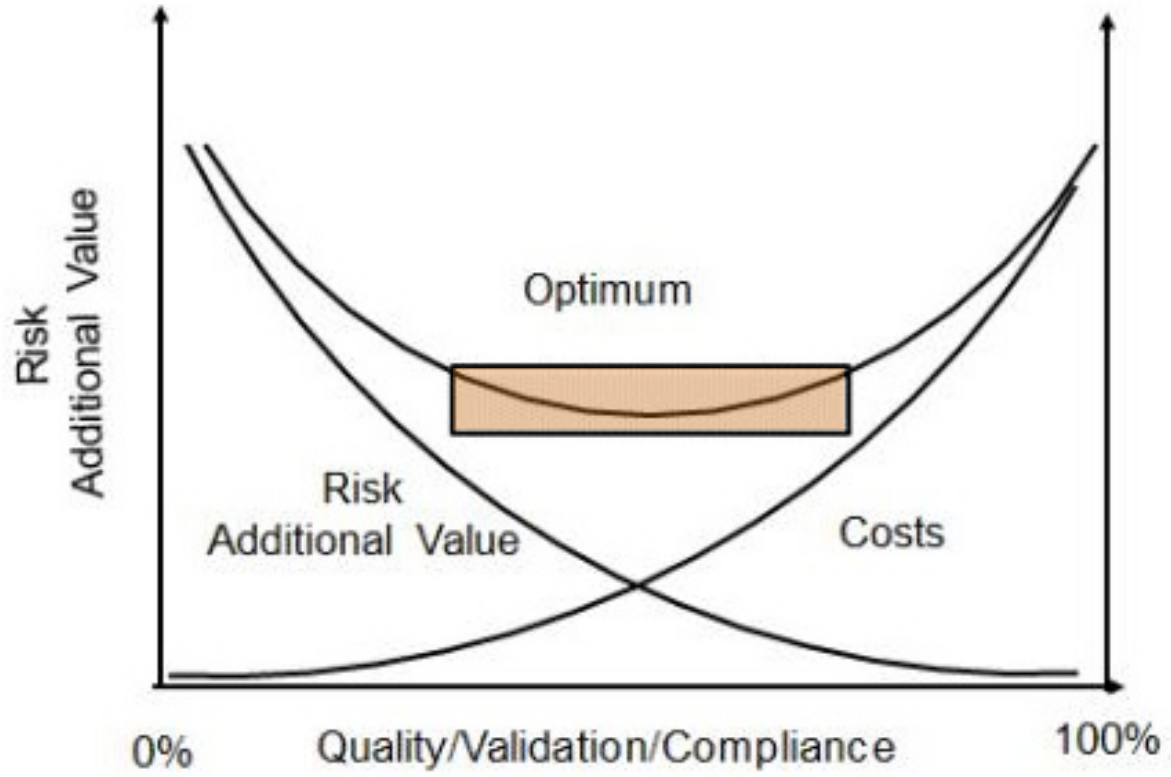
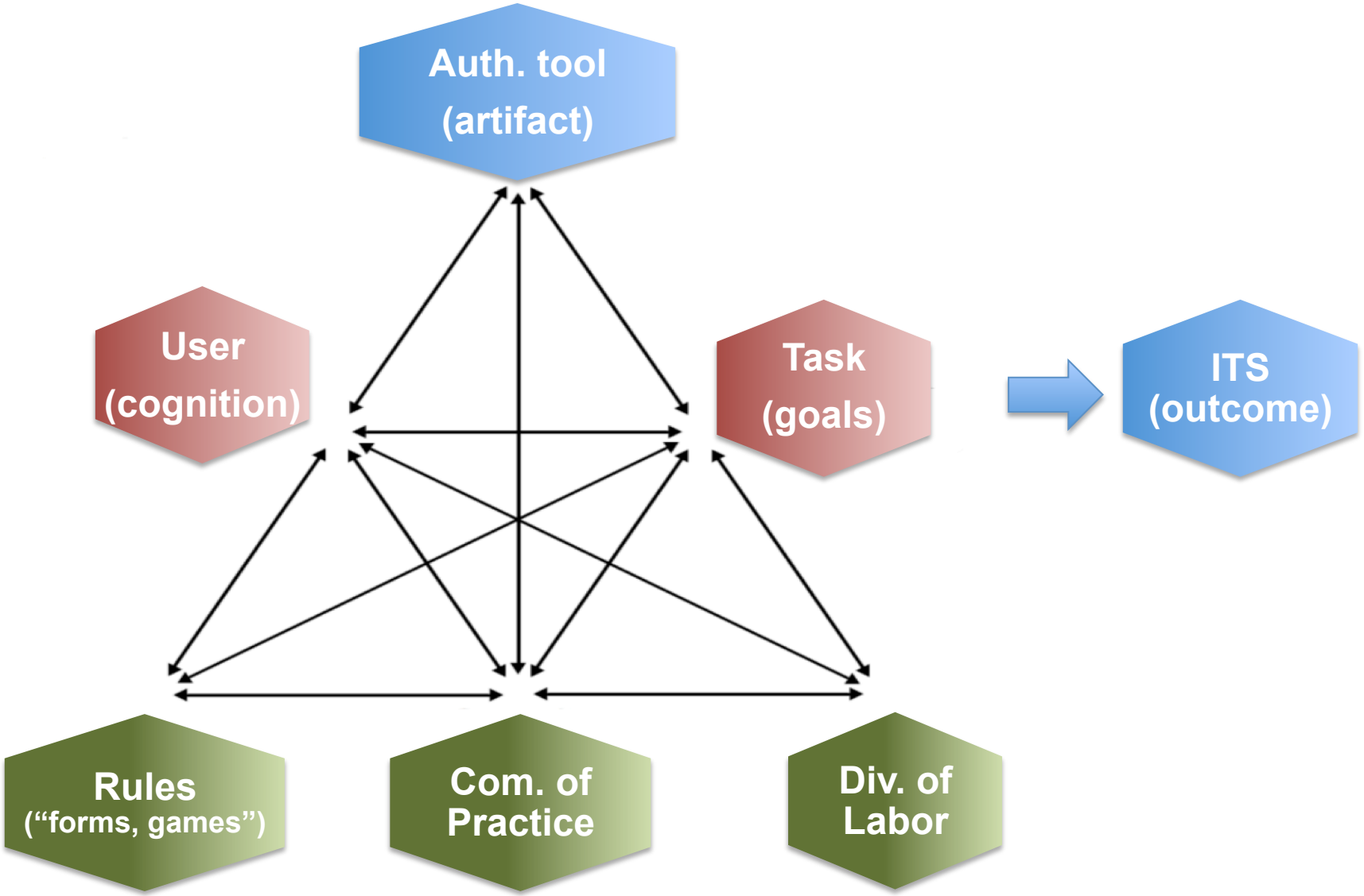
1) Know your user (anticipate user needs)
2) Usability Testing ("early and often")
3) Theory (of usability, cognition...)

Complex Software: (investment) Risk Assessment



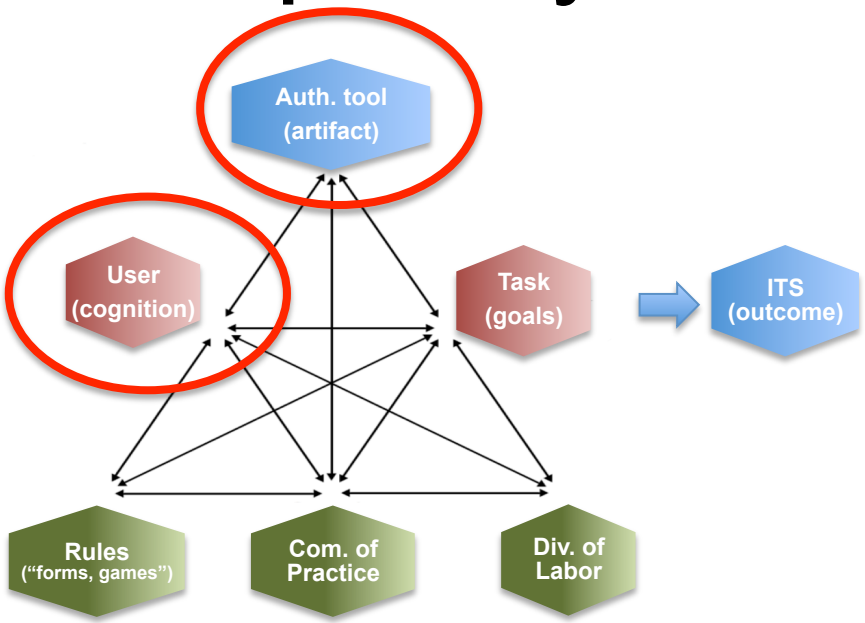
ITS design == AI-complete…….ITS A-Tool design == ITS-Complete!

Activity Theory



Jonassen & Rohrer-Murphy 1999; Engestrom et al. 1999;

Complexity Coordination



- *Cognitive Complexity (user)*
- *Task Complexity*
- *Tool Complexity*
- *Socio-cognitive complexity (COP)*

Complexity matching:

1. *User <> Tool*
2. *Task <> User*
3. *COP (& user) <> Tool*

Authoring Tools for All Users?

(Tiered Authoring/Work Flow)

Roles (tool use roles)	**Benefits** (of that role)	**Problems** (of that role)	**Complexity Design Capacity**
Teachers PRACTICAL	Practical experience	Not good at articulating or abstracting expertise	LOW
Domain Experts & Content Developers PARTIAL	Auth. tool infers the instructional methods	A fixed instructional method	MED
Instructional Designers & Learning Theorists THEORETICAL	Know learning theories & research	Rare; not trained in knowledge engineering	MED
Knowledge Engineers and ITS Developers EXPERIENCED	Know the tools; Are sometimes also plugged into user testing	May not know what it is like to teach or learn the material	MED-HIGH
Computer scientists & Software developers (ACTUAL?!)	Complexity capacity. Don't have to build to a real user base.	"its intuitively obvious to the casual observer…"	HIGH

Capacity is context-dependent

- **User complexity** capacity: f(S,I,T)

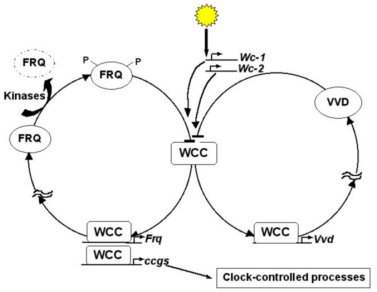
  Background **skill** (generic—see table)

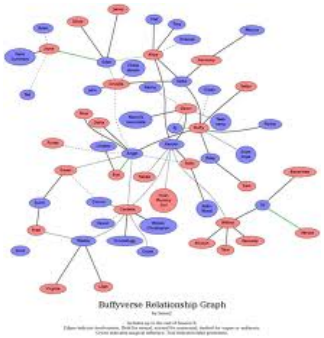
  + Investment in **training** A-Tool

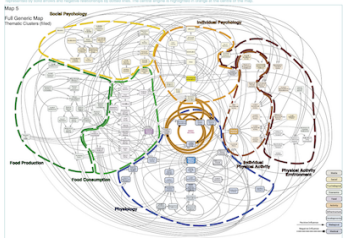
  + **Time** available to author this ITS

Sources of (software) system complexity

- Structural complexity (space)
  - Object has many properties
  - Many parts
  - Many types of parts
  - Many relationships
  - Many types of relationships
- Perspectival complexity
  - alternatives, hypotheticals, variables, decision spaces
- Dynamic complexity
  - Loops, Feedback, recursion relationships (“non-linearity”)





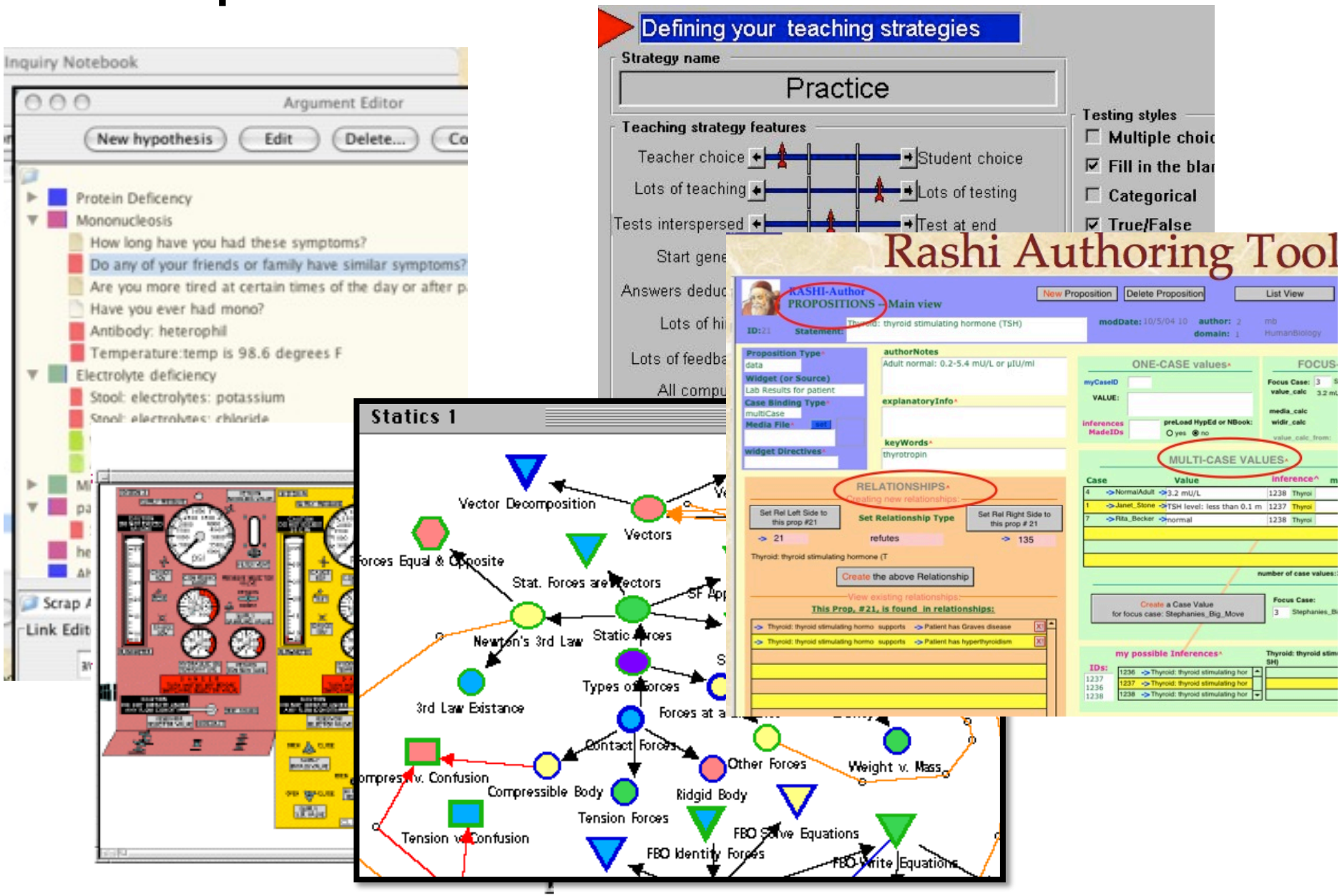


Epistemic Forms & Games (Mental Models)

(Collins & Furgeson, 1993)

- list
- matrix or table
- molecular model
- periodic table
- web page menu
- x-y graph
- pert chart
- binary tree
- floor plan
- street map
- org. chart
- musical score
- timeline
- cause/effect diagram
- network
- relational database
- sentence diagram
- term paper outline

Epistemic forms in interfaces



Can we estimate the complexity of epistemic forms/games in authoring tools?

- >> use cognitive developmental theory

Cognitive Developmentalists

Kegan; Fisher; Commons; Cook-Greuter...

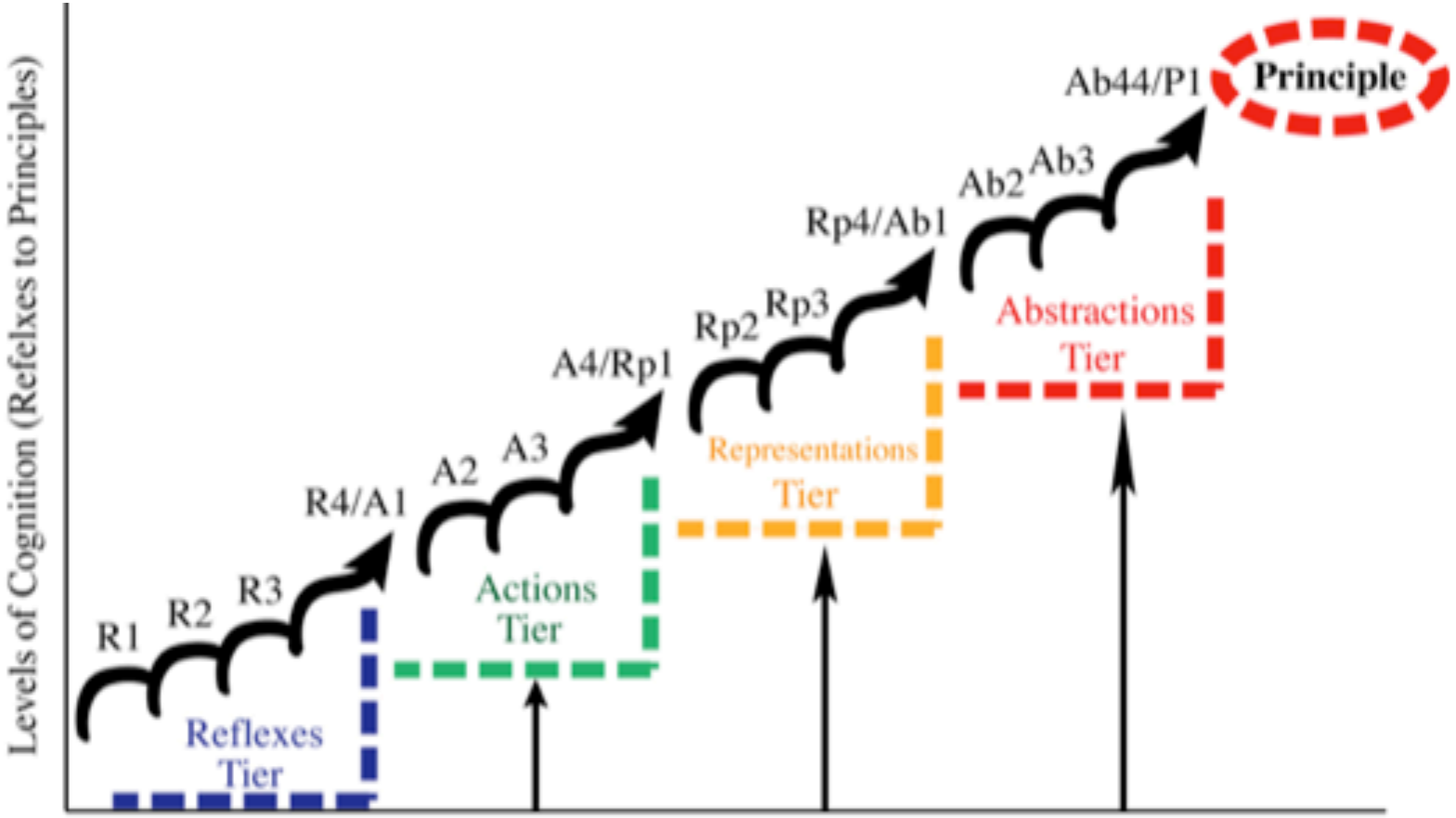
- Human development and learning can be described in terms of "**qualitative differences in mental complexity**."
- …that add a **hierarchical "structural perspective** in analyzing the organization of actions and thought."

Development: the concept of Fun

Single Rep. (unconnected list)	Fun is swinging on a swing. It's sliding on a slide.
Rep. Mapping (connections)	Fun is when Tommy and I put blocks together and then knock them down so that they make a loud noise that makes us laugh.
Rep. System (interconnections)	Fun is different things. Sometimes I like to climb… that makes me…
Single Abstr. (unconnected list)	Fun is a way of enjoying yourself. It is a form of pleasure.
Abst. Mapping (connections)	There are a variety of ways that a person can have fun. Some people enjoy physical activities, like sports or just exercise. Some people…

- Actions at a higher order of hierarchical complexity **organize and transform** the lower order actions
- Complexity level (or “order”) based on:
  1. complexity of **objects** operated upon (**vertical** complexity; order of abstraction)
  2. complexity of object **coordination** (**horizontal** complexity; structure of objects)

Fisher's Skill Theory



For any skill

algebra, reading, piano, parenting, tennis…

Addition > Multiplication > Algebra > Calculus > …

- **Single Set (e.g. a list)**

  (e.g. addition; subtraction…)

- **Mapping (e.g. linear causal link)**

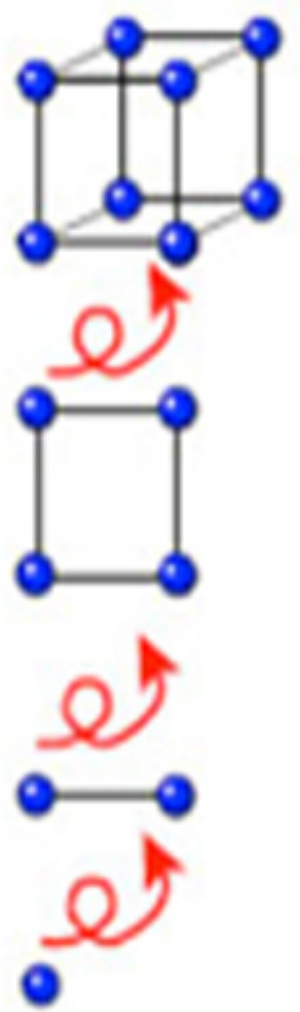
  (coordinating addition & subtraction)

- **System (e.g. many interconnected parts)**

  (e.g. coordinating +, -, x, /)

- **[System of Systems (an entire complex system)**

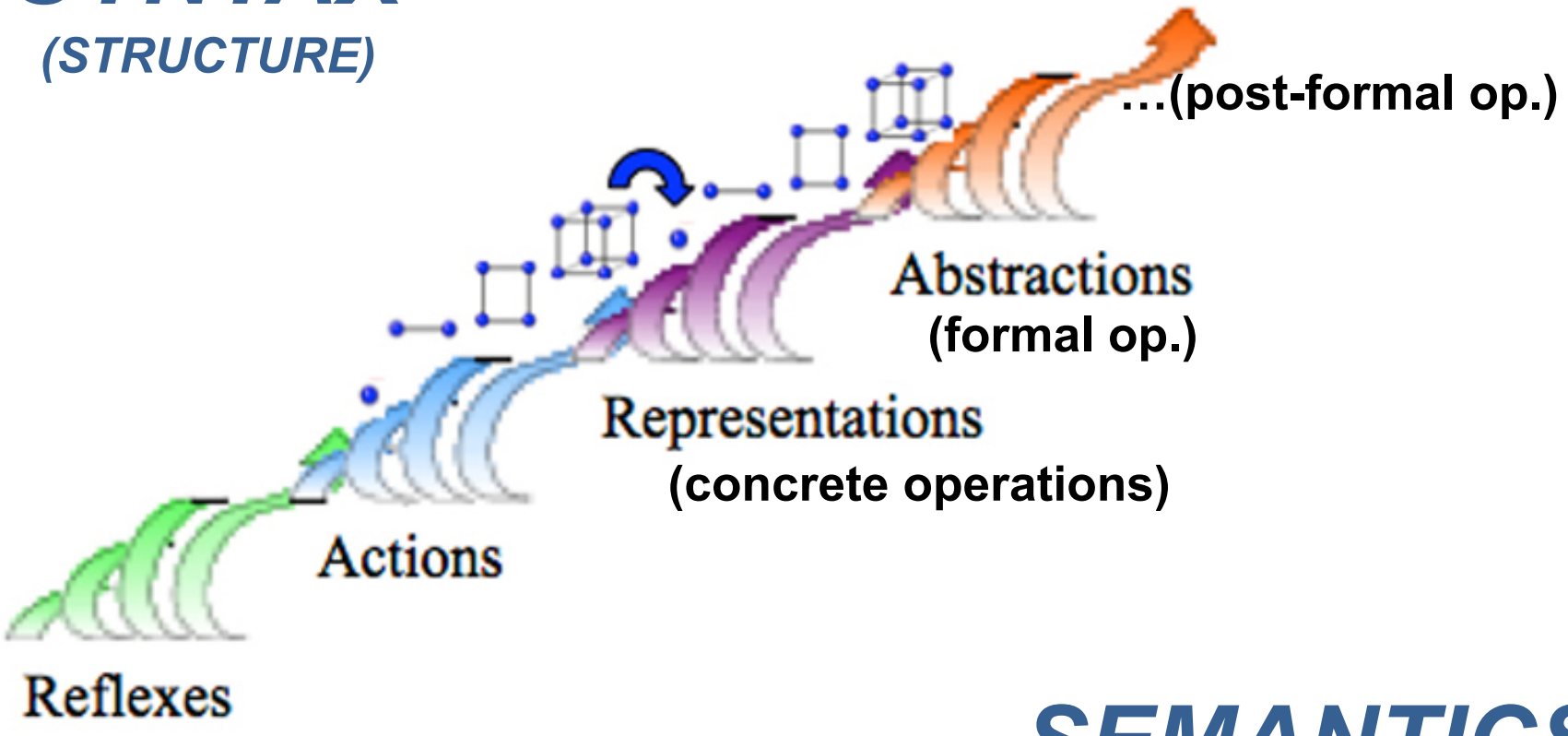
  (moving to Algebra)]



- **System of Systems** (an entire complex system with feedback loops)
- **System** (e.g. many interconnected parts)
- **Mapping** (e.g. linear causal link)
- **Single Set** (e.g. a list)

SYNTAX

(STRUCTURE)



SEMANTICS

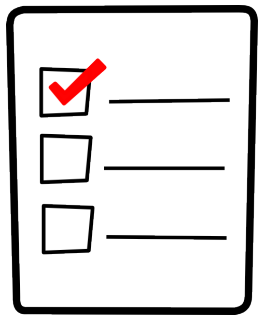
(OBJECTS)

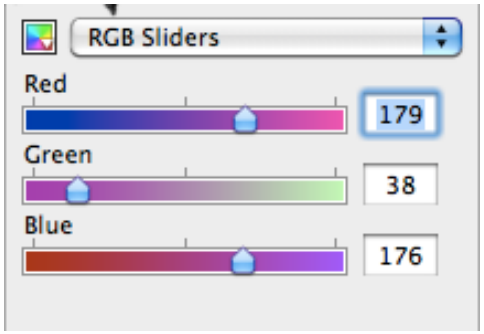
Increasing complexity of the Mental Model

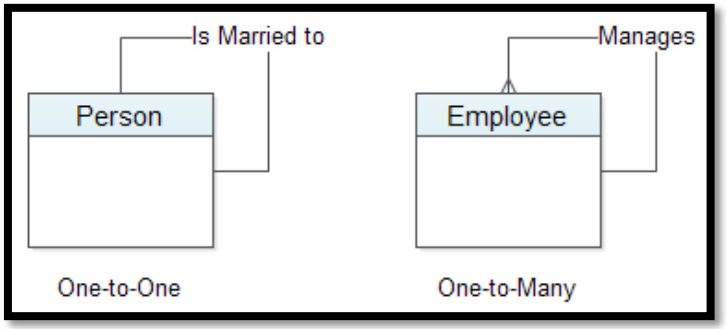
Complexity Level	Epistemic Form
1. Simple objects/info	Text information fill-in boxes Lists, choices, sliders, and check boxes
2. Mappings & Abstractions	Tables and matrices Hierarchies and trees Simple scripts, Forms, schemas, or templates
3. Formal Systems	Procedures with branches Variables/Equations and Boolean logic Structural models: concept networks, boxology diagrams
4. Dynamic Systems	Causal and constraint models, Decision Trees Behavioral/procedural models: If/then and rule-based procedural representations Complex interactions
5. Architectures & Ecosystems	Systems of systems, models, or rule-sets

Epistemic Forms Complexity

1. **Simple objects**: lists, sliders, simple relationships

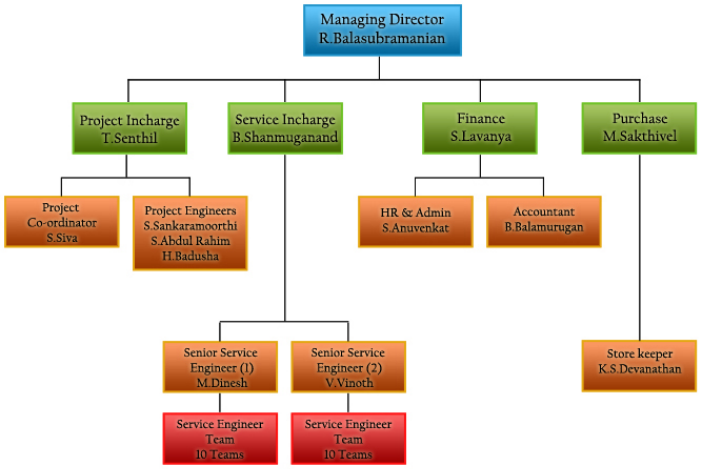


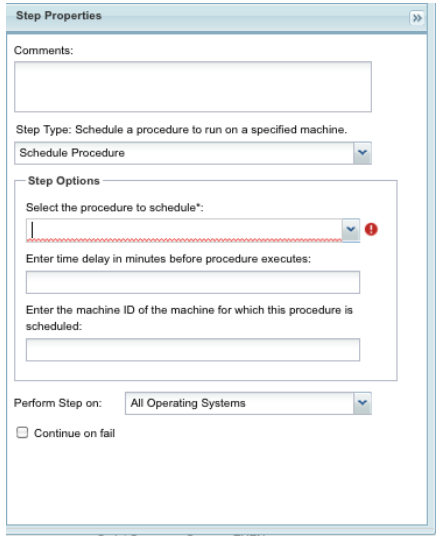




2. **Complex mappings**: tables, trees, scripts, concept nets

	A	B	C	D
1	Date	Appl	Orang	Total Fr
2	6/1/2012	125	75	200
3	6/2/2012	118	84	202
4	6/3/2012	164	72	236
5	6/4/2012	114	65	179
6	6/5/2012	98	96	194
7	6/6/2012	172	82	254
8	6/7/2012	122	82	204
9	6/8/2012	143	91	234
10	6/9/2012	137	87	224





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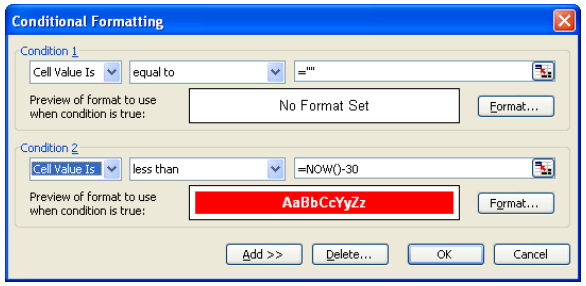
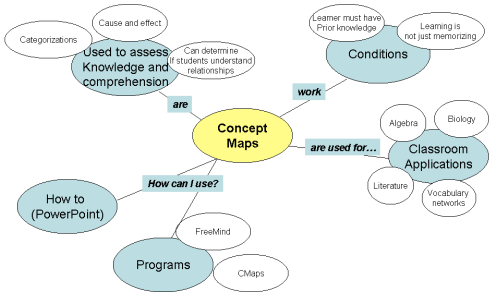
3. **Formal systems**: Add variables, equations, static models

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

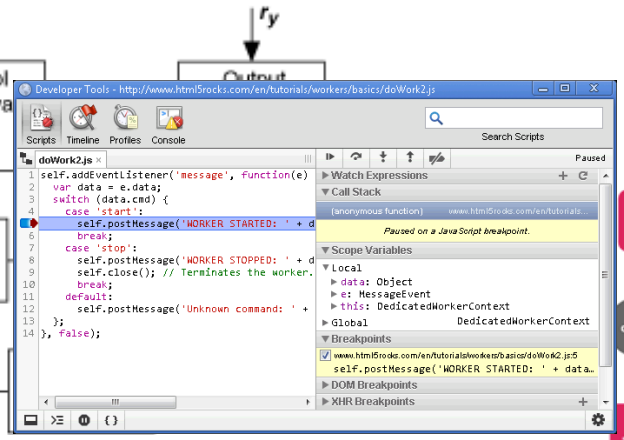


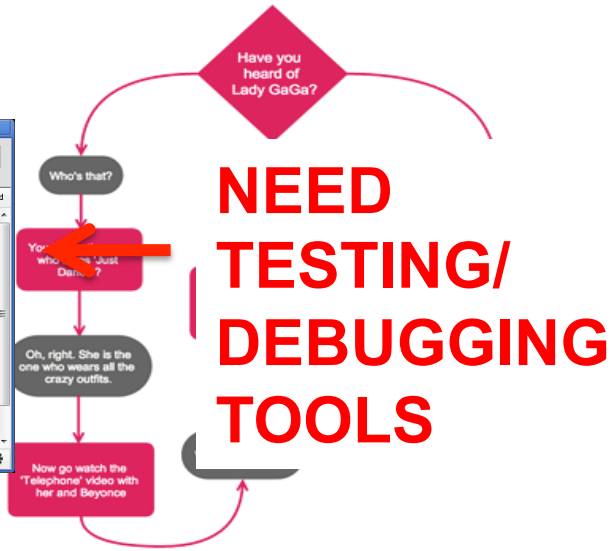


4. **Dynamic Systems**:
Loops, conditionals, dynamic/constrain models, rule systems

```
/**
 * Simple HelloButton() method.
 * @version 1.0
 * @author john doe <doe.j@example.com>
 */
HelloButton()
{
  JButton hello = new JButton( "Hello, wor
  hello.addActionListener( new HelloBtnList

  // use the JFrame type until support for t
  // new component is finished
  JFrame frame = new JFrame( "Hello Button"
  Container pane = frame.getContentPane();
  pane.add( hello );
  frame.pack();
  frame.show();              // display the fra
}
```





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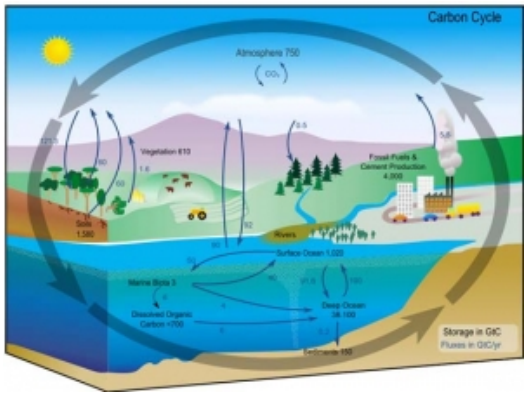
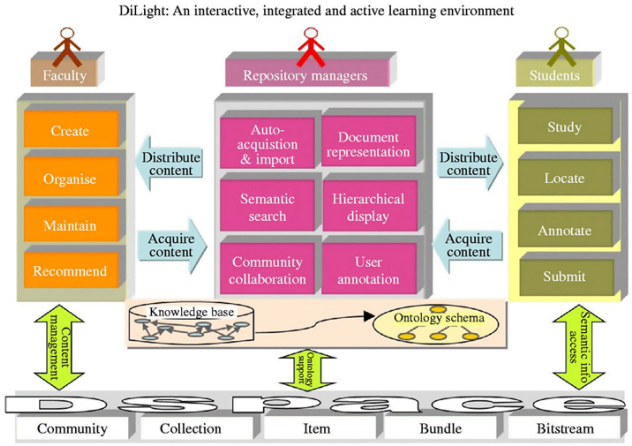
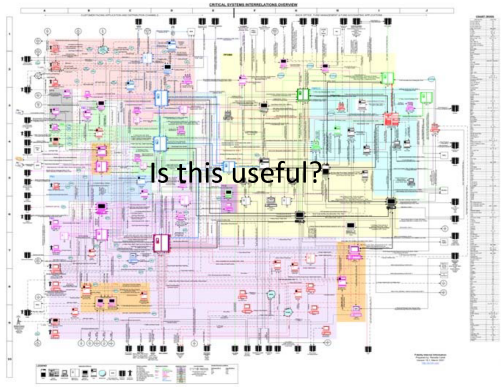
5. **Dynamic Systems/ Architectures**
(version control; constant monitoring)

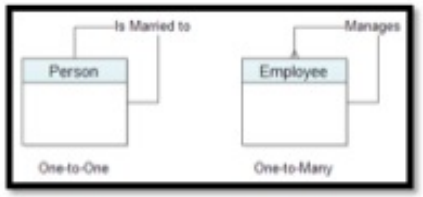


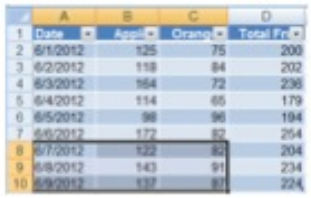


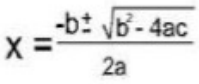


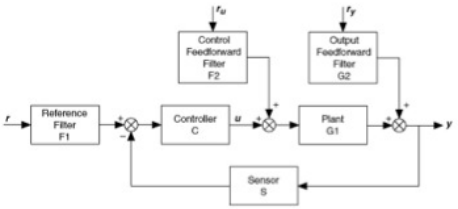
Increasing complexity of the Mental Model

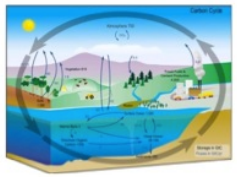
Complexity Level	Mental Model Characteristics
1. Simple objects	Facts, isolated info-bits
2. Mappings & Abstractions	Many relatinships, fairly linear, predicatable
3. Formal Systems	Abstractions, variables, decisions
4. Dynamic Systems	Non-linearities, sub-systems, decision trees
5. Architectures & Ecosystems	Complex interactions, whole-systems, evolving, unpredicatable

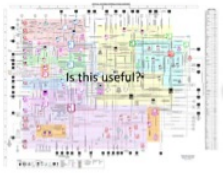












Complexity Design Capacity
LOW
MED
MED
MED-HIGH
HIGH

Review

- User Roles vs Tools: Matching **Complexity**
- **Activity Theory**: Tools, Tasks, Users, Community
- **Epistemic Forms**/Games
- **Developmental** Theory (of complexity)

Conclusions:
If “we build it will they come”?

- **Market & Buy-in**: Have ITSs demonstrated cost-benefit yet? In what situations?
- Creating a **pipeline for training** and trained ITS authors and knowledge engineers
- Building **communities of practice** (examples: CTAT, WISE, Knowledge Forum…)
- Expectation management: **matching tool and user complexity** (and constraining the breadth/ depth of the outcome ITSs)
- Building an ITS authoring tool is like…?? What known completed project? Using lessons from a **parallel domain**?

Thank You