ADAPTIVE LEARNING ENVIRONMENTS: Introduction

January 16th

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Overview (L1 and L2)

1. General course info: note - course based on version by A. Alcorn (2013/14) plus some earlier material
2. Reveal the mystery systems!
3. Example – modelling subtraction
4. Talk about "big questions" for the course
5. Reminders and what's coming up …

Mystery systems: Who built what when?

(see handout)

System C: WHY System ~1977-1979

- Teaching geography and meteorology concepts through dialogue with the student
- *Socratic dialogue* formalised as *production rules*.
- Computer's utterances and teaching based on analysis of human tutorial dialogues
  - Led authors to create tutor's rules
- Different strategies are different "rules" for the dialogue

Following dialogue example from Stevens & Collins (1977)

Example WHY System dialogue

- **WHY: Do you think the Andes mountain range has any effect on the rainfall in the Amazon jungle?** *(rule 5: suggest a factor and ask it if is a cause)*
- **Student: * yes ***
- **WHY: How?** *(rule 3: ask for intermediate causes)*
- **Student: *the prevailing wind hits the Andes and the air cools***
- **WHY: How does the fact that prevailing wind hits the Andes, lead to air cooling?** *(rule 3 again)*

- **WHY: Do you think that any place with mountains has heavy rainfall?** *(rule 6: form a general rule for an insufficient cause)*
- **Student: * yes ***
- **Why: Southern California has mountains. why doesn't southern California have heavy rainfall?** *(rule 7: Pick a counter-example for an insufficient cause, and rule 2: Ask for prior causes)*

Tutor has 2 main dialogue sub-goals:

1. **Diagnosis** - probe for factors; make Student make predictions; entraps into incorrect predictions

2. **Correction**

- **Factual and outside-domain bugs** - simply gives answer
- **Over-generalisation** - counterexamples; probe for factors not considered; hypothesise based on insufficient factors; point out factors not considered
- **Over-differentiation** – *same as for over-generalisation*
- **reasoning strategy bugs** - variety of ways

+ also has heuristics for prioritising which bugs to correct first.

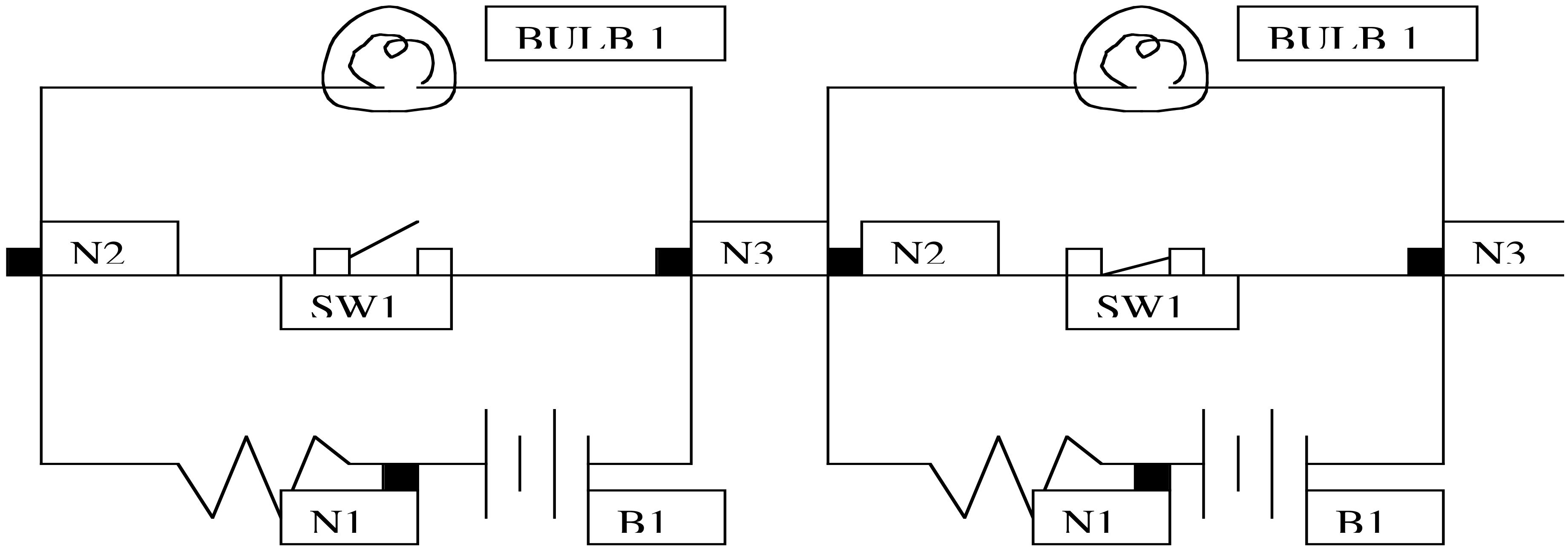
X

NOT BUILT

System F: QUEST ~1984-1986

- The domain is electrical circuits, with focus on predicting and explaining their behaviour
- Qualitative modelling
- Internal representation uses causal calculus:
  - basically component-oriented
  - incorporates some higher-level concepts guiding evaluation of component states.
- Progressions of mental models; modelling “evolution” of reasoning about domain

- *The more advanced the student’s understanding, the higher level the model*



“In order for the bulb to light, there must be a voltage drop across it. There is a device in parallel with the bulb, the switch. Two devices in parallel have the same voltage across them. Voltage drop is directly proportional to resistance: If there is no resistance, there can be no voltage....”

Example image and explanation from White & Frederiksen, 1986c

System A: Andes physics tutor ~1996-2002

- U. of Pittsburgh and US Naval academy collaboration
- Transferring paper-and-pencil physics problems to the computer
- Coached problem-solving
  - Different interactions depending on progress
  - Tutor only helps when student off “path” of solution
- Student constructing new knowledge: a few hints, but they do most of the work
- More later on how this system actually works, and how evaluated in university classes! (Spoiler alert: It helped most students)

This figure and following are from VanLehn et al., 2005 “The Andes Physics Tutoring System: Lessons Learned” (page 6-7)

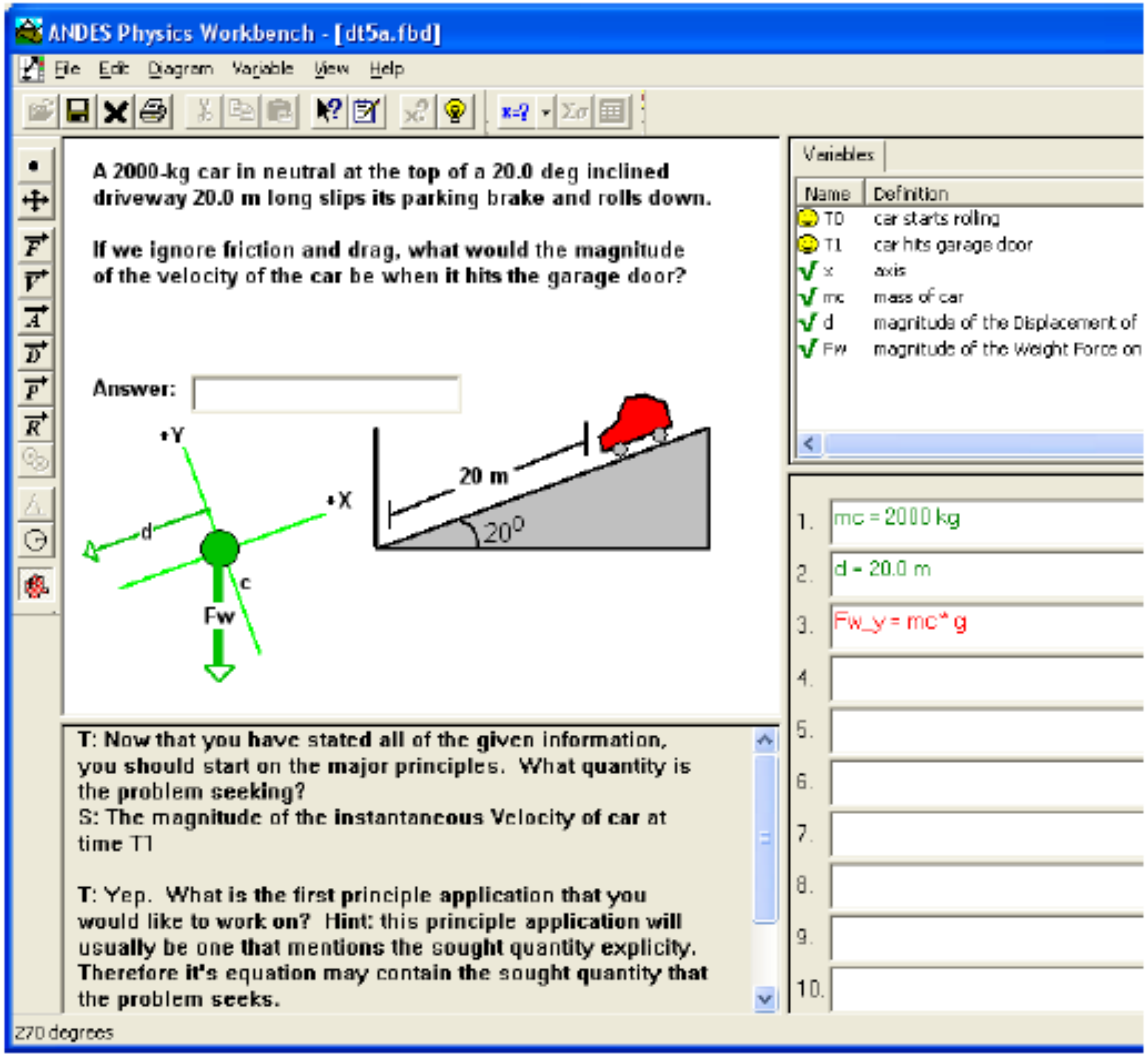


Figure 1: The Andes screen (truncated on the right)

A 2000-kg car in neutral at the top of a 20.0 deg inclined driveway 20.0 m long slips its parking brake and rolls down.

If we ignore friction and drag, what would the magnitude of the velocity of the car be when it hits the garage door?

Problem statement (provided by system)

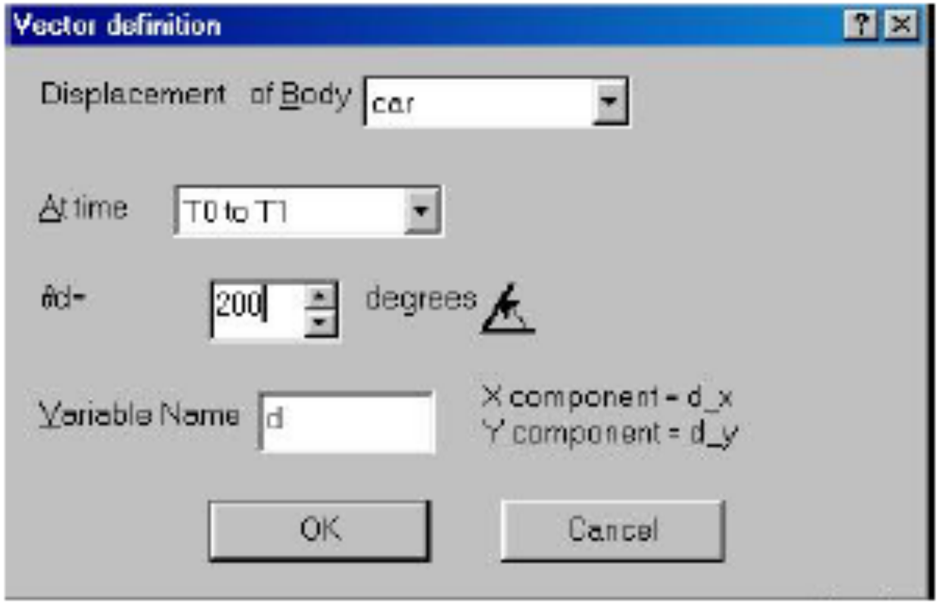


Figure 2: A dialogue box for drawing a vector

Student draws vectors with dialogue box

Student defines given information as variables

Variables

	Name	Definition
☺	T0	car starts rolling
☺	T1	car hits garage door
√	x	axis
√	mc	mass of car
√	d	magnitude of the Displacement of
√	Fw	magnitude of the Weight Force on

Example student-tutor dialogue

T: Now that you have stated all of the given information, you should start on the major principles. What quantity is the problem seeking?
S: The magnitude of the instantaneous Velocity of car at time T1

T: Yep. What is the first principle application that you would like to work on? Hint: this principle application will usually be one that mentions the sought quantity explicity. Therefore it's equation may contain the sought quantity that the problem seeks.

Ambient Wood ~2002-2004

- Student-directed “augmented field trip”
- Use range of devices in a real ecosystem, to learn about ecology
- Devices give contextually-relevant (i.e. location-aware) information
- Also meant to help facilitate reflection, move from concrete observations to abstract processes, relationships

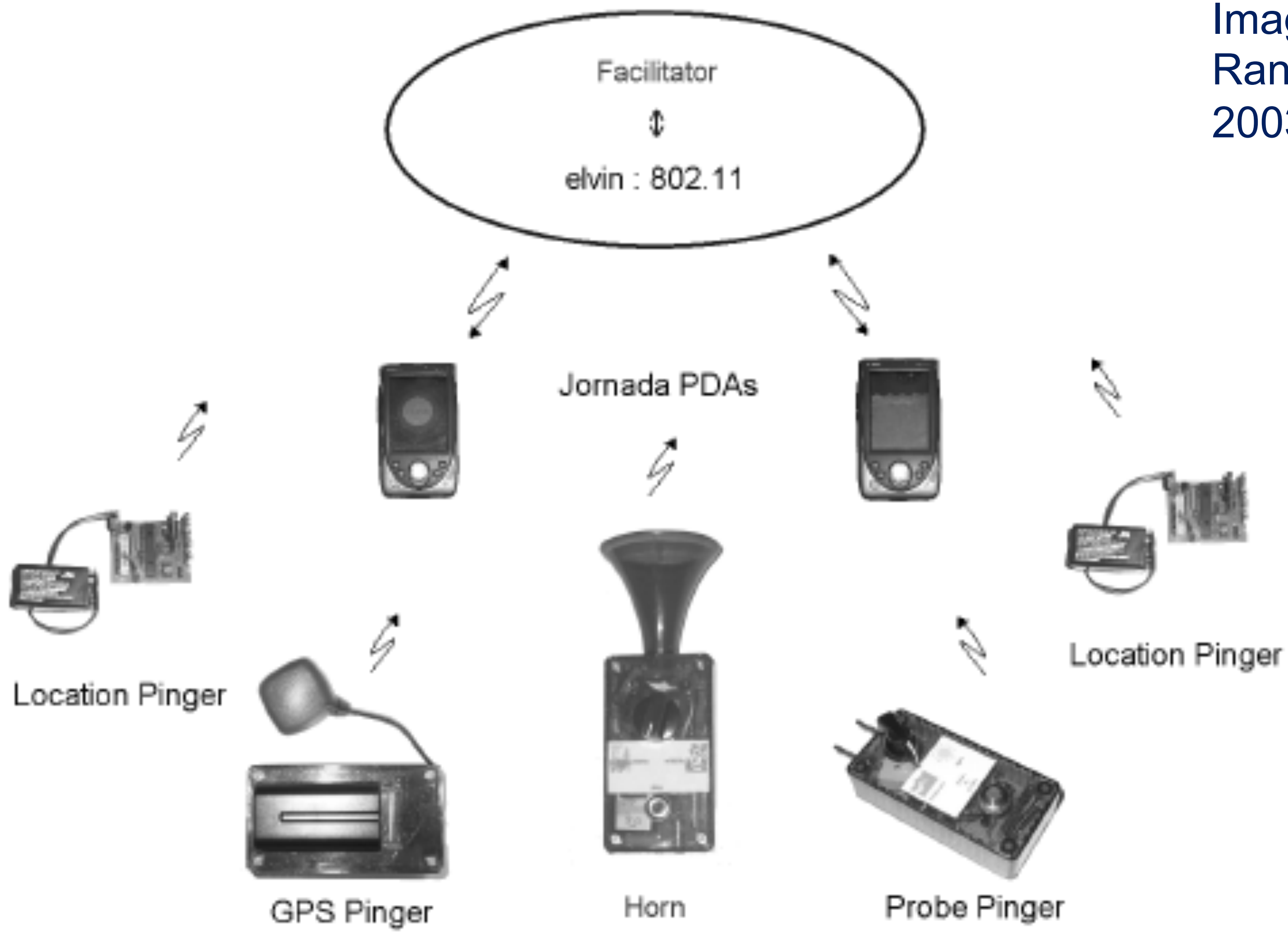


Image from Randell et al., 2003

Figure 2: Ambient Wood Device Architecture.

Figure 1: Displayed information in the Ambient Wood. A moisture reading, light reading and badgers tracks.

Top: Child using the probe tool to take a moisture reading from the soil (From Rogers et al., 2004)

Right: Information from the PDA and two child participants (From Weal et al., 2008)

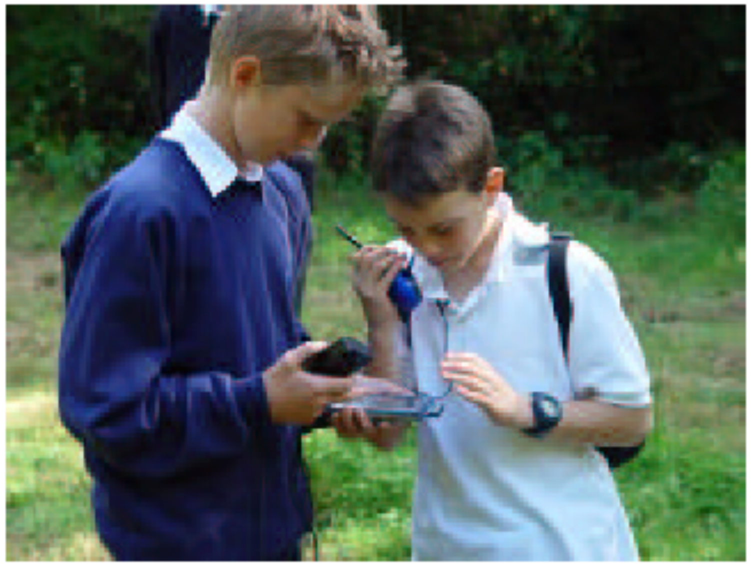


Figure 2: The children exploring the wood.

System E: Crystal Island Outbreak ~2008-2011

Target Audience and Overall Goals

- Middle-school level microbiology science curriculum structured around five main narrative-embedded problems.
- Dual game goals of achievement (content learning) and engagement with the topic/ environment
- Teach science based on discovery and "doing," not just facts. Science as process and skills
- Similar "inquiry learning" philosophy to Ambient Wood

Narrative

- **Student is the protagonist in a science mystery**, and must gather information to determine the source of a disease and recommend a cure.
- Must learn and apply skills like hypothesis testing to finish the game
- Narrative meant to provide a *concrete* structure **for understanding and applying** facts.
- Narrative, graphics, bells and whistles to **engage students**

Approaches to Teaching: *The philosophy behind the design*

Crystal Island research and development focuses strongly on affective modeling and tutoring: The dynamic in which students and tutors recognize, predict and respond to each other's emotional and motivational states is central to learning and topic engagement, and has previously been left out of (or underdeveloped in) other ALEs.

Recognition and prediction of students' goals help to drive narrative and tutorial interactions.

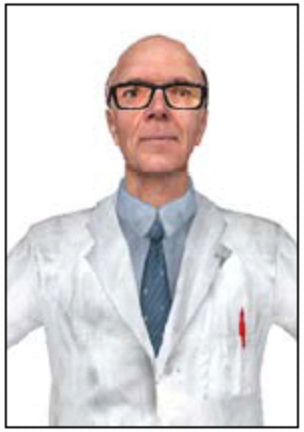
Allowing skill generalization and a mutable approach to science– science is a process, and even good theories may change!

Affective Learning = Effective Learning

- Crystal Island cast of “**embodied” virtual agents** have distinctive personalities, expressions and motivations.
- Tutor characters provide **cognitive and motivational scaffolding** via “expert knowledge” and advice.
- Affective modelling, affective tutoring shown to increase topic engagement, motivation for further learning. [Robison et al, 2009]

Alex Reid
(User)

Audrey Newsome
(Field Scientist)

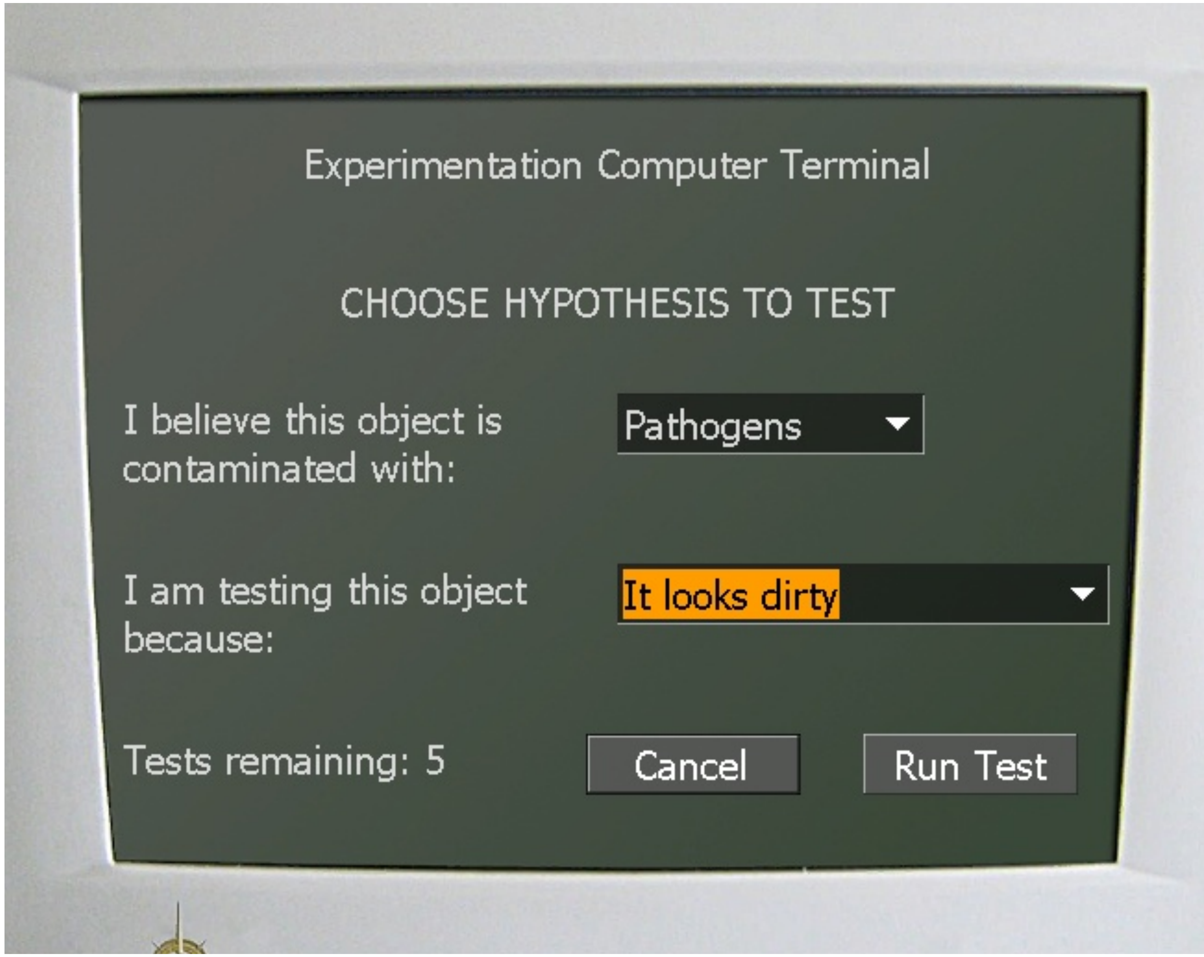


Bryce Reid
(Lead Scientist)

Sample Interactions

Students receive hints and help via in-game PDA

Explicit hypothesis-testing



System B: Bird Hero 2013

- Recent, small-scale project (Lund Uni. in Sweden)
- Uses principle of *learning by teaching* and applies to preschool-aged children– can it work?
- Targets “number sense” and pre-math skills.

System B: Bird Hero 2013

- Interested in *theory of mind,* a skill developed in early childhood
- Need this skill for a "learning by teaching" method to work?

Here, Panders **sees** the bird holding up 5 feathers and **thinks** about 5-ness.

Thinks "5"

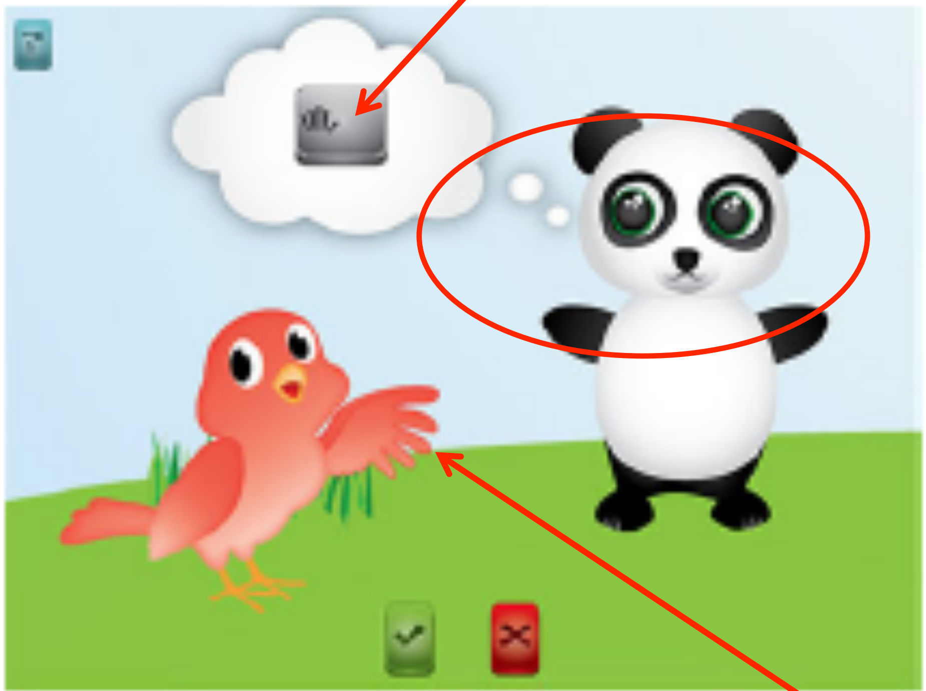


Image from Axelsson, Anderberg, & Haake (2013)

Sees 5

This image from Lund cogsci pdf

Figure 2. The final digital version of the game showing the tree with nests, the lift going up, and the TA watching.

Panders helps the bird go home to the right branch of the tree (using the "elevator")

Image from Anderberg, E., Axelsson, A., Bengtsson, S., Håkansson, M. & Lindberg, L. (2013).

See required readings for system details.

Example 1: modelling subtraction

Example problem: subtraction

a.	b.	c.	d.	e.
73	**32**	**164**	**187**	**19763**
-11	**-16**	**- 37**	**- 99**	**-16824**

How do you do each of them?

What methods do you use?

Do you use the **same method for all** of them?

How did you **learn** to do it?

How would you **teach** someone else to do it?

What would **they** need to know to do so?

What would **you** need to know to teach them?

What if their answers were:

	a.	b.	c.	d.
	73	32	164	187
	-11	-16	- 37	- 99
S1	62	24	133	112
S2	62	26	137	198
S3	62	24	214	817
S4	61	14	130	89

or no response at all....

Modelling learners

- trying to find out what the student knows, believes, can do
- looking for evidence that user fails to exploit some knowledge
- looking for inconsistent beliefs, differences between student and domain models
- teach accordingly

Diagnosing Student Models

If the teacher believes student has a different model from their own (correct) one:

- make list of common errors and match to it
- reason about what student would believe in order to exhibit behaviour indicating this

Representation of student's current state of knowledge = **STUDENT MODEL**

Inferring the Student Model = **DIAGNOSIS**

Possible Diagnoses

	a.	b.	c.	d.
	73	32	164	187
	-11	-16	- 37	- 99
S1	62	24	133	112
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Possible Diagnoses

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	-11	-16	- 37	- 99
S1	62	24	133	112
		take higher from lower		
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S1	62	24	133	112
	take higher from lower			
S2	62	26	137	198
	give 10 but don't pay back			
S3	62	24	214	817
	work l to r, higher from lower			
S4	61	14	130	89

Possible Diagnoses

	a.	b.	c.	d.
	73	32	164	187
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S1	62	24	133	112

take higher from lower

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guess…

Design an ALE that can:

Do subtraction for itself

Know how to teach subtraction

Determine what the student knows already

Adapt its teaching to the learners ability

Infer how the student learns as they do it

Diagnose errors

Know how and when to talk to student

Give appropriate feedback

Suggest other exercises

Adapting to errors and misconceptions

What are we adapting to?

- Hypothesised misconceptions of students, inferred from their behaviour and knowledge of common problems
- Knowledge of the students ability in arithmetic and literacy level

How do we adapt?

- Customise feedback to:
- the specific errors a child makes
- literacy level
- Select further problems to fit students ability

Big question 1

Definitions:

What IS an *adaptive learning environment* (ALE) and/or an *intelligent tutoring system* (ITS)?

How would we differentiate these (or *can* we differentiate these) from other categories of technologies?

Big question 2

Synthesis:

How, why, and when do ALE/ ITS projects draw on multiple disciplines, theoretical positions, and types of expertise?

Big question 3

Goals:

3A. What has this research area set out to accomplish? What are its current overarching goal(s), and do these seem to have changed over time? If they have changed, what seems to have driven those changes? *[Think very high-level here, bigger than individual projects]*

3B. To what extent has this research area made progress toward those overarching goals? (and what is the evidence for that assessment of progress?)

Big question 4

Course scope:

Why aren't we building a new system this semester, or modifying an existing one?

Why ask these questions?

- Provide a theme that runs through the course with MANY topics
- Draw attention to "big picture"
- Help to organise many small pieces of info from individual topics and systems
- Draw attention to where there is consensus in this field...and where there is not

Announcements

- **Readings and materials** for Lect. 1 are online – will update others as we go
- See you **Tuesday** same time, same place to talk about more “core systems”

End Notes

Slides were combination of previous years' ALE course materials by Alyssa Alcorn and Helen Pain