ADAPTIVE LEARNING ENVIRONMENTS:

L2 More core systems

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Reminders

Assignments, reading list online – will be available by next week

Future lecture: BB teachable agents

- To do that, volunteers need to register for Betty's Brain. It is free and easy to install!
- See Vanderbilt Teachable Agents group website. Takes a few days to process!
- Install, and bring laptops, if you can

Opening activity

Group 1: What is a THEORY?

Group 2: What is a MODEL? (Not the fashion kind, everybody!)

Group 3: Why might we want to build an intelligent tutoring system (ITS) in the first place? What's the point?

DISCUSS.

Write down your QUESTION NUMBER

Write down some KEY POINTS for your answer

Cognitive Tutors: testing theory

CORE SYSTEM(S): Cognitive Tutors

Family of systems all based on ACT/ACT-R cognitive architecture

Systems created with initial goal of testing the architecture. Goals later evolved to be more "traditionally" educational

Earliest versions mid 1980's; development on their "children" continues today

Systems include LISP tutor, an algebra tutor, and the **geometry tutor,** also newer **geometry explanation tutor.**

ACT/ACT-R

Originally proposed by John Anderson
Allows creation of program-like models

"A theory of learning and problem solving"*

Is a **"cognitive architecture"**
Is a framework

* Anderson, Corbett, Koedinger, & Pelletier, 1995, p. 168

ACT/ACT-R: components

Symbolic: a **production system**
and
Sub-symbolic: assorted **mathematics** to determine relative **utility** of possible productions (i.e. actions)

Today we focus on: The symbolic production system
Has two components:

- propositional database *(won't discuss this)*
- database of **production rules**

Basic function of a production system is choosing and applying rules *(in this case, based on their utility)*

Rules about what?
Utility to whom?
Towards what goal?

ACT/ACT-R: Key point 1

Cognitive skills are made up of smaller **units of "goal-related knowledge"** (1995; 168)

Cognitive skills as modular

- Example cognitive skill: subtraction
- smaller unit of knowledge: number differences, idea of "borrowing"

These "units" are represented by the **production rules**

Theory says: we **acquire cognitive skills** by **formulating production rules**

Rules relate conditions to actions

IF.... lower number greater than upper number

THEN... borrow...

ACT/ACT-R: Key point 2

Theory hinges on having TWO main types of knowledge

Declarative: explicit knowing **that**; memorisable facts

Procedural: more implicit knowing **how;** application

"Declarative knowledge by itself is inert and often quite useless"*

* Anderson, Corbett, Koedinger, & Pelletier, 1995, p. 170

Two types of modules:

1. **Perceptual-motor modules** - take care of the interface with the real world (i.e., with a simulation of the real world), Most well-developed perceptual-motor modules are visual and the manual modules.

2. **Memory modules**.
Two kinds:
- declarative memory, facts such as
  Washington, D.C. is the capital of United States,
  France is a country in Europe, or *2+3=5*
- procedural memory, productions, how we do things:
  how to type the letter "Q" on a keyboard,
  how to drive, or about how to perform addition.

ACT/ACT-R: Key point 3

How do we get the difficult, procedural knowledge?

ACT says: by **using the declarative knowledge**

- relating it to task and/or goals
- likely facilitated by overt instruction, analogy to other known contexts (**interpretive procedures)**

This declarative knowledge plus interpretation generates **problem-solving behaviour**

ACT/ACT-R: Key point 3

Knowledge compilation converts this interpretation/problem solving into **production rules** (the "units" of goal-related knowledge)

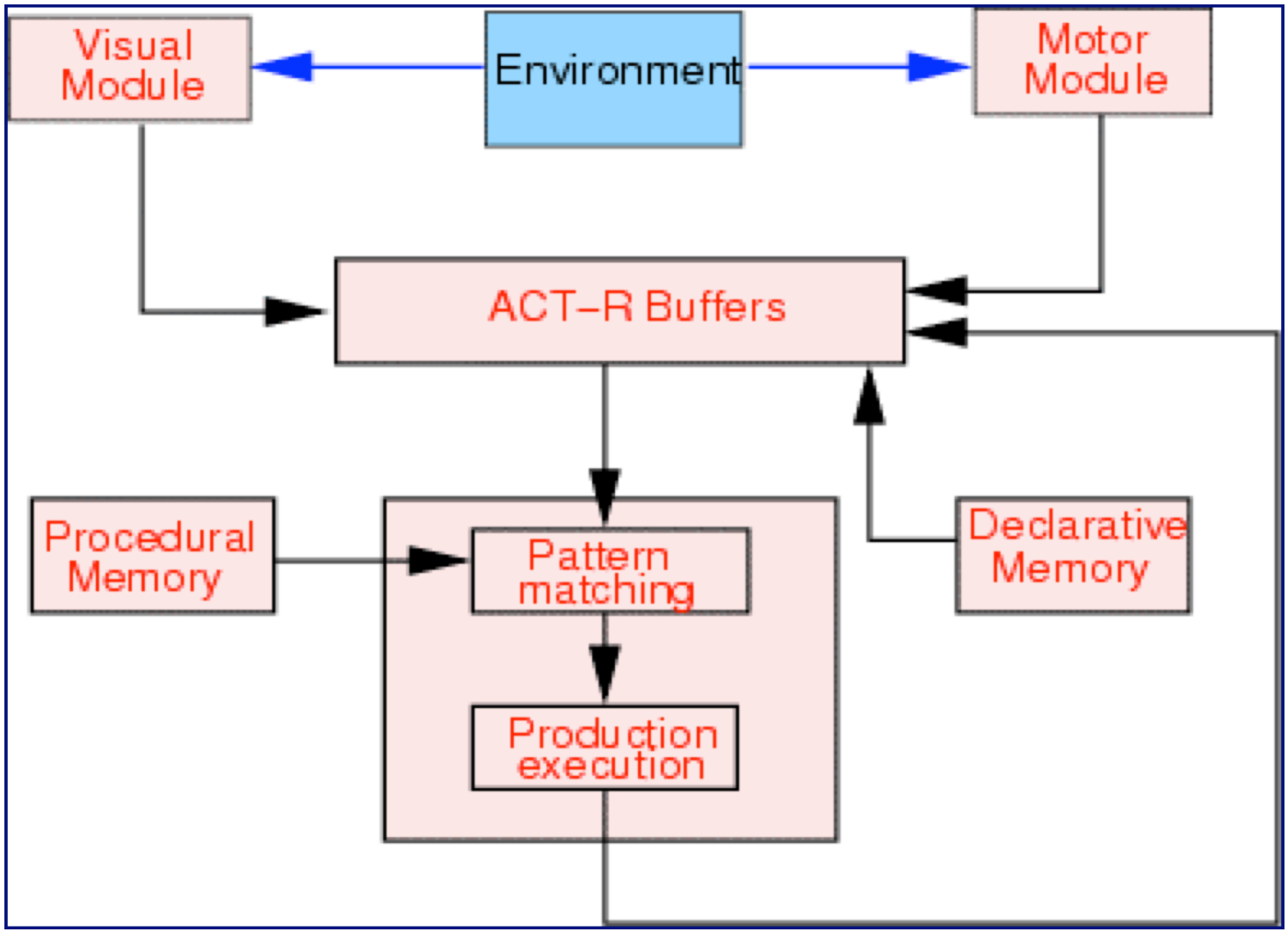
...and **production rules** are the representation of **procedural knowledge!**

Making sense of ACT

Direct teaching of factual information
"Interpretive procedures"
Task goals
Declarative knowledge ("that")
Procedural knowledge ("how")
Cognitive skill
Individual production rule
Database of production rules
Knowledge compilation

Can you draw a diagram that show how these concepts and processes are related?

ACT-R Architecture



http://act-r.psy.cmu.edu/about/

What does this have to do with tutoring, again?

From ACT to tutoring

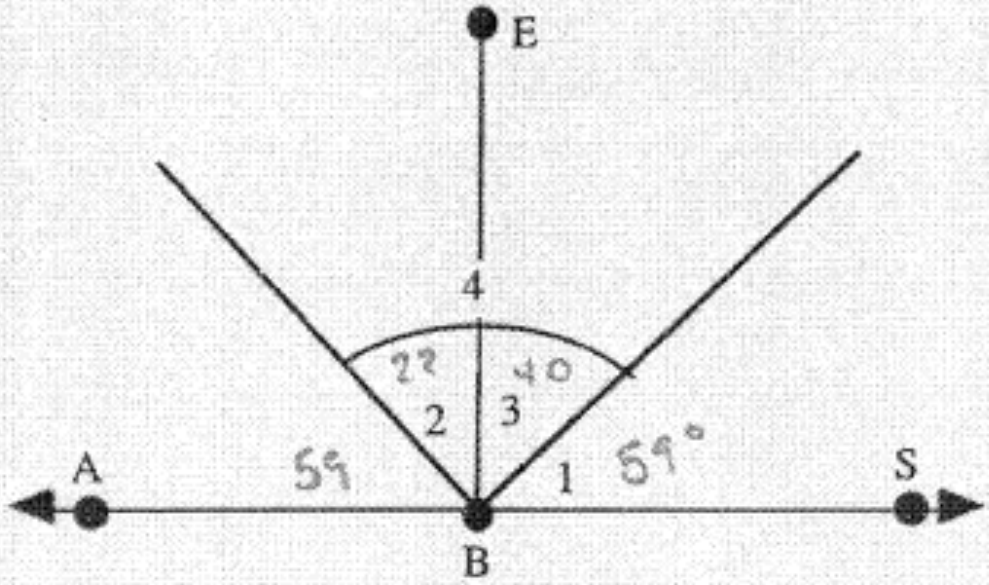
About DOING not MEMORISATION
Focus on PROCEDURAL KNOWLEDGE
Turning the “inert” declarative knowledge to appropriate action

An **intelligent tutoring system** is...

- Source of limited direct instruction
- Source of feedback and explanation

***Context in which to practice application!

Geometry Tutor

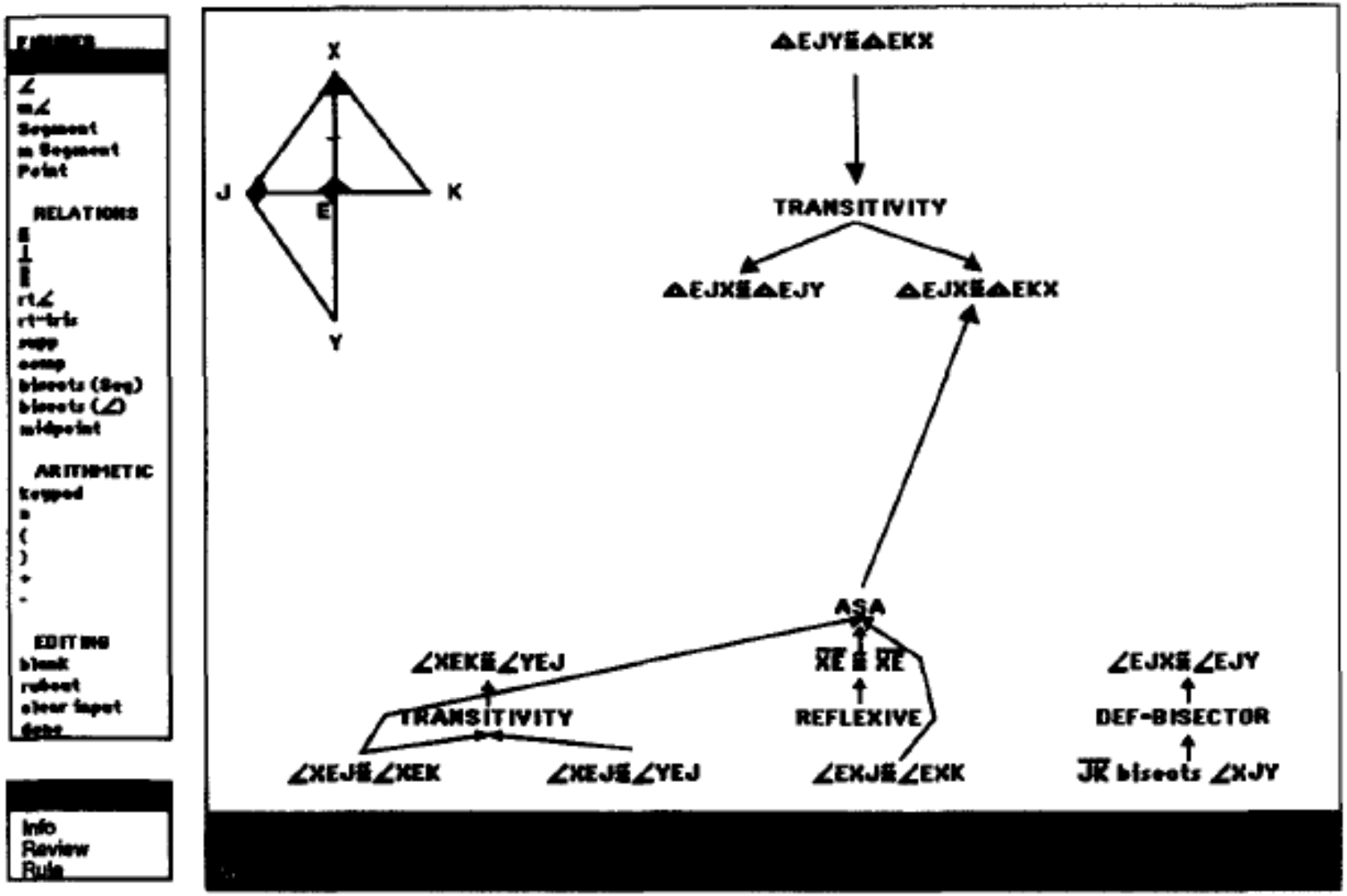


3. Segment EB is perpendicular to Line AS. If the measure of Angle 1 is 59° and the measure of Angle 2 is 22°, find the measure of Angle 4.

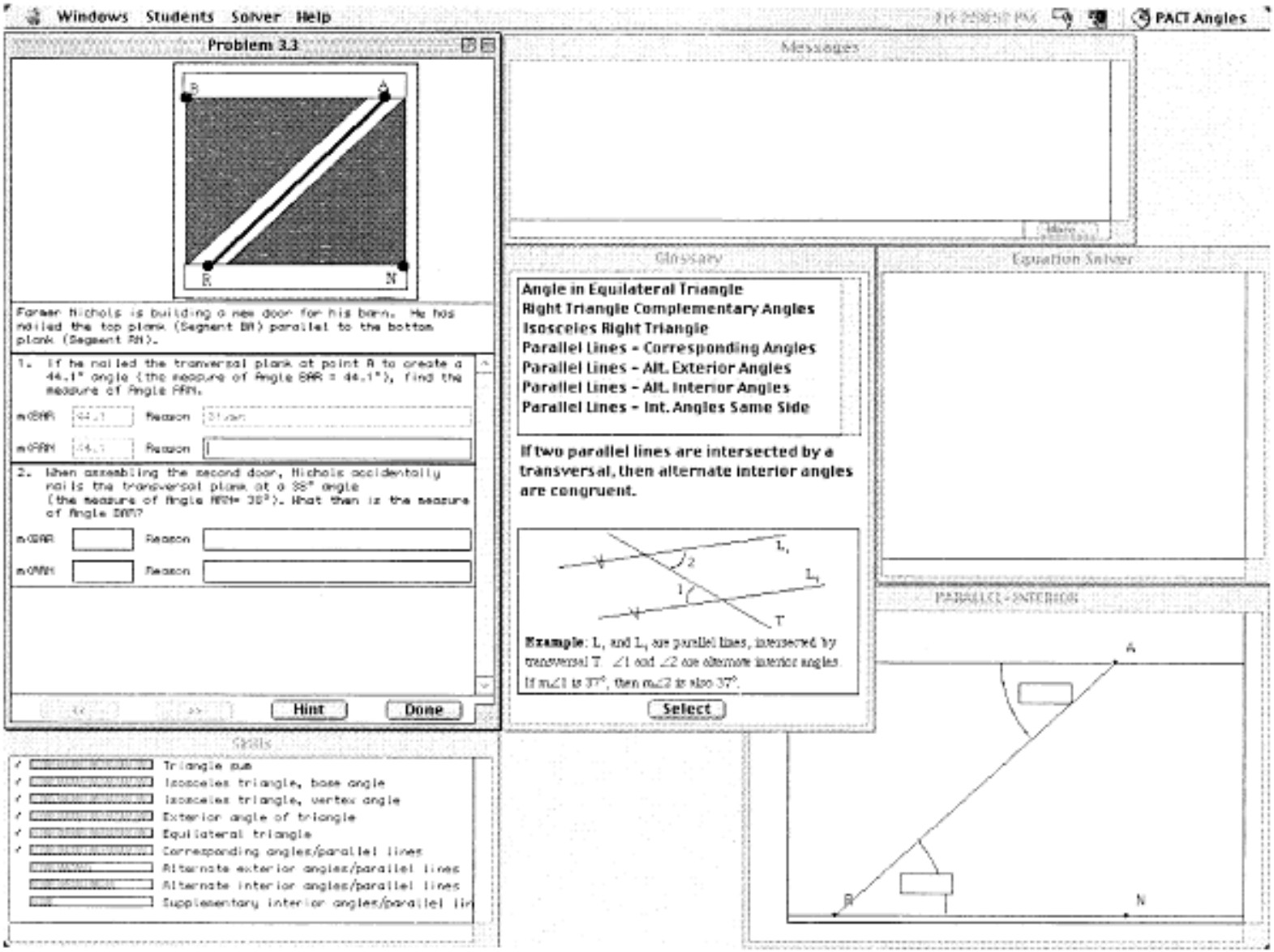
m∠3 : 40° Reason: Supplamentary

m∠4 : CC Reason: supplamentary

(Image from Aleven & Koedinger, 2002)



Screenshot from the Geometry Tutor, circa 1993 (Image from Anderson, Corbett, Koedinger, & Pelletier, 1995)

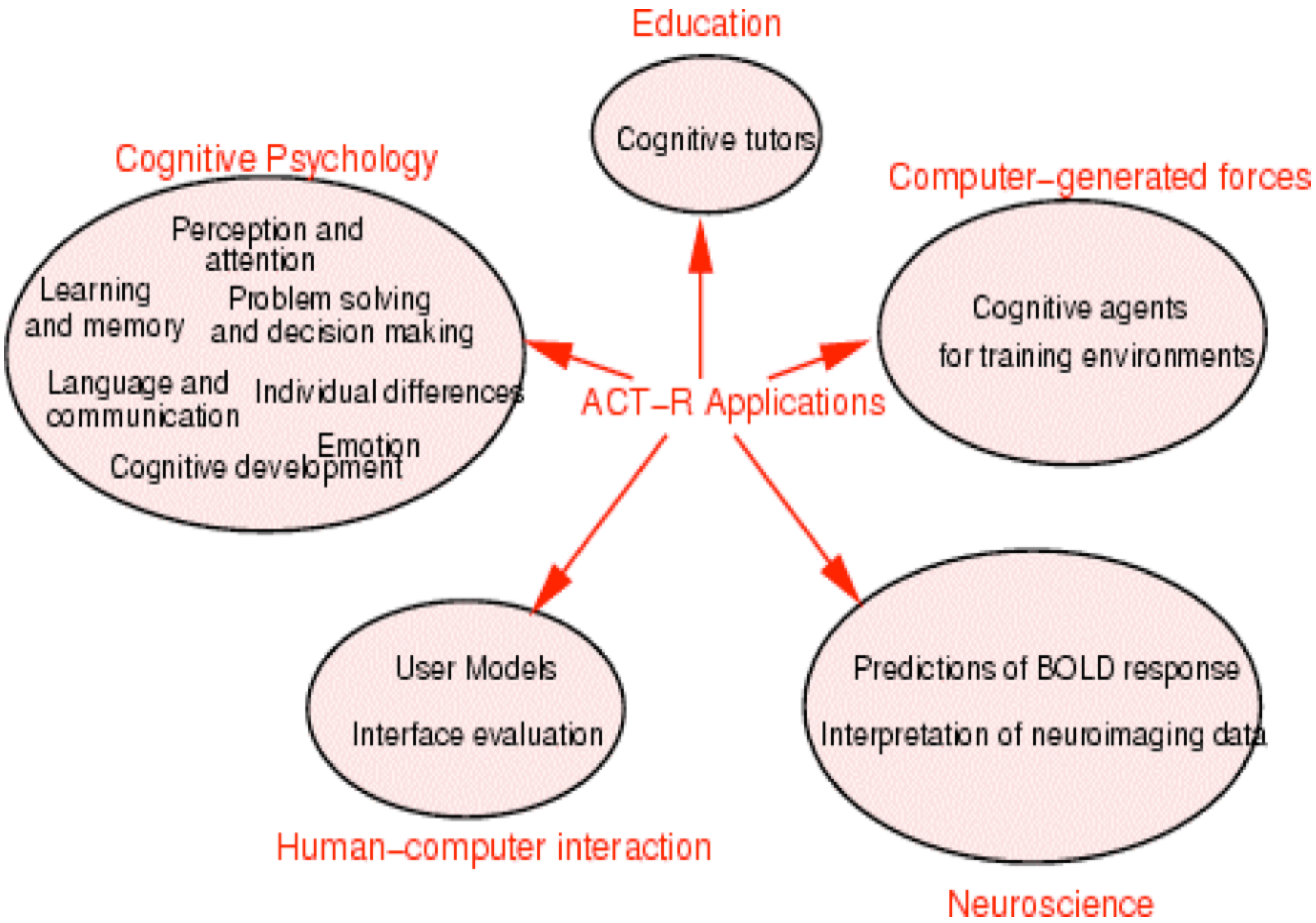


Screenshot from the Geometry Tutor, circa 2001(?)
(Image from Aleven & Koedinger, 2002)

Theory testing, not educating the masses (at least at first), according to Anderson, Corbett, Koedinger, & Pelletier (1995, p 171): c

> Our initial motivation in developing intelligent tutoring systems was mainly to learn more about skill acquisition rather than to produce practical classroom results. It was a significant test of the ACT theory to see whether we could produce successful learning by getting students to act like the underlying production-rule model. It was by no means obvious at the time whether or not there were going to be major gaps in ACT production-rule models when applied to such instructional situations.

We will RETURN later in the course to the modelling parts of the Cognitive Tutors, and to their evaluation in schools!


Education
Cognitive tutors
Cognitive Psychology
Perception and attention
Learning and memory
Problem solving and decision making
Language and communication
Individual differences
Emotion
Cognitive development
Computer–generated forces
Cognitive agents for training environments
ACT–R Applications
User Models
Interface evaluation
Human–computer interaction
Predictions of BOLD response
Interpretation of neuroimaging data
Neuroscience

Onwards to Autotutor! It's exactly what it sounds like!

Autotutor (and family)

Another "family" of systems with common theoretical underpinnings and methodology, across multiple domains. Most work with:

- Newtonian physics
- Computer literacy
- Critical thinking (ex. Social science research methods)

Key researcher: Art Graesser at University of Memphis

Broadly based on explanation-based **constructivist learning theories**, plus empirical evidence that suggests constructivist activities are routine in **human tutoring**

- active construction of "explanation-based meanings and knowledge" through interaction
- "Students learn by telling and doing"

(D'Mello & Graesser, 2012, p. 2)

PAUSE:

What is constructivism?

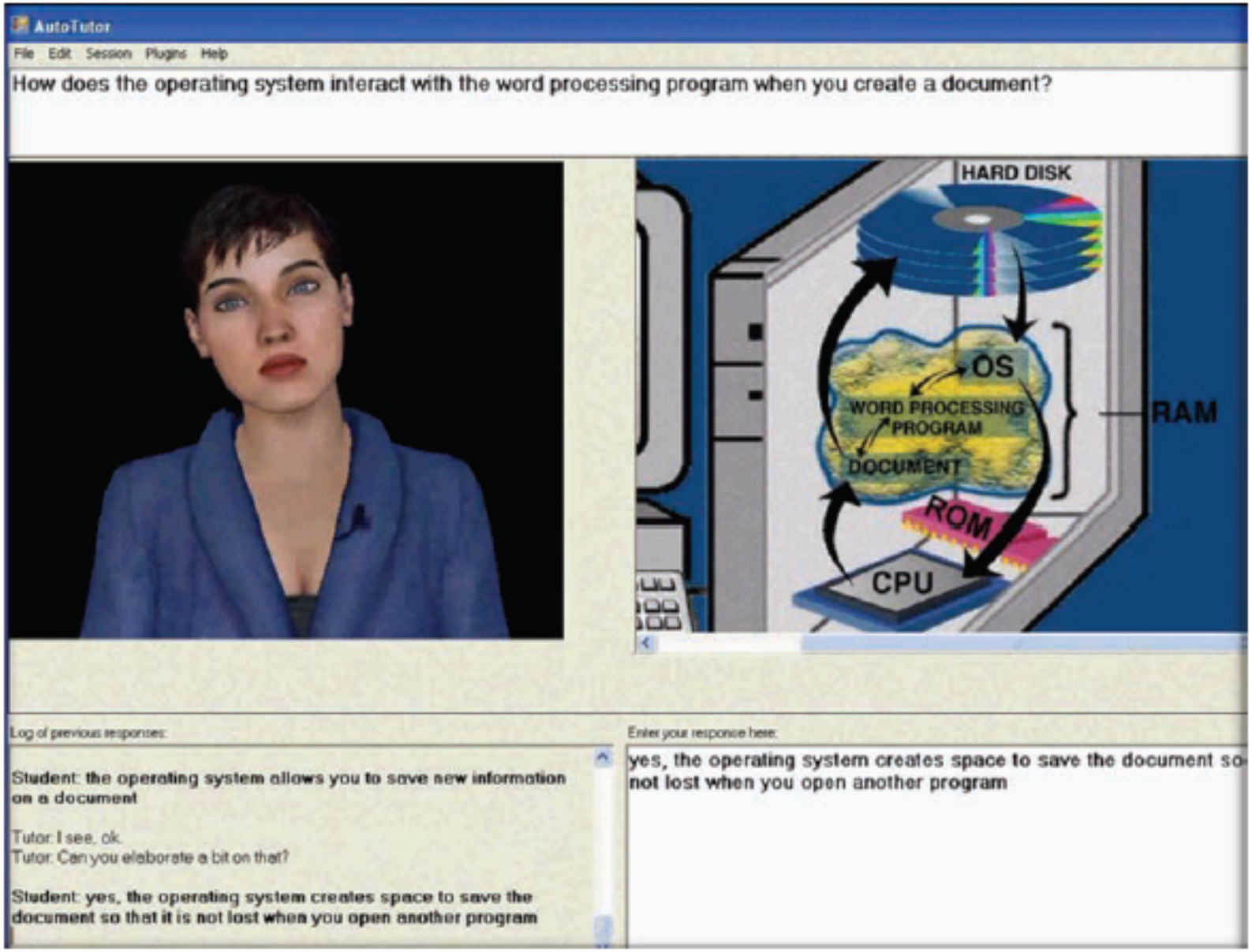
Automated tutoring?

Autotutor as automating human tutoring, focusing on **tutorial dialogue actions** and (more recently) affect

Main method: Strives to directly emulate the actions of experienced human tutors

- Context: Experienced human tutors (1-on-1) generally considered "gold standard" of effectiveness for teaching
- Context: This 1-on-1 attention is costly in time and resources
- ITSs to bridge the gap?

To go with this goal, the tutor is "embodied: onscreen as a semi-realistic **virtual character** (not just text)



Screenshot from Autotutor problem about operating systems interacting with a word processor (Image from D' Mello & Graesser, 2012)

Interface

Window 1 (top of screen) is the main question that stays on the computer screen throughout the conversation about the question.

Window 2 (left middle) is the animated conversational agent that speaks the content of AutoTutor's turns.

Window 3 (right middle) is either blank or has auxiliary diagrams.

Window 4 (right bottom) displays the students' answers as they type them in.

Window 5 (left bottom) displays the dialog history of student and tutor

Constructivist teaching: What should the ITS do?

Encourage process of **actively constructing answers** to questions (ex. word problems)

- Reasoning required: How, why, what-if
- NOT just declarative recall questions

Tutor provides...

- Feedback and explanations
- Repair of misconceptions ("buggy" knowledge)

→ As with Cognitive Tutor, system does NOT just "deliver" information! (this will start to be a theme)

Example Dialogue

AutoTutor: *When a car without headrests on the seats is struck from behind, the passengers often suffer neck injuries. Explain why. (**main question)***

Student: I don't know. (metacognitive speech act:
This expression by the student is classified as a metacognitive speech act because it conveys what the student knows about his/her own knowledge.)

AutoTutor: Could you at least try to give me an answer? That way, we'll have something as a starting place to work from.
(**pump:** This **indirect dialog move** encourages the student to say more, but does not direct the student to express particular information.)

Example Dialogue contd

As the dialog continues, AutoTutor detects that an important expected piece of information is missing *(i.e., the impact of the collision on the neck).*

AutoTutor: ***Let's try this together. (discourse marker:***
This is a discourse marker that introduces or connects dialog moves within a turn.)

When the collision provides a large force to accelerate the head, what could happen to the neck?
(hint: This dialog move leads the student to articulate a particular sentence, clause, or proposition.)

Will discuss dialogue in detail in Topic unit B

- For now, keep in mind...
  - Autotutor is trying to imitate “best” features of human tutorial dialogue
  - Adaptivity: ITS is fitting strategies to students and their level/correctness of knowledge (per the model)

Adding affect to Autotutor

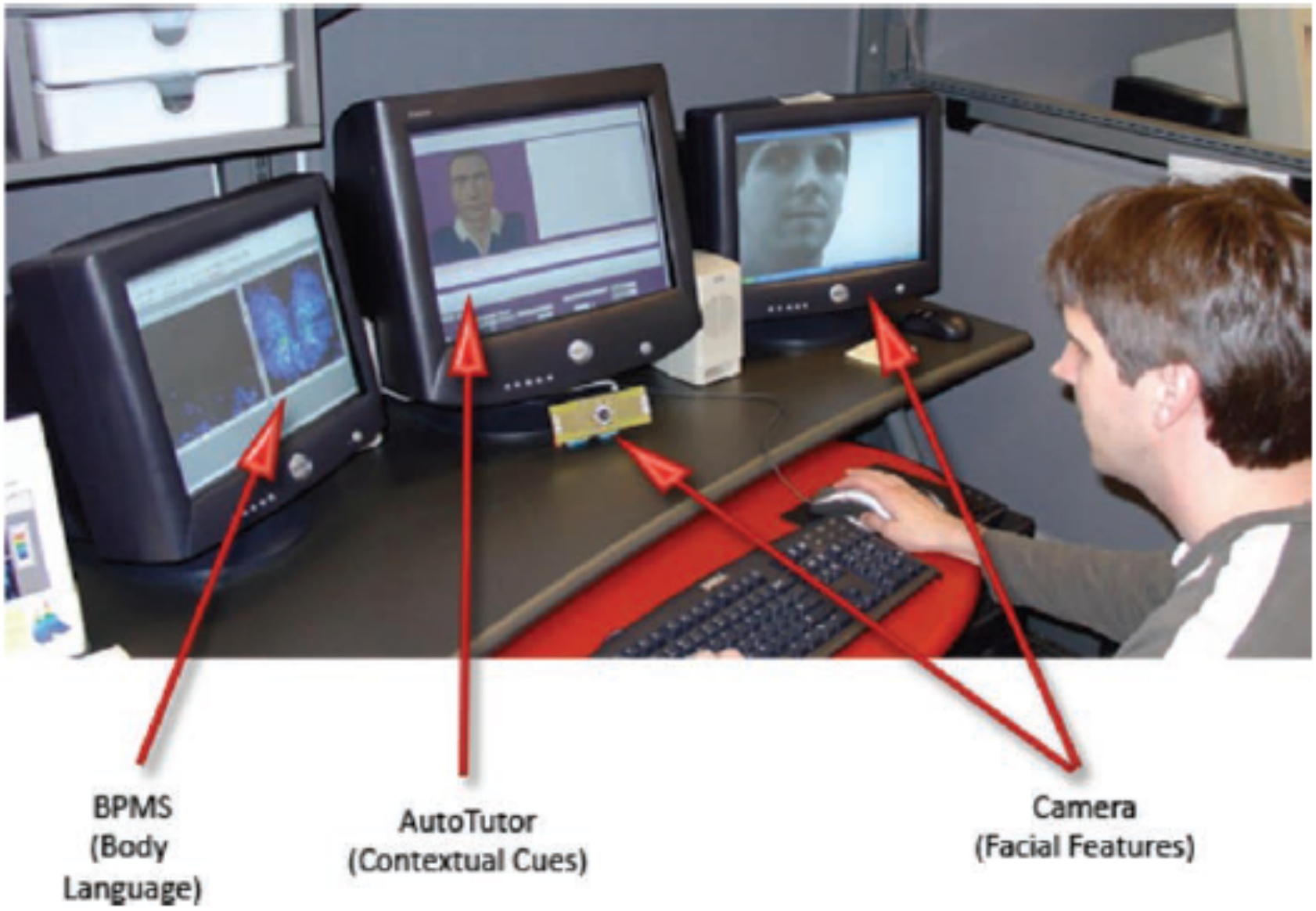
Emotions (affect) can strongly impact learning.

We will return to this in topic unit B.

Goal is to map affective states to production rules (i.e. possible actions)

- Tutor can respond appropriately to student affect
- Priority on addressing **negative emotions** like boredom, frustration, confusion

Use **multi-modal affect detection** at special workstation



Affective Autotutor (Image from D' Mello & Graesser, 2012)

Affective loop

Affective loop is the name for this process:

1. Real-time detection of student affective state
2. Selection of appropriate tutor actions
3. Synthesis of tutor expression--> try to engage with the student's affect

Freeing up teachers?

"One-on-one human tutoring does have a payoff because there is considerable empirical evidence showing that human tutoring is extremely effective when compared to typical classroom environments... However, the cost associated with providing each student with a human tutor makes the adoption of widespread tutoring programs unfeasible... AutoTutor and Affective AutoTutor provide a technological solution to this problem by simulating the pedagogical and motivational aspects of human tutors in a scalable and cost-effective way."

(D'Mello & Graesser, 2012, p3).

Some other examples next time…

Reflection questions for today:

1.ACT-R is supposed to give a general (domain-independent) representation of cognitive skill acquisition. Do you think that it would apply equally well to all domains and cognitive skills? If not, what sort of cognitive skills do you think would not fit well with this framework?

2.What do Cognitive Tutors and Autotutor tell us about Big Question 3, especially with respect to goals changing over time?

3.Consider the differences in the attitude toward learners and learner experience in a system like Crystal Island versus in the original Cognitive Tutors.

- What is mentioned or not mentioned?
- What is identified as important?

4.Consider the rhetoric of tutoring systems "freeing up" human teachers to work with difficult material and students while they (computers/systems) do "routine" tutoring.

- Does this vision of instruction seem realistic in the classroom of the "near future"? Why or why not?
- Does this vision of instruction seem desirable? Why or why not?