INFSCI 2480: Adaptive Information Systems

Adaptive E-Learning Systems

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Find out more about any of these Grand Challenges:

Make solar energy economical

Provide energy from fusion

Develop carbon sequestration methods

Manage the nitrogen cycle

Provide access to clean water

Restore and improve urban infrastructure

Advance health informatics

Engineer better medicines

Reverse-engineer the brain

Prevent nuclear terror

Secure cyberspace

Enhance virtual reality

Advance personalized learning

Engineer the tools of scientific discovery

Overview

- The Context

- Technologies

- Adaptive E-Learning Systems vs. Learning Management Systems (LMS)

Major Aspects of AIS

- What is adaptive?
  - Adaptive sequencing of educational tasks
  - Adaptive content presentation
  - Adaptive ordering of search results
- What kinds of information about user?
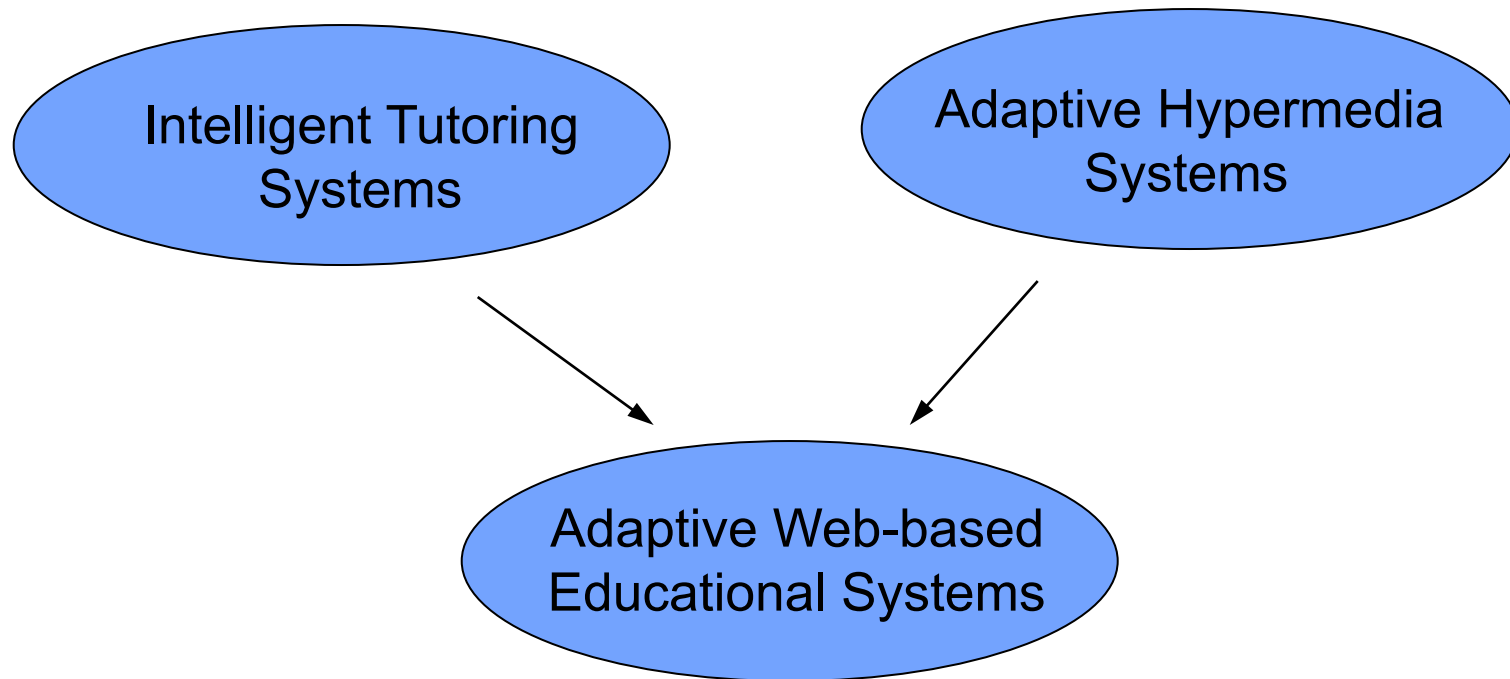 - User knowledge
  - User interests
  - User individual traits

Why Adaptive E-Learning?

- Adaptation was always an issue in education - what is special about the Web?
- greater diversity of users
  - "user centered" systems may not work
- new "unprepared" users
  - traditional systems are too complicated
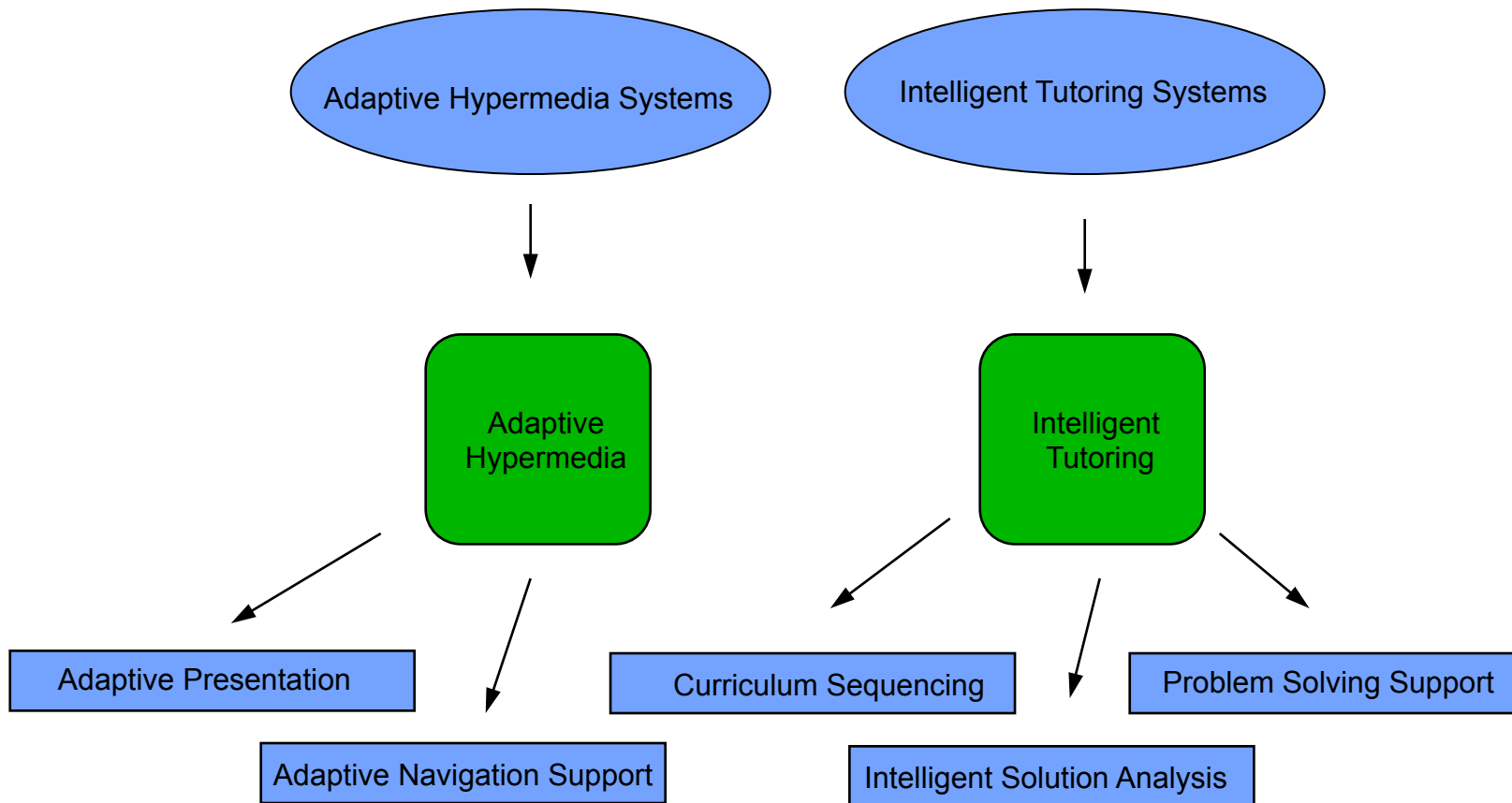- users are "alone"
  - limited help from a peer or a teacher

Technologies

- Origins of AEL technologies

- ITS Technologies

- AH Technologies

- "Native" Web Technologies

Origins of AEL Technologies
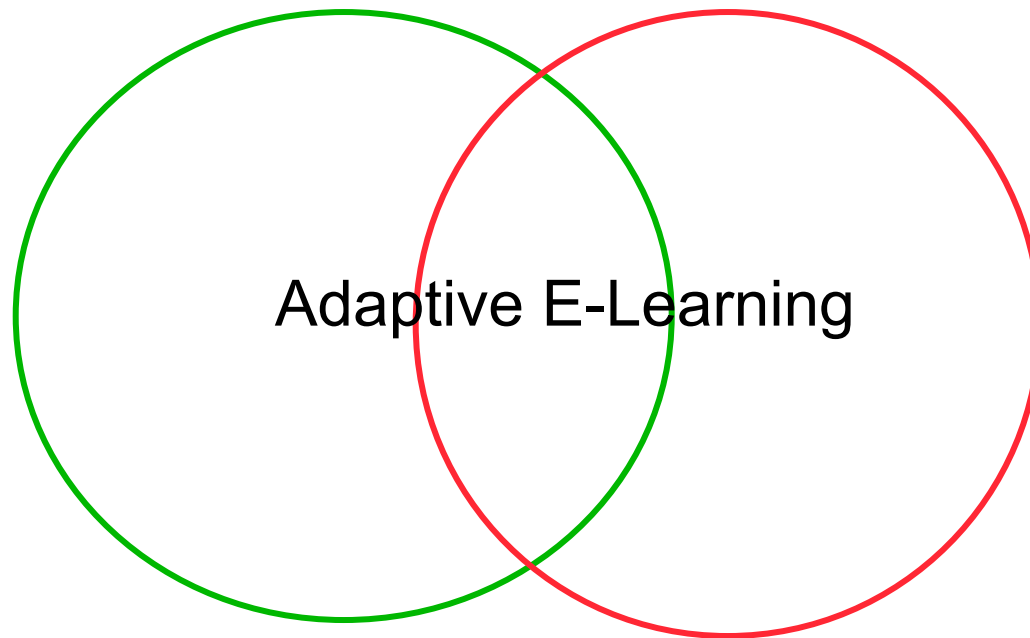
Origins of AEL Technologies (1)

```
       ( Adaptive Hypermedia Systems )          ( Intelligent Tutoring Systems )
                     │                                        │
                     ▼                                        ▼
            ┌─────────────────┐                      ┌─────────────────┐
            │    Adaptive     │                      │   Intelligent   │
            │   Hypermedia    │                      │    Tutoring     │
            └─────────────────┘                      └─────────────────┘
```

- Adaptive Presentation
- Adaptive Navigation Support
- Curriculum Sequencing
- Intelligent Solution Analysis
- Problem Solving Support

Technology inheritance examples

- Intelligent Tutoring Systems (since 1970)
  - CALAT (CAIRNE, NTT)
  - PAT-ONLINE (PAT, Carnegie Mellon)
- Adaptive Hypermedia Systems (since 1990)
  - AHA (Adaptive Hypertext Course, Eindhoven)
  - KBS-HyperBook (KB Hypertext, Hannover)
- ITS and AHS
  - ELM-ART (ELM-PE, Trier, ISIS-Tutor, MSU)

Technology Fusion

Adaptive Web

Adaptive Educational
Systems

Adaptive E-Learning

Origins of AEL Technologies (2)
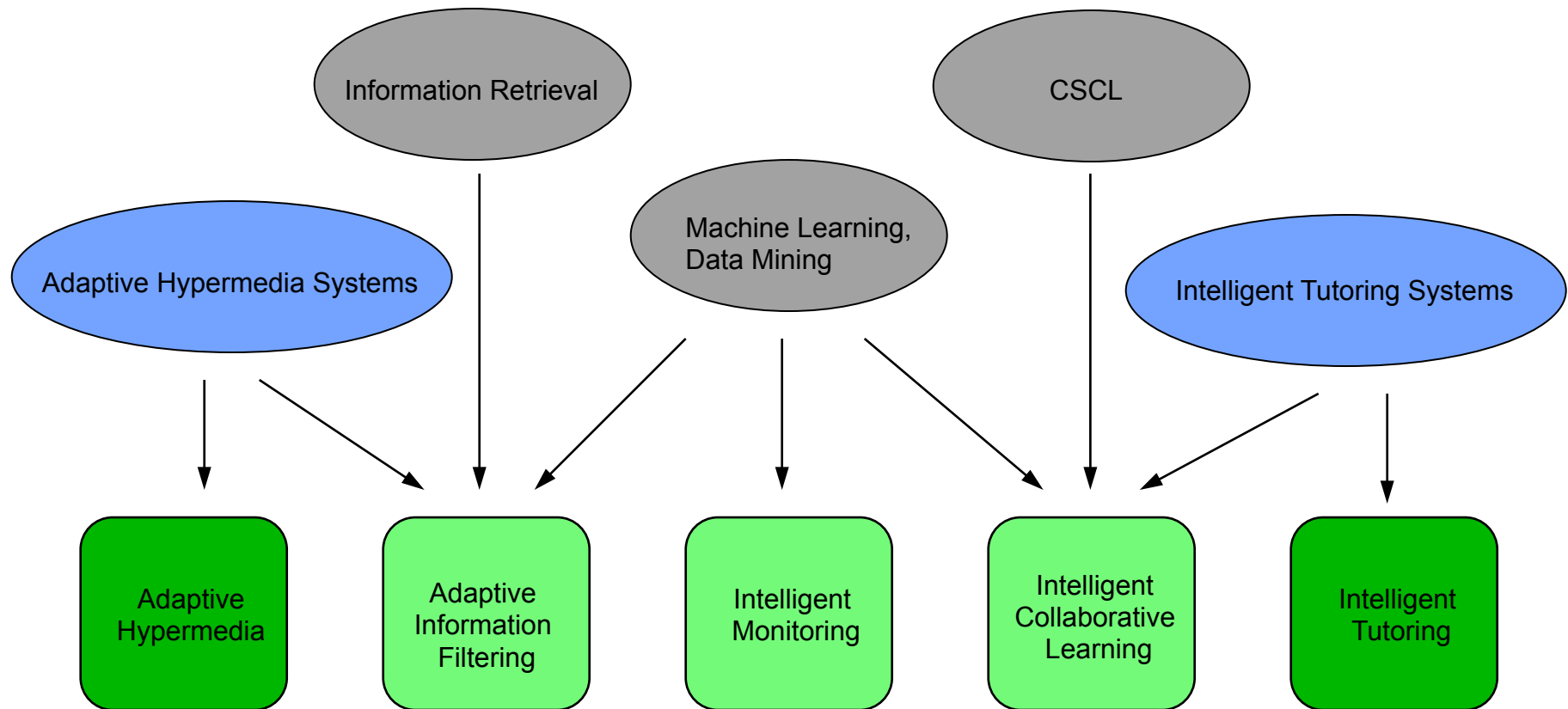
Inherited Technologies

- Intelligent Tutoring Systems
  - course sequencing
  - intelligent analysis of problem solutions
  - interactive problem solving support
  - example-based problem solving
- Adaptive Hypermedia Systems
  - adaptive presentation
  - adaptive navigation support

How to Model User Knowledge

- Domain model
  - The whole body of domain knowledge is decomposed into set of smaller knowledge units
  - A set of concepts, topics, etc
- Student model
  - Overlay model
  - Student knowledge is measured independently for each knowledge unit

Simple overlay model
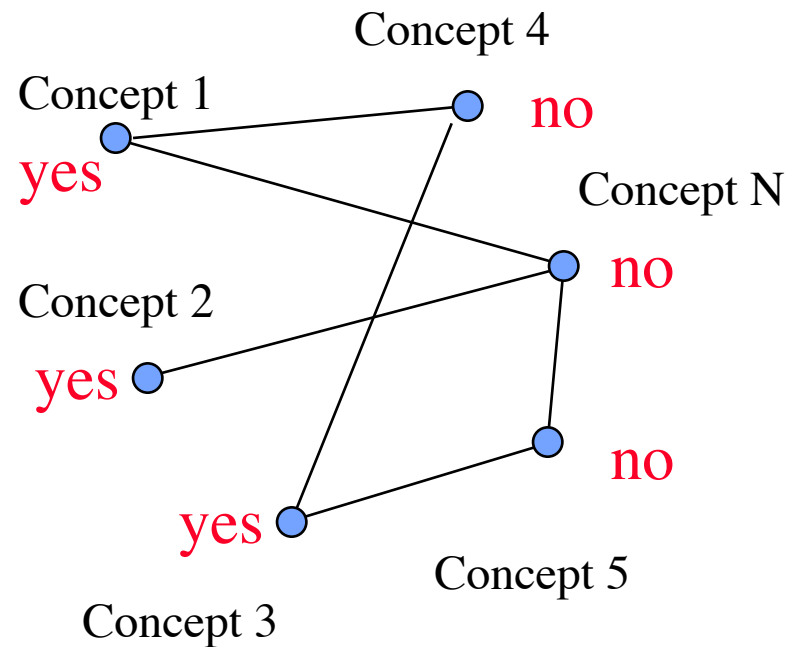
Weighted overlay model
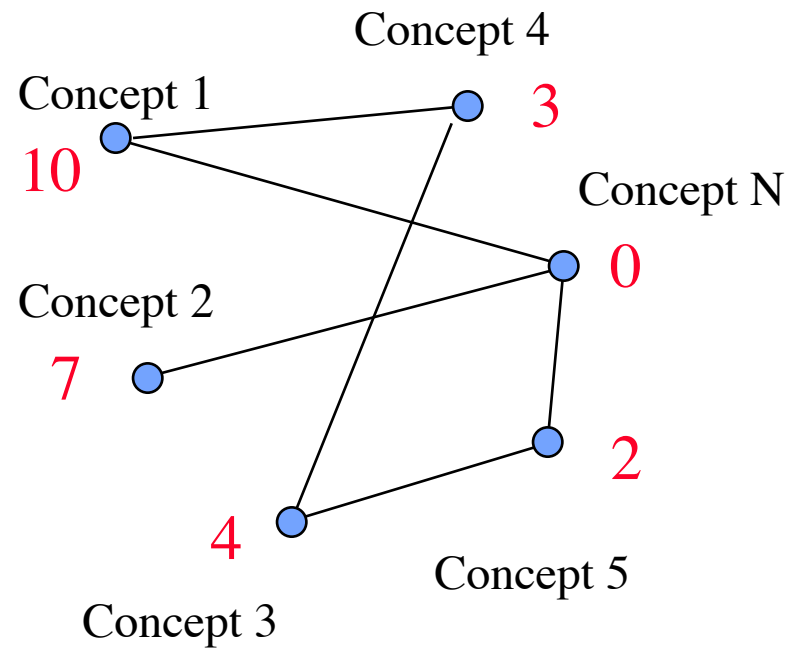
Course Sequencing

- Oldest ITS technology
  - SCHOLAR, BIP, GCAI...
- Goal: individualized "best" sequence of educational activities
  - information to read
  - examples to explore
  - problems to solve ...
- Curriculum sequencing, instructional planning, ...
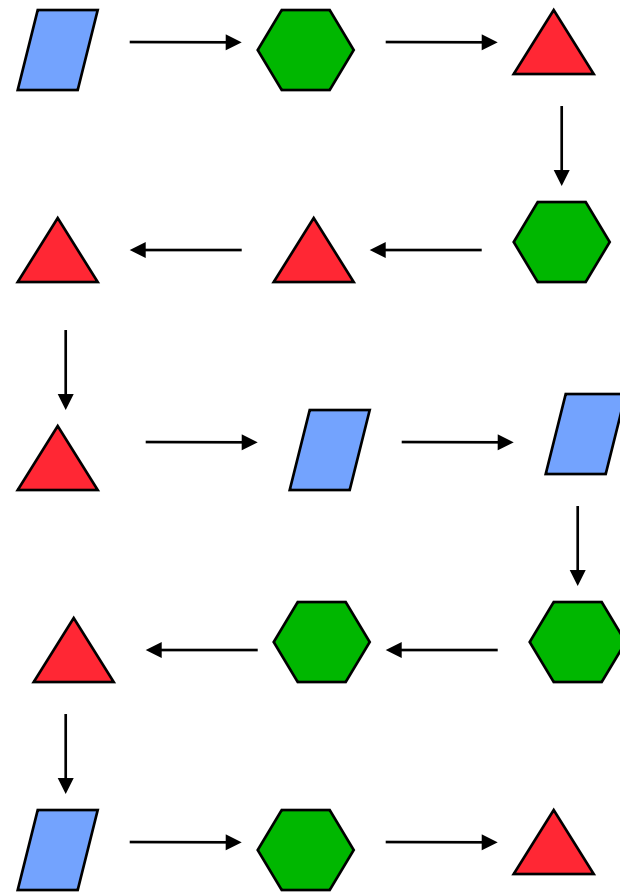
Course Sequencing

- What is modeled?
  - User knowledge of the subject
  - User individual traits
- What is adapted?
  - Order of educational activities
  - Presentation of hypertext links
  - Presented content
  - Problem solving feedback

Active vs. Passive Sequencing

- Active sequencing
  - goal-driven expansion of knowledge/skills
  - achieve an educational goal
    - predefined (whole course)
    - flexible (set by a teacher or a student)
- Passive sequencing (remediation)
  - sequence of actions to repair misunderstanding or lack of knowledge

Levels of sequencing
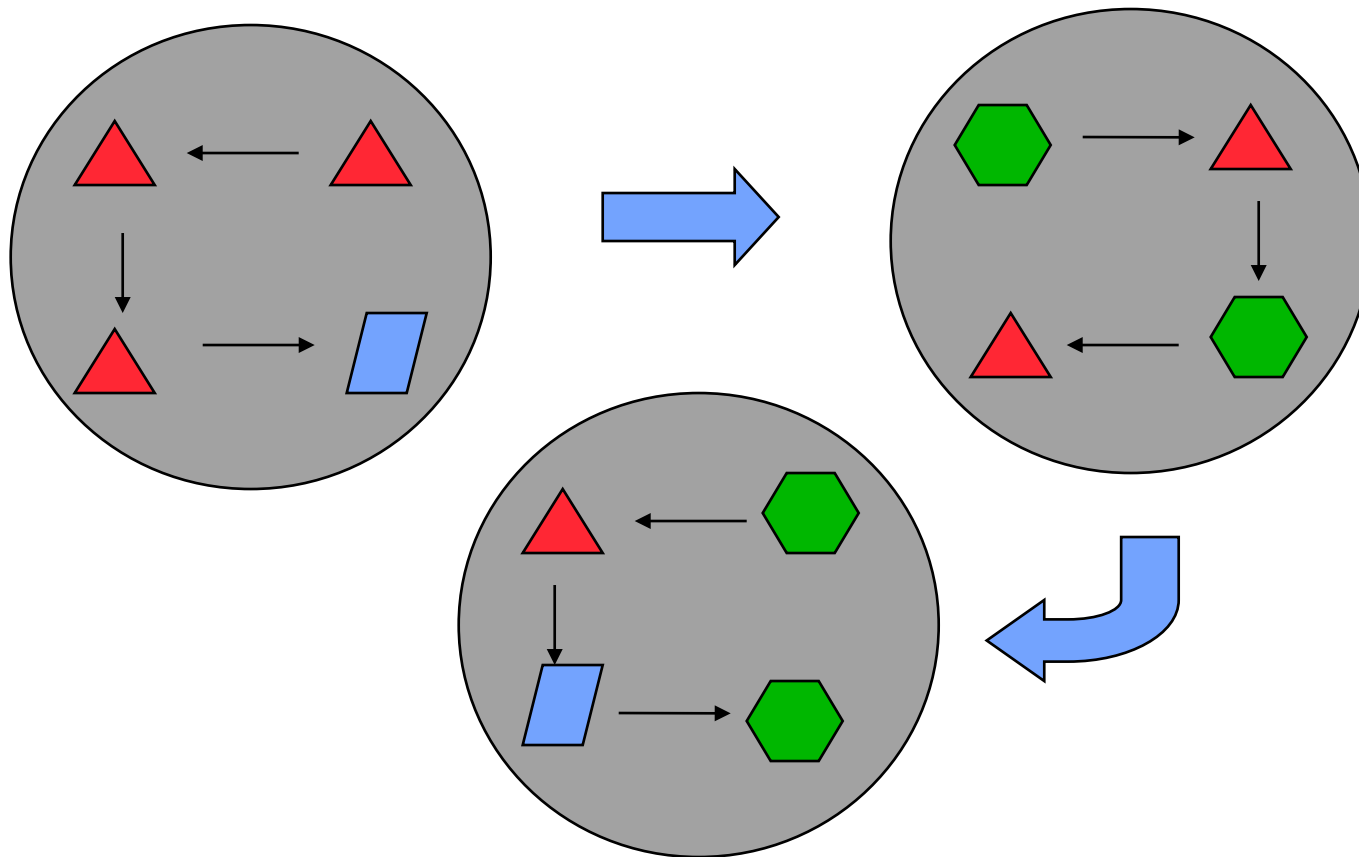
- High level and low level sequencing

Sequencing options

- On each level sequencing decisions can be made differently
  - Which item to choose?
  - When to stop?
- Options
  - predefined
  - random
  - adaptive
  - student decides

Simple cases of sequencing

- No topics
- One task type
  - Problem sequencing and mastery learning
  - Question sequencing
  - Page sequencing
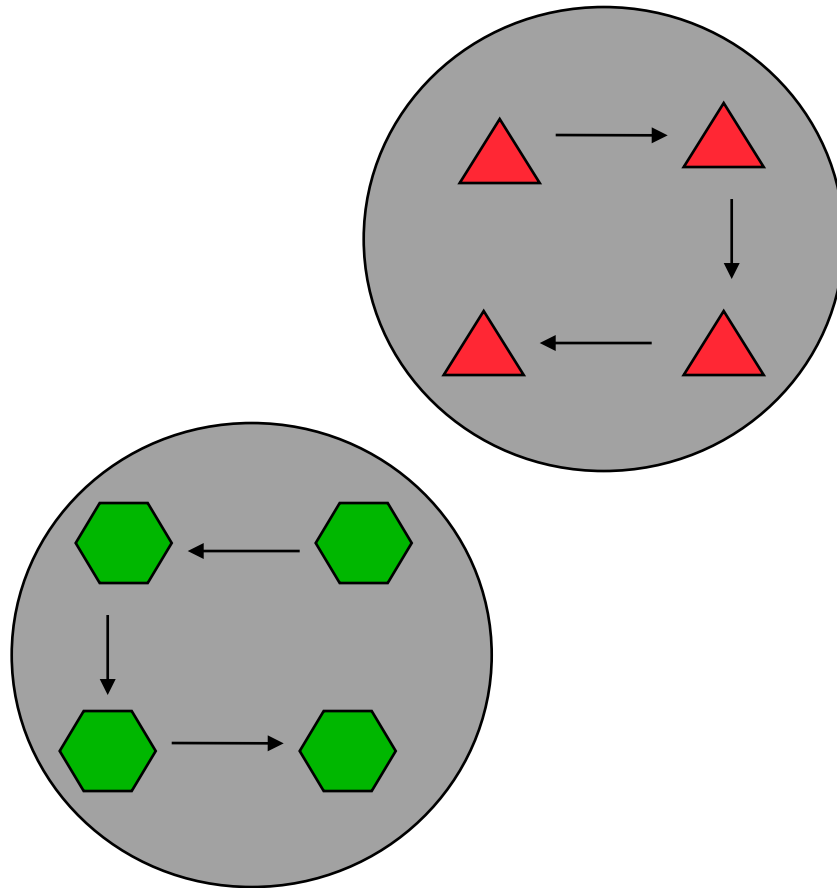
Sequencing with models

- Given the state of UM and the current goal pick up the best topic or ULM within a subset of relevant ones (defined by links)

- Special cases with multi-topic indexing and several kinds of ULM

- Applying explicit pedagogical strategy to sequencing

Sequencing for AES

- Simplest technology to implement with CGI
- Important for WBE
  - "no perfect order"
  - lack of guidance
- No student modeling capability!
  - Requires external sources of knowledge about student
  - Problem/question sequencing is self-sufficient

ELM-ART: question sequencing

SIETTE: Adaptive Quizzes

Combination of
CAT and concept
Based adaptation
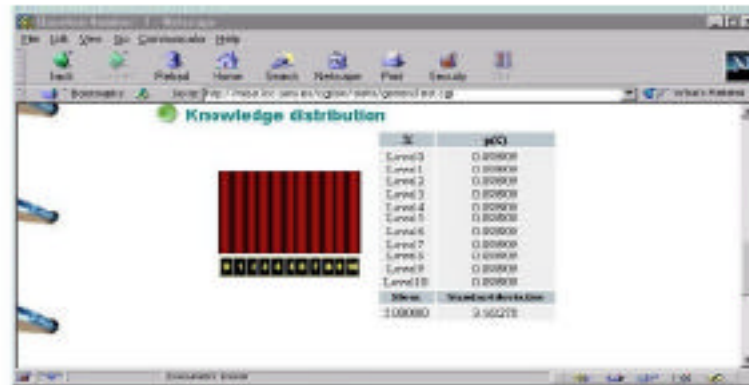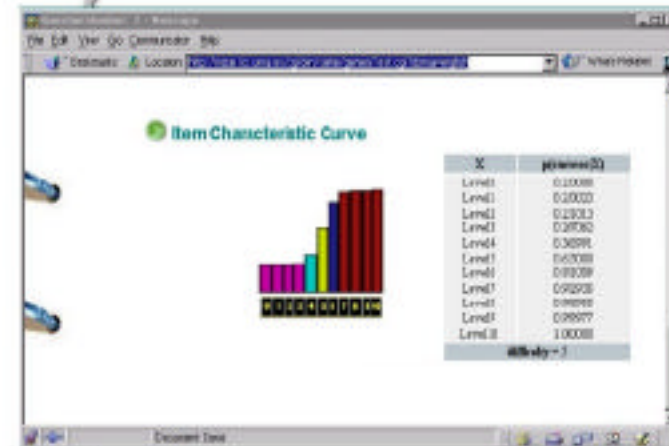
Models in SIETTE
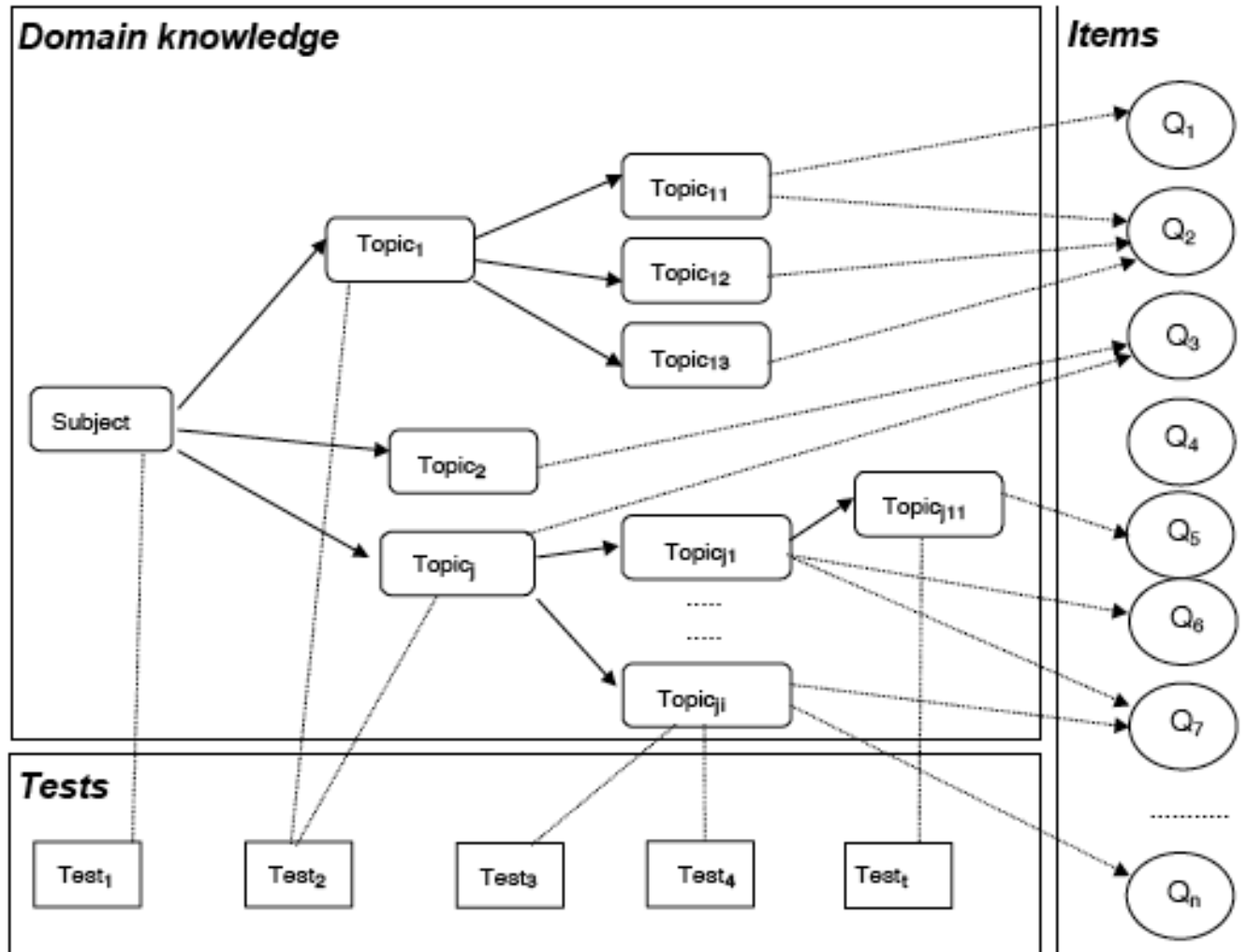
Beyond Sequencing: Generation

Adaptive Problem Solving Support

- The "main duty" of ITS
- From diagnosis to problem solving support
- Highly-interactive support
  - interactive problem solving support
- Low-interactive support
  - intelligent analysis of problem solutions

Adaptive Problem Solving Support

- What is modeled?
  - User knowledge of the subject
  - User individual traits
- What is adapted?
  - Order of educational activities
  - Presentation of hypertext links
  - Presented content
  - Problem solving feedback

Intelligent analysis of problem solutions

- Intelligent analysis of problem solutions
- Classic system: PROUST
- Support: Identifying misconceptions (bug model) and broken constraints (CM)
- Provides feedback adapted to the user model: remediation, positive help
- Low interactivity: Works after the (partial) solution is completed

Example: ELM-ART

Example: SQL-Tutor

Interactive Problem Solving Support

- Classic System: Lisp-Tutor
- The "ultimate goal" of many ITS developers
- Several kinds of adaptive feedback on every step of problem solving
  - Coach-style intervention
  - Highlight wrong step
  - What is wrong
  - What is the correct step
  - Several levels of help by request

Example: PAT-Online

You have just been promoted at PAT-E-OH Furniture Inc. and have received a raise to $5.50 per hour.

1. How much would you get paid if you worked 5 hours?
2. How much would you get paid if you worked 25 hours?
3. How much would you get paid if you worked 10 1/2 hours?
4. How much would you get paid if you worked 100 hours?
5. How much would you get paid if you worked 200 hours?
6. If you plan on working 10 hours a week during a forty week school year, what would be your total earnings be for the entire year?

For the formula, define a variable for the time worked and use this variable to write a rule for your total pay.

Heading	**Time worked**		**Earnings**	
Unit	Hours	?		?
Formula		?		?
Question 1		?		?

Example: WADEIn

Problem-solving support

- Important for WBE
  - problem solving is a key to understanding
  - lack of problem solving help
- Hardest technology to implement
  - research issue
  - implementation issue
- Excellent student modeling capability!

Models for interactive problem-solving support and diagnosis

- Domain model
  - Concept model (same as for sequencing)
  - Bug model
  - Constraint model
- Student model
  - Generalized overlay model (works with bug model and constraint model too)
- Teaching material - feedback messages for bugs/ constraints

Bug models
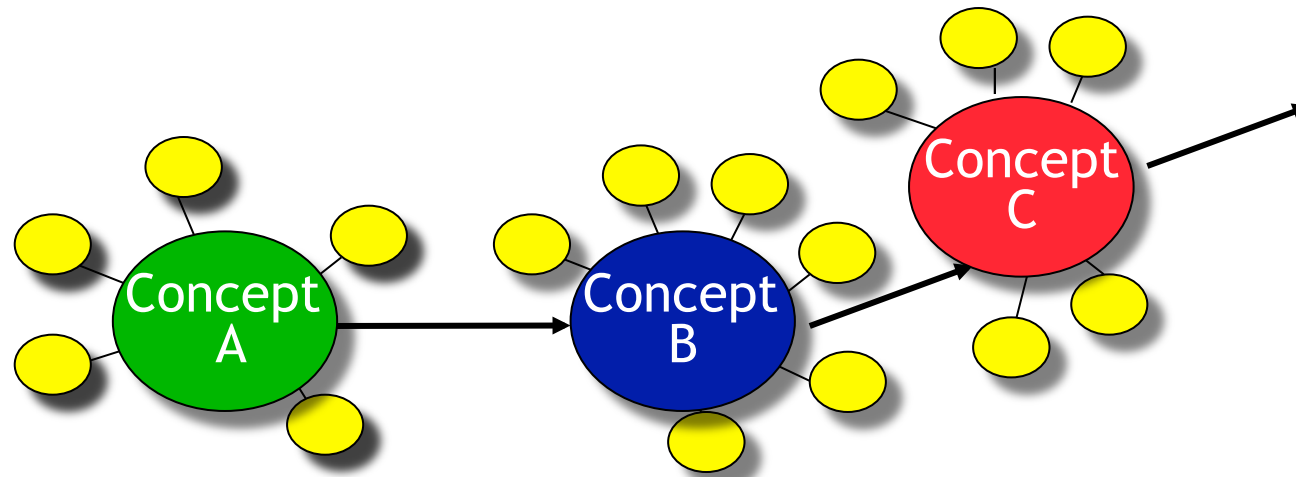
- Each concept/skill has a set of associated bugs/misconceptions and sub-optimal skills
- There are help/hint/remediation messages for bugs

Do we need bug models?

- Lots of works on bug models in the between 1974-1985

- Bugs has limited applicability
  - Problem solving feedback only. Sequencing does not take bugs into account: whatever misconceptions the student has - effectively we only can re-teach the same material
  - Short-term model: once corrected should disappear, so not necessary to keep

Models for example-based problem solving support

- Need to represent problem-solving cases
- Episodic learner model
  - Every solution is decomposed on smaller components, but not concepts!
  - Keeping track what components were used and when - not an overlay!
- ELM-PE and ELM-ART - only systems that use this model

Adaptive hypermedia

- Hypermedia systems = Pages + Links

- Adaptive presentation

  – content adaptation

- Adaptive navigation support

  – link adaptation

- Could be considered as "soft" sequencing

  – Helping the user to get to the right content

Adaptive Navigation Support

- What is modeled?
  - User knowledge of the subject
  - User individual traits
- What is adapted?
  - Order of educational activities
  - Presentation of hypertext links
  - Presented content
  - Problem solving feedback

Adaptive Annotation: Icons
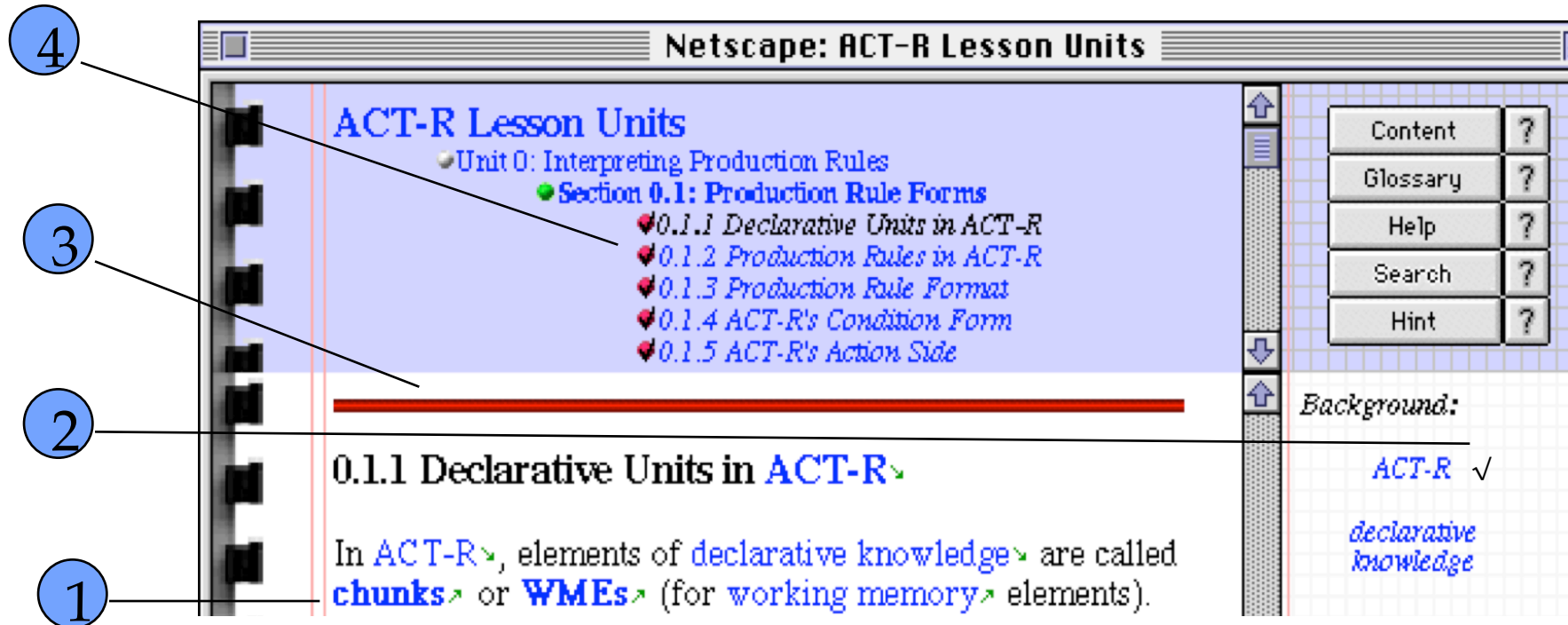
InterBook system

1. Concept role
2. Current concept state
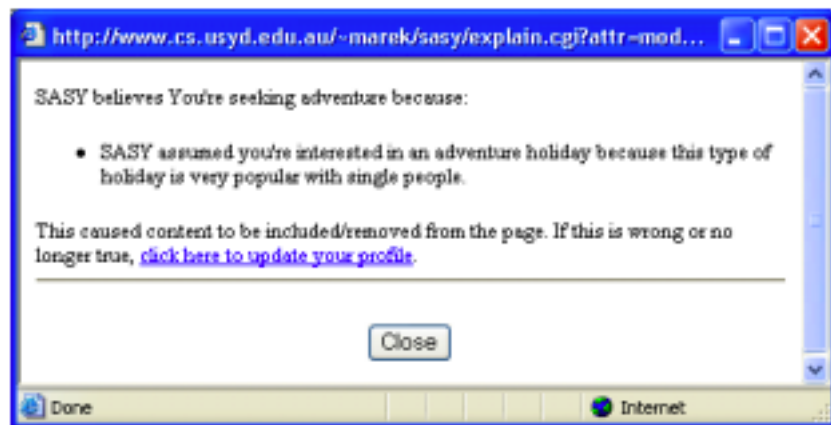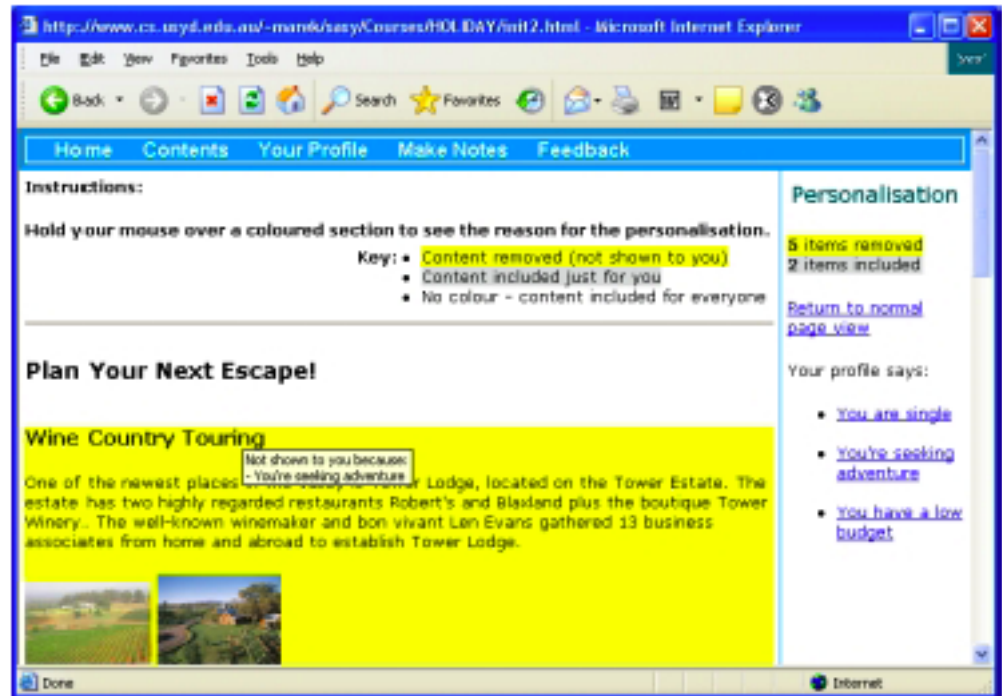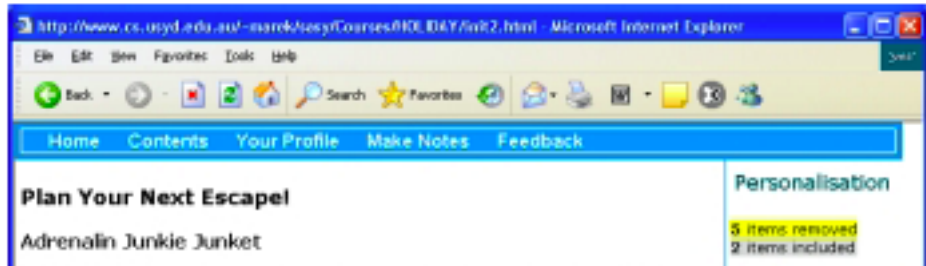3. Current section state
4. Linked sections state

Adaptive Presentation

- What is modeled?
  - User knowledge of the subject
  - User individual traits
- What is adapted?
  - Order of educational activities
  - Presentation of hypertext links
  - Presented content
  - Problem solving feedback

Example: SASY

Scrutable adaptive presentation

http://www.cs.usyd.edu.au/~marek/sasy/

Adapting to User Knowledge: Other Ideas

- Adaptive interface
  - Presence of menus and widgets in an educational applet can be adapted to user knowledge
- Educational animation and simulation
  - Adaptive explanations
  - Adaptive visualization

Demo: WADEIn

Monitor your progress with operations that are your current goals

A — The length of the bar indicates the amount of exploration (Exploration Mode), and the color saturation indicates the confirmed knowledge (Knowledge Evaluation Mode)

Use the progress indicators to identify operations that need your attention

Navigate the evaluation of the current expression

F — Go slowly on a step-by-step basis attending all the changes on the screen

G — Go quicker skipping operators

H — Quickly jump to the beginning or the end of the evaluation

Set everything and START the evaluation

B — Select one of the predefined expressions OR type in your own

C — Select the mode

D — Set the values of variables

E — START the evaluation

Learn by watching animations and reading explanations

I — At any time consult the original expression AND the order of execution (precedence of operators)

J — Monitor values of variables appearing in the current expression

K — Watch all visualizations, observe how the current expression changes as it is being evaluated

L — Read the explanations of the visual actions happening above

M — Watch for controls indicating that more complicated concepts are involved in the context of the current operation

Check your current context

N — Check the current Topic

Screen contents

1. Expression: ○ Predefined [(3 / 2) - (4 + 5) * 6 ▾]
   ○ Custom [ ]

2. Mode: ○ Exploration   ○ Knowledge Evaluation   STOP!

3. Variables: Integer A 10   B 20   C 30
   Double K 10.0   L 20.0

Goals and Progress
`()` `+` `-` `*` `/` `%`

Original Expression: `1 + ( K * 3 / 2 ) – ( 4 + 5 ) * 6`

Correct Order: 4 **3** 1 2 8 6 5 7

K 10.0

`1 + ( 15.0 ) – ( 4 + 5 ) * 6`

`15.0`

The value of (15.0) is 15.0. Parentheses never change the value of the expression inside them, they only change the precedence of operations.

◀ Step ▶   ◀ Operator ▶   ◀◀ Expression ▶▶

Login: a   Current topic: Simple Arithmetic

Adapting to Individual Traits

- Source of knowledge
  - educational psychology research on individual differences
- Known as cognitive or learning styles
  - Field dependence, wholist/serialist (Pask)
  - Kolb, VARK, Felder-Silverman classifiers

Style-Adaptive Hypermedia

- What is modeled?
  - User knowledge of the subject
  - User individual traits
- What is adapted?
  - Order of educational activities
  - Presentation of hypertext links
  - Presented content
  - Problem solving feedback

Style-Adaptive Hypermedia

- Different content for different style
  - Recommended/ordered links
  - Generated on a page
  - Mixed evidences in favor
- Different navigation tools for different styles
  - Adding/removing maps, advanced organizers, etc.
- Good review:
  - Bajraktarevic, N., Hall, W., and Fullick, P. 2003. Incorporating Learning Styles in Hypermedia Environment: Empirical Evaluation, In Proceedings of Workshop on Adaptive Hypermedia and Adaptive Web-Based Systems, Nottingham, 41-52. http://wwwis.win.tue.nl/ah2003/proceedings/paper4.pdf

Example: AES-CS

Interface for field-independent learners

Example: AES-CS

Interface for field-dependent learners

Style-Adaptive Feedback

- What is modeled?
  - User knowledge of the subject
  - User individual traits
- What is adapted?
  - Order of educational activities
  - Presentation of hypertext links
  - Presented content
  - Problem solving feedback

Overview: Classic Technologies

What?	Knowledge	Styles
Order of activities	Sequencing	?
Feedback	Adaptive diagnosis	Style-adaptive feedback
Content	Adaptive presentation	Adaptive presentation
Links	Adaptive navigation support	Adaptive navigation support

Origins of AEL Technologies (2)
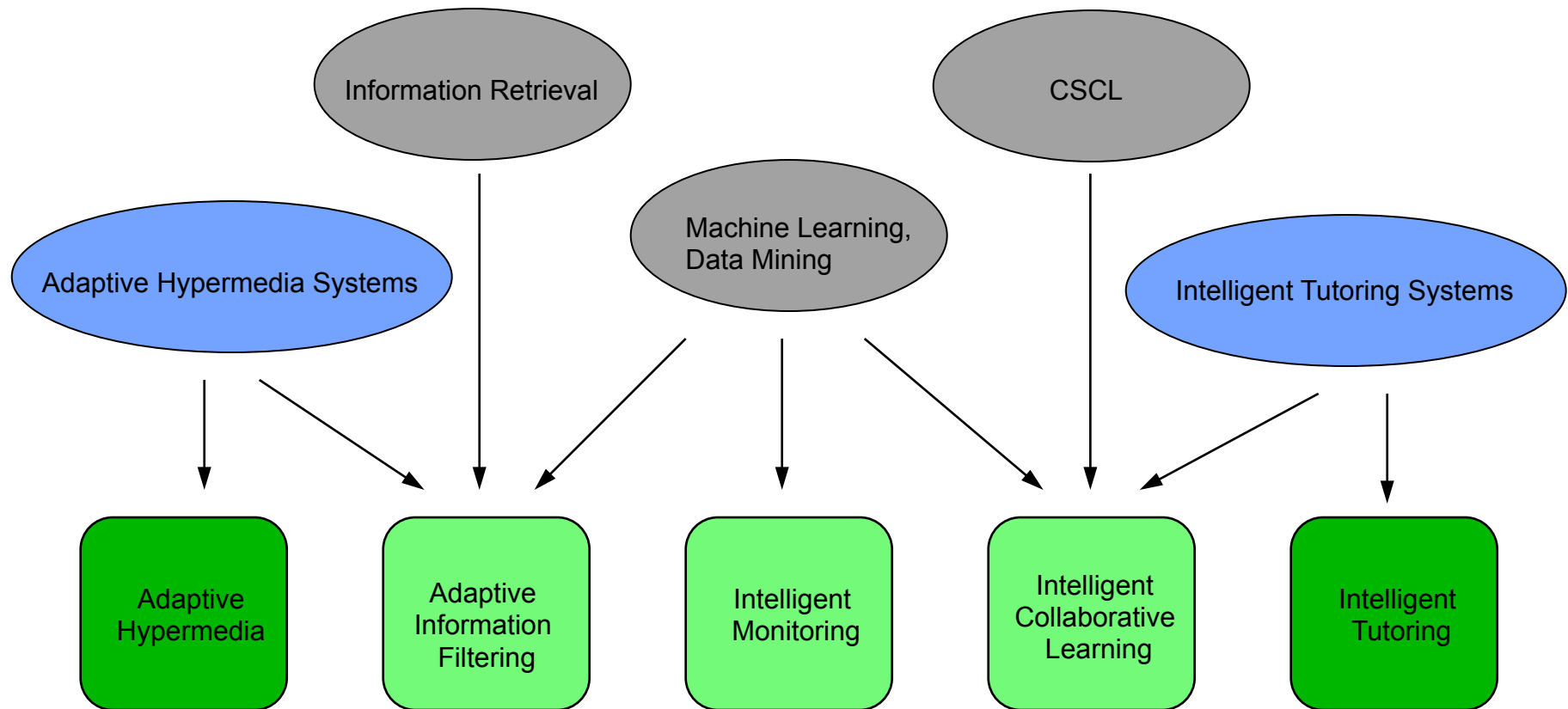
Native Web Technologies

- Availability of logs
  - *Log-mining*
  - *Intelligent class monitoring*
  - *Class progress visualization*
- One system, many users - group adaptation!
  - *Adaptive collaboration support*
- Web is a large information resource - helping to find relevant *open corpus* information
  - *Adaptive content recommendation*

Modern Fusion Technologies

- *Collaborative Content Recommendation*
  - *Logs, CF, sequencing*
  - *Challenge – changing context*
- *Social navigation*
  - *Collaboration, logs, ANS*
- *Learning Analytics*
  - *Helping the teacher and the process*
  - *Logs, visualization, data mining*

What You Can Get from Logs?

- Log processing and presentation
  - Presenting student progress on topic and concept level: making sense of class
- Course/site improvements
- Grouping users by learning styles
- Intelligent class monitoring
  - Comparing progress, identifying students way ahead and behind

Adaptive Collaboration Support

- Peer help
- Collaborative group formation
- Group collaboration support
  - Collaborative work support
  - Forum discussion support
- Mutual awareness support

Personalized Access to Educational Resources

- A lot of resources are available on the Web and in educational DL/Repostitories
- A new direction of adaptation - provide personalized access to these resources
  - Content based recommender
- Adding advantage of community wisdom
  - Collaborative recommender systems
  - Social navigation systems

Modeling User Interests

- Concept-level modeling
  - Same domain models as in knowledge modeling, but the overlay models level of interests, not level of knowledge
- Keyword-level modeling
  - Uses a long list of keywords (terms) in place of domain model
  - User interests are modeled as weigthed vector or terms
  - Originated from adaptive filtering/search area

Use of Profiles in AES: ML Tutor

MLTutor's suggestions

Social Computing for WBE

- Web 2.0 for education
- Collaborative resource discovery systems
  - CoFIND
  - UMtella (Demo)
- Presence-based collaboration (Educo)
- Social navigation support for open corpus resources (Knowledge Sea II)
- Social guidance (Progressor)

Example: UMtella

Example: EDUCO

Demo: Knowledge Sea II

Progressor

Demo: Progressor+
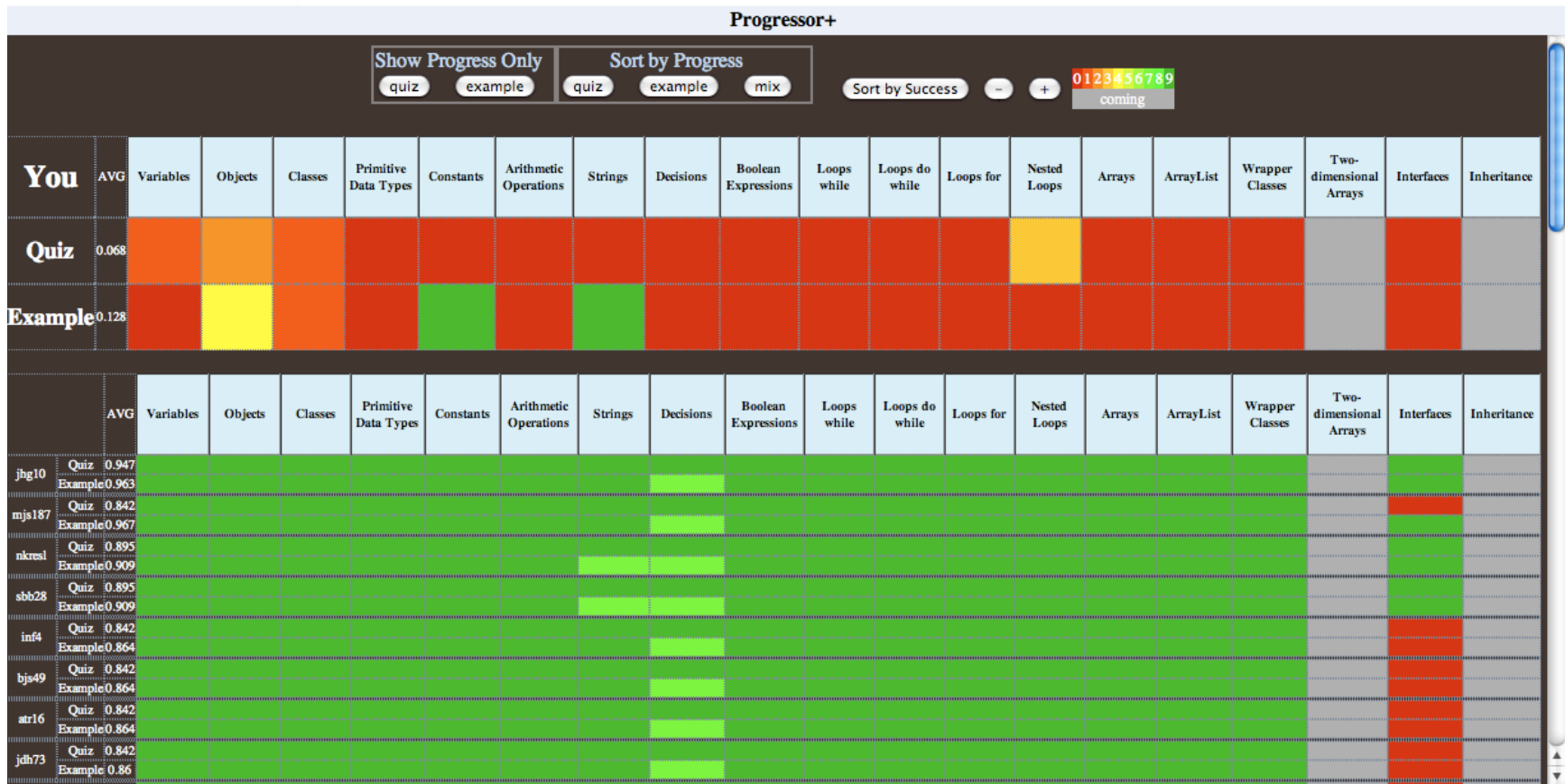
What LMS Can Do

- For students
  - Course information and content delivery
  - Assessment and grades
  - Communication and collaboration
- For teachers
  - Authoring
  - Learning control
  - Student monitoring
  - Communication

What AES Can Do for Students

- Presentation
  - Adaptive presentation, adaptive navigation support, adaptive sequencing
- Assessment
  - Adaptive testing
- Communication and collaboration
  - Peer help and collaborative group formation
  - Collaboration coach
- Learning by doing
  - Problem solving support

What AES Can Do for Teachers

- Student monitoring
  - Identifying students in trouble
- Control
  - Sequencing
  - Adaptive navigation support
- Authoring
  - Concept-based authoring and courseware engineering

AES vs. LMS

- Adaptive E-Learning systems can provide a more advanced support for most functions
    - Course material presentation - InterBook, AHA
    - Assessment with quizzes - SIETTE
    - Threaded discussions - collaboration agents
    - Student management - intelligent monitoring
- Why LMS are not really adaptive?
    - Except simple control and learning design

Challenges

- How to make it working in practice?
  - AES systems use advanced techniques - hard to develop
  - AWBES content is based on knowledge - hard to create
  - AES require login and user modeling - hard to integrate
- Possible solutions - (watch, PhD students!)
  - Component-based architectures for AWBES
  - Authoring support
  - Open Corpus adaptive systems

Component-based Architectures

- Research systems can provide a better support of almost each function of E-Learning process
- Adaptive systems show how to implement nearly each component adaptively
- We need the ability to assemble from components
  - Course authors can choose best components and best content for their needs
  - Components providers and content providers have a chance to compete in developing better products

Current State

- Several component-based frameworks
  - ADAPT^2, ActiveMath, MEDEA,…
- Attempts to develop systems with internal components
- Reusable user/student model servers
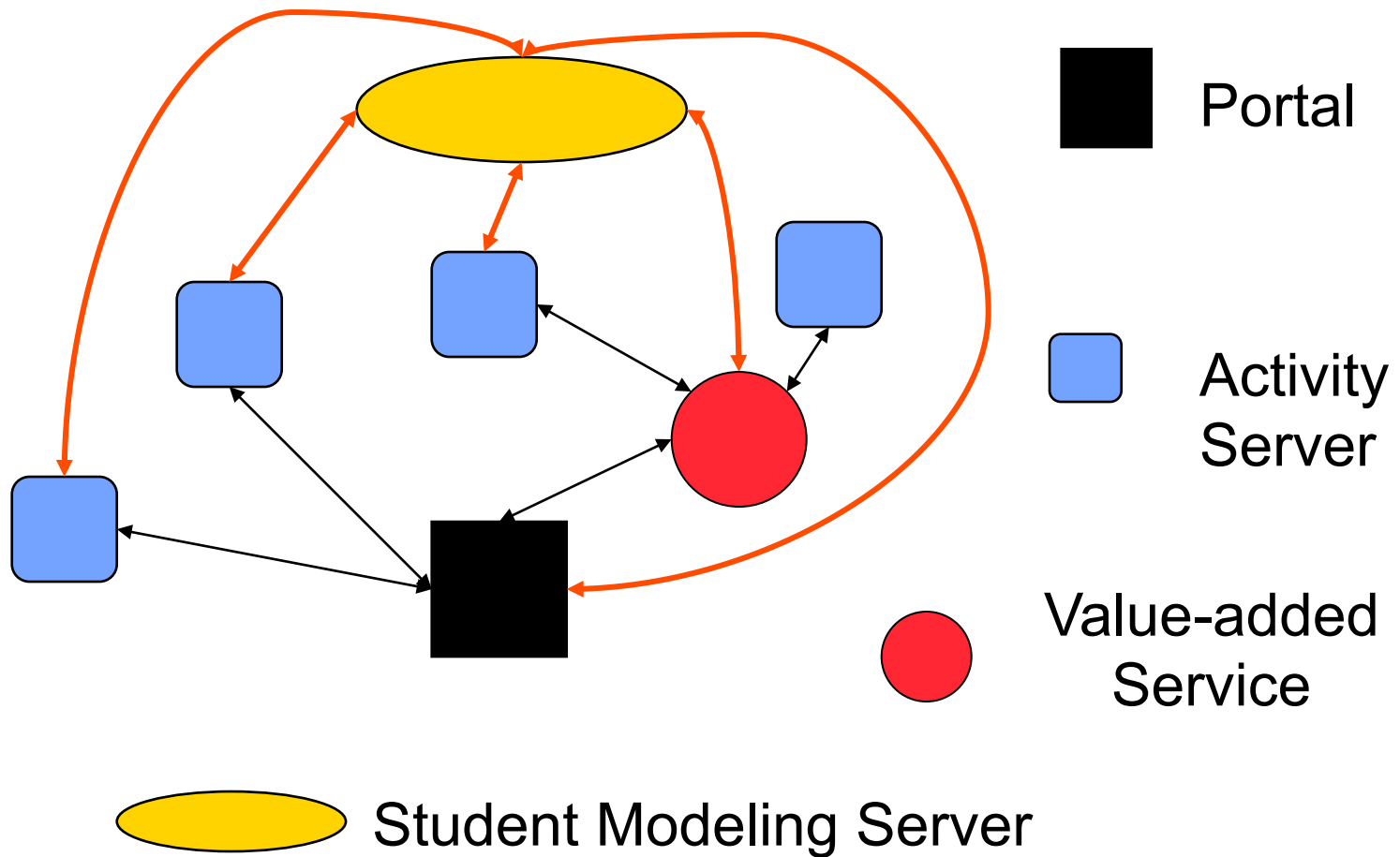- Some matching work in the standardization movement

Re-use/Standards Movement

- Learning Object Re-use supported by coming standards is another major research direction in E-Learning
- The re-use movement joins many existing streams of work driven by similar ideas
  - Create content once, use many times
  - Content independent from the "host" system
  - Content and interfaces with the host system are based on standards (metadata, CMI, etc)
- Let content providers be players in E-Learning
- The future is components and re-use

What is the Future?

- How to use good component/content if you have a Blackboard, Moodle or other major CMS?
- Is the future model a Blackboard-style giant system where all components are advanced and adaptive?
  - Wait for the CMS giants to integrate better tools?
  - Create our own "adaptive Blackboards"
- Is there any other choice?

ADAPT² Architecture

⬛	Portal
🟦	Activity Server
🔴	Value-added Service
🟡	Student Modeling Server

Knowledge Tree II Portal