ADAPTIVE LEARNING ENVIRONMENTS:

Student Modelling

Why model students?

C**ustomisation (or personalisation) to learners.**
- major research theme in ALEs for past decade or so, and in other education policy changes
- this is a big part of the "adaptivity" in "adaptive learning environments"

Back earlier discussion of "why build an ALE?"
- issues of efficiency in learning,
- accommodate student styles

Goals re: learning about learning, e.g. how and why DO students make mistakes

Goals of Student Modelling

Find out what the student knows, believes, can do

- Look for evidence that user fails to exploit some knowledge
- Look for inconsistent beliefs, differences between student and domain models

If teacher believes students has different beliefs or skills:

1. make a list (bug catalogue) and match to it
2. reason about what student would have to believe in order to exhibit behaviour indicating this

Component of an ITS that represents student's current state of knowledge = ***STUDENT MODEL***

Process of inferring the Student Model = ***DIAGNOSIS***

Models and Adaptivity

WHICH students to model?

- students studying a domain, with non-expert, “buggy” versions of domain model?
- a “profile” (e.g. Low vs. High domain experience, male vs. female students, “competitive” vs cooperative...)
- default settings for different profiles, different problem set, dialogue strategies, etc.
- individual student sitting in front of the computer?

Models and Adaptivity

WHAT to include in your models?

- How or what do we "diagnose" regarding issues with student knowledge?
- What about diagnosing affect? Motivation?
- Student "profiles" or strategies?
- Something else?

How to UPDATE model as the students/their knowledge changes?

...And what do you DO with the working model when you have it?

Example: BUGGY project

Understand student modelling with simple example

- Student procedures for addition/subtraction
- Correct and "buggy" ***sub-procedures.***

Buggy procedure=like bug in a program

BUGGY (Brown and Burton, late 1970's)

Used corpus of student work to identify arithmetic bugs

Created a game for student teachers to learn about better arithmetic teaching

- Help look for, identify sub-procedure errors
- Target these errors in feedback

Diagnosing Models: BUGGY

1. BUGGY selects a faulty algorithm

   BUGGY: Welcome to Buggy. I have chosen a bug. Here is an example of the bug.

```
   17
+   5
  13
```

   Now you give me problems to determine the bug.

2. the user sets some problems

   User: 18 + 6 43 + 79

3. BUGGY gives the answers (by faulty algorithm)

   BUGGY: 15 23

4. user diagnoses the problem

   User: Got the bug!

BUGGY contd.

BUGGY: Please describe the bug.

User: Student adds the number to be carried into the last column worked in.

5. BUGGY sets test, user predicts answers

BUGGY: Here are some problems to test your theory about the bug.What is:

```
    21
+   39
```

User: 51

BUGGY: That's not the bug I have. Using my bug:

```
    21
+   39
    15
```

Try giving me some more examples.

BUGGY contd.

User:		**51**			**99**			**68**
	+	**1707**		**+**	**99**		**+**	**9**
BUGGY:		**21**			**36**			**23**

User: Got the bug!

BUGGY: Please describe the bug you think I have.

User: The student is adding all the digits together.

BUGGY: Here are some problems to test your theory about the bug. What is:

		33		**1091**			**8**		**28**	**90**
	+	**99**	**+**	**60**		**+**	**34**	**+**	**70**	**+ 6**
User:		**24**		**17**			**15**		**17**	**15**

BUGGY: Very good. My description of the bug is:

The student always sums up all the digits with no regard to columns.

Modelling for (error) diagnosis

Sub-procedures linked into a **procedural network** of sub-goals for a single skill (i.e. Addition)

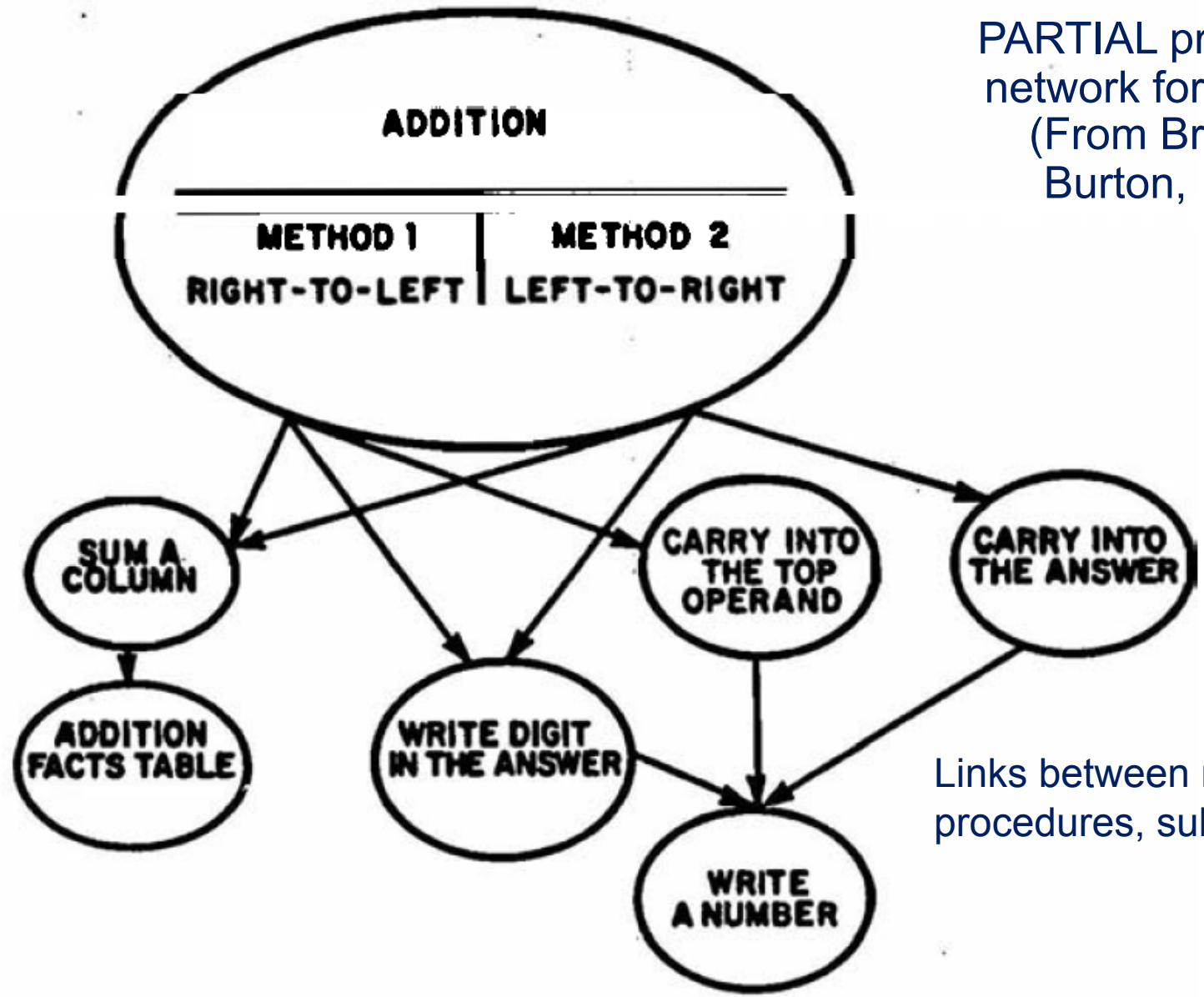
Any skill constituent (i.e. sub-skill) that could be mis-learned needs separate representation

Can **run the network** on a set of problems

Goal of a diagnostic model is to have an abstracted representation of the student's skill at a point in time

- Exact composition of correct, buggy procedures that individual uses for subtraction
- **Running the network** (i.e. the model) should mimic student's actual behaviour

PARTIAL procedural network for addition (From Brown & Burton, 1978)



Links between nodes “call” procedures, sub-procedures

BUGGY: Drawbacks

Misconception represented as a single node:

- can contain any code as its executable part
- single out bugs, but can only explain misconception by means of demonstration or canned text attached to node

Representation supposes that:

- ***user is merely executing some kind of algorithm,*** in a context-free way
- ***basic misconceptions represented in same way as basic components of the skill***
- depends on decomposition of skill to level where ***single bug is a separate procedure***

Only procedural knowledge?

System builder has to do all representational work

Andes: more bugs

Also includes “buggy” knowledge in representations

Has **“solution model”** of a problem, and tracks student progress in relation to it **(a *model-tracing tutor)***

See Woolf ch 3 p 79 for partial solution graph, too small to show here

Time for hints is when students straying from a correct path (likely to be multiple paths)

Understanding what students know: Two pronged approach
- Current state of problem solving (for individual problem)

PLUS
- “longer term” assessment of overall physics knowledge

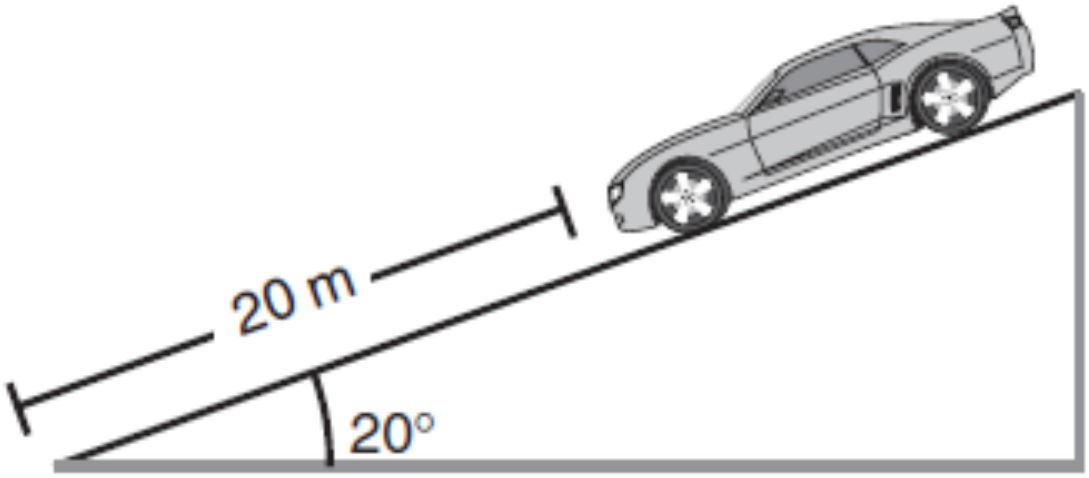
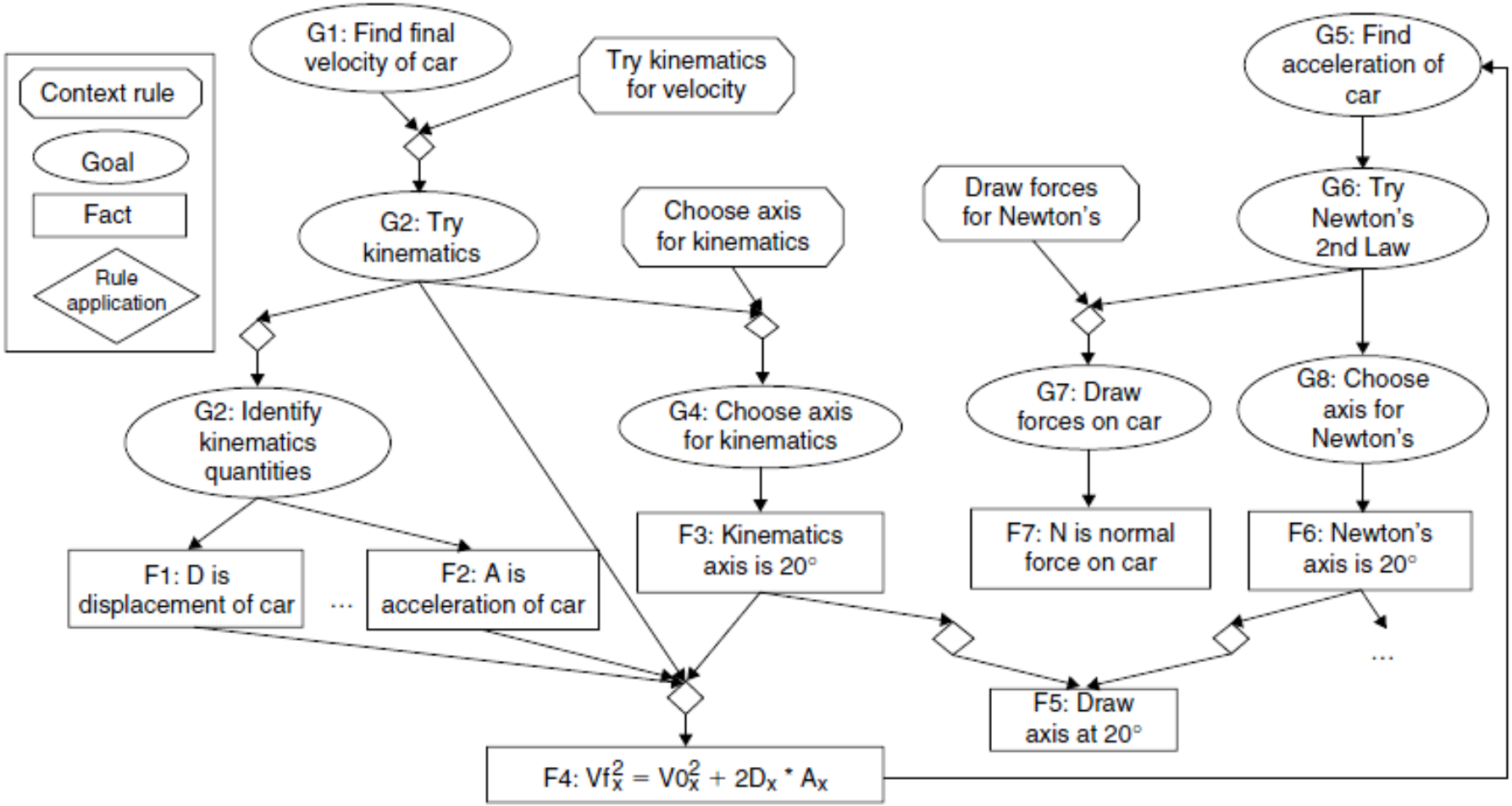


FIGURE 3.13

The car problem. A 2000 kg car at the top of a 20° inclined driveway 20 m long slips its parking brake and rolls down. Assume that the driveway is frictionless. At what speed will the car hit the garage door (Gertner et al., 1998)?

A typical ANDES problem and diagram, reproduced from Woolf (2009), p. 78



Andes "solution graph" for car problem, reproduced from Woolf (2009), p. 79

Updating Andes' model

Uses Bayesian networks (probabilistic representation)

- One problem= network representing one complete solution space (100-200 **nodes**)
- Nodes equate to student actions, states (and performing action in program can turn nodes on/off)
- "General knowledge" estimates updated at end of each problem based on state of network→ **initialise model** for next problem

To do an action that relies on student knowledge or mental state (e.g. TUTORIAL ACTIONS), other system modules can query network about relevant nodes and their probabilities.

Student Modelling: Language Examples

Example: difficulties in spelling

A child types

e.g. “neiz”

“wen”

What did they intend?

Identifying and Correcting Errors

e.g. “neiz” -> **knees/niece**

“wen” -> **when/went/we/win**

“fiknusiz” ->

Identifying and Correcting Errors

e.g. “neiz” -> **knees/niece**

“wen” -> **when/went/we/win**

“fiknusiz” -> **thicknesses**

Possible Inferences

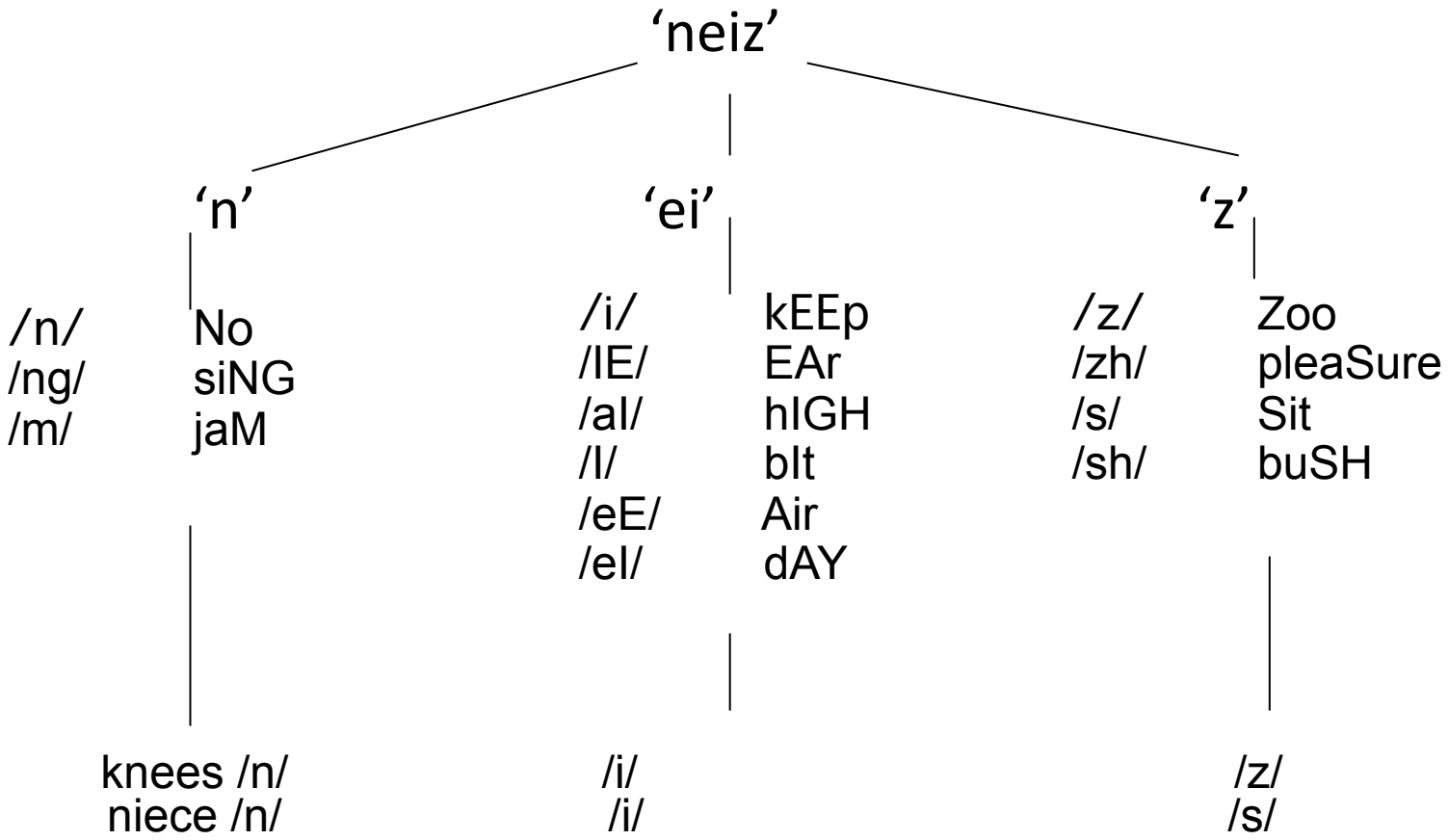
Work back from the misspelling to the correction

k w i c	**quick**
r i d	red, rid, **ride**, write, rite, read
f a t	**fate**

Letter as its name? **i** for **i_e** **a** for **a_e**

Phoncode (Pain, 1985)

Based on phoneme-grapheme grammar: consider what phonemes error was intended to represent, then see if any word matches



Using language: Autotutor

Student modelling all about **semantic matching,** regular expressions and similar

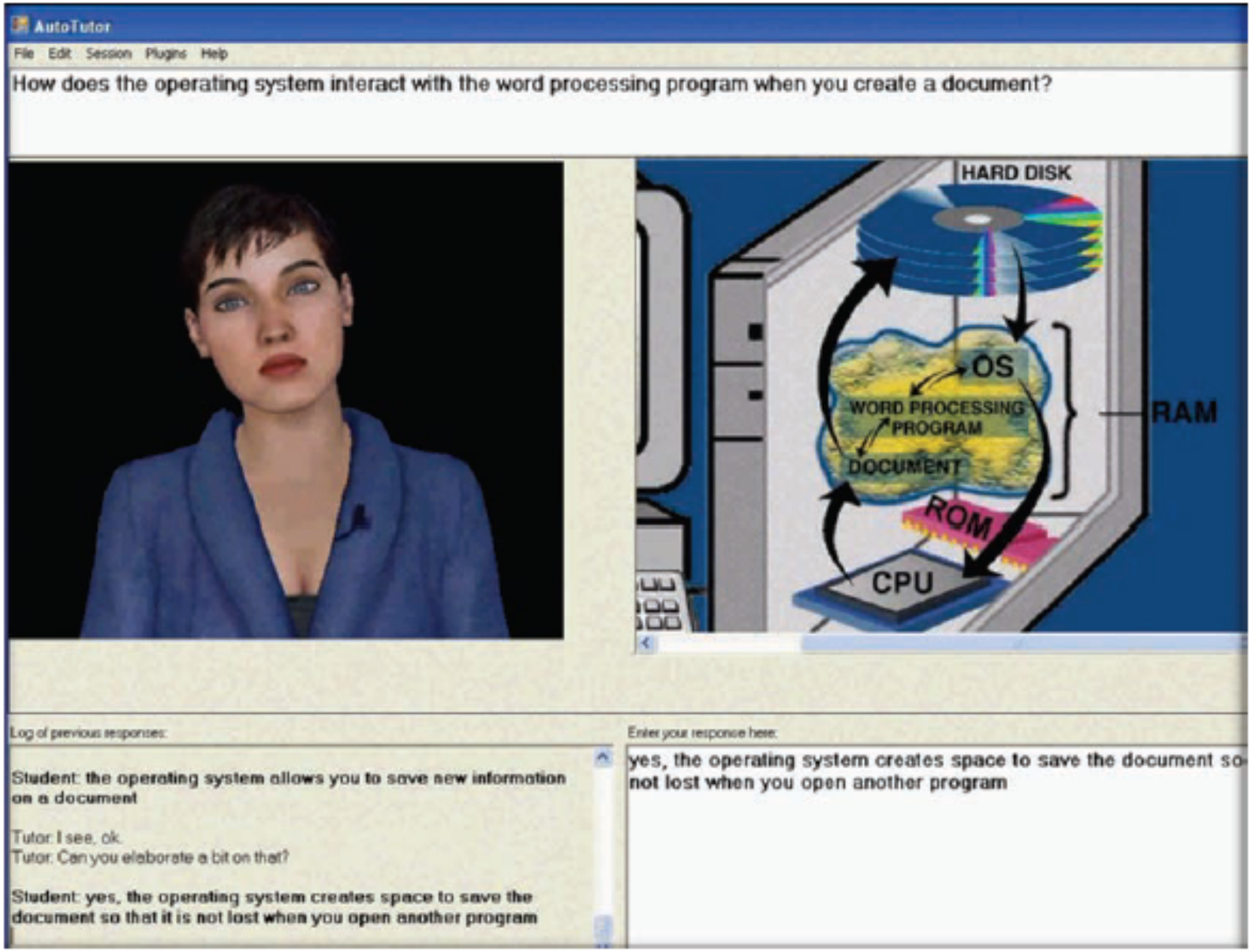
Inferring student concept knowledge through their natural-language (text) input

- For each **main question**, compare input to pre-generated list of expectations and misconceptions via **latent semantic analysis (LSA)**

Expectations= anticipated "good answers", productive procedural steps

LSA compares conceptual similarity of two pieces of text

See D'Mello & Graesser, 2012, section 3 for gory linguistic details.



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

Semantics for DOING

Multiple rounds of tutorial dialogue for a main question, doing analyses on each round of input

System [dialogue] actions aim to identify (i.e. **diagnose**) and **target** "missing" expectations related to main question

Trying to reach a **threshold LSA value**: This means that student is using same concepts and propositions in an "expected" answer. *Don't worry about the details of this.*

More bugs: Parts of student input may match **stored misconceptions**.

This then triggers system to **take certain tutorial actions** (e.g. offer hint or explicit correction)

Using Language: ARTCHECK

Correct article usage problem for English language learners:

Some native languages do not include an article category, e.g.
Finnish - definiteness and indefiniteness expressed in quite different ways (also **Basque, Chinese, Russian**)

Aims to help such learners use articles appropriately

Rules which determine correct article usage:

- how do you know whether you are talking about a specific object, or any old object?
- how do we choose the correct article to indicate the indefinite or definite property of the noun in an utterance?

Indefinite **a/an,** eg *John is* **a teacher**

zero, eg *Do you take* **milk** *in* **coffee?**

Definite **the,** eg *He is* **the only teacher** *I like*

ArtCheck Tutor (Sentence,1993)

Applying knowledge to user input, to **detect** when the incorrect article is used

Example errors:

*I have visited__Tower of London

*We discussed our plans over the breakfast

There may be **patterns** in the errors

* John is teacher.

* Sandy is pig.

* I am doctor.

John is a good man.

Use rules as basis for generating explanations, customised to learner, to help them learn correct user

Determining correct usage

Rules indicate whether article before noun should be:

- the **definite article *the***
- the **indefinite article *a/an***
- no article at all, **(*the zero article*)**

Some are *fixed* rules: *the definite article should be used when the noun is modified by a superlative adjective,*

eg *the largest dog*

Other depend on context of use: *the indefinite article should be used to introduce new information.*

The sources of information used by the system:

the **lexicon**, the **parser,** the **morphological analyser,** and a **discourse history module.**

Examples of rules

Article Usage Rules	**Example**	**Information needed**
The definite article can be used where the noun is modified by a relative clause	*The* **man** *who I saw . . .*	Syntactic
The zero article can be used before plural count nouns	*Do you like* **eggs**	Morphological
The zero article can be used with proper nouns	*My dog is called* **Marcus**	Lexical
The indefinite article is used in some expressions of frequency	*I go running* **twice a day**	Idiomatic

Providing feedback

Uses *rule induction* to learn rules from positive and negative training instances of the error:

* John is teacher.	*Positive instance*
* Sandy is pig.	"
* I am doctor.	"
John is a good man.	*Negative instance*

Produce new rules, based on the expert ones, in this case:

Rule 11: *Use the article* **a/an** *where a singular count noun is used as the complement of the verb* to be.

Identify incorrect (mal-rule) proposed to account for data:

Where there is a singular, unmodified, common, count noun preceded by a singular form of the verb be, **use the zero article**.

And explain this to the student:

"You seem to use ***no article*** *instead of* ***a*** *or* ***an before a singular count noun*** *and* ***after the verb to be****"*

Learning from errors

One goal is for user of **the system** to learn from any errors made.
To do this it must:

- be able to understand the observed errors,

- be able to communicate effectively with the user

- provide a good explanation for that error.

Explanation in Artcheck is tailored to the learner in three ways:

1. ***relating to the learner's level of ability,***
2. ***learning style,*** and
3. the ***type of error*** observed.

In addition, the learner is given some control over the information received.

Example dialogue

Student: I am doctor

AC: identify error: ***doctor*** in ***I am doctor*** is incorrect.

AC: correct error: It should be: ***a doctor*** .

AC: ask student for feedback

Select: m more q quit explanation

Student: m

AC: state rule The rule is: RULE 11

Use a or an before singular count nouns which come after the verb to be.

AC: ask student for feedback

Select: m more q quit explanation

Student: m

AC: *explain mal-rule:*

I have noticed that you seem to use no article instead of a or an before a singular count and after the verb to be in the singular

Dialogue, continued

AC: ask student for feedback

Select: m more q quit explanation

Student: m

AC: exemplify mal-rule

You also said: ***** Sandy is pig *** John is teacher**

which are similar errors.

Try one of these again: **Sandy is **** pig**

Choose the correct article: **1 a**

2 an

3 the

4 no article

Student: 1

AC: Well done. That is the correct answer.

Continue? (y/n) n

Evaluation of ArtCheck

Can understand **many types of sentence structures**.

Cannot understand questions and imperatives.

- **grammar could easily be extended**

Sometimes **wrongly predict appropriate article** usage:

- less common idiomatic usages.
- distant or complex referring expressions, where semantic information required

Lot of data required for mal-rule to be generated.

Feedback during external evaluation generally positive:

- students confirmed this was an area of difficulty
- were enthusiastic about experimenting with system
- found the system easy and helpful to use.

Most showed some improvement after using *ArtCheck* for a short period of time.

Verbal and written feedback generally very positive.

Open Learner Modelling:

LeActiveMath

http://www.leactivemath.org/

Open Learner Modelling

Should only the system access the model? Should students see them? What about teachers? Why would we do that anyway?

- Help learners and teachers to reflect on their own knowledge, misconceptions and learning processes

- Give an alternative for diagnosis by enabling students (or even peers and teachers) to intervene in the diagnosis process and influence the system judgments

A challenge: *how best to collect, analyse and externalise data from learner interactions and how to represent this for most effective support of reflection*

OLM in LeActiveMath

Externalisation of the Learner Model

- Organise and display LM beliefs about the learner's *knowledge, skills, competencies, affective and motivational states*.

Interaction with the learner based on:

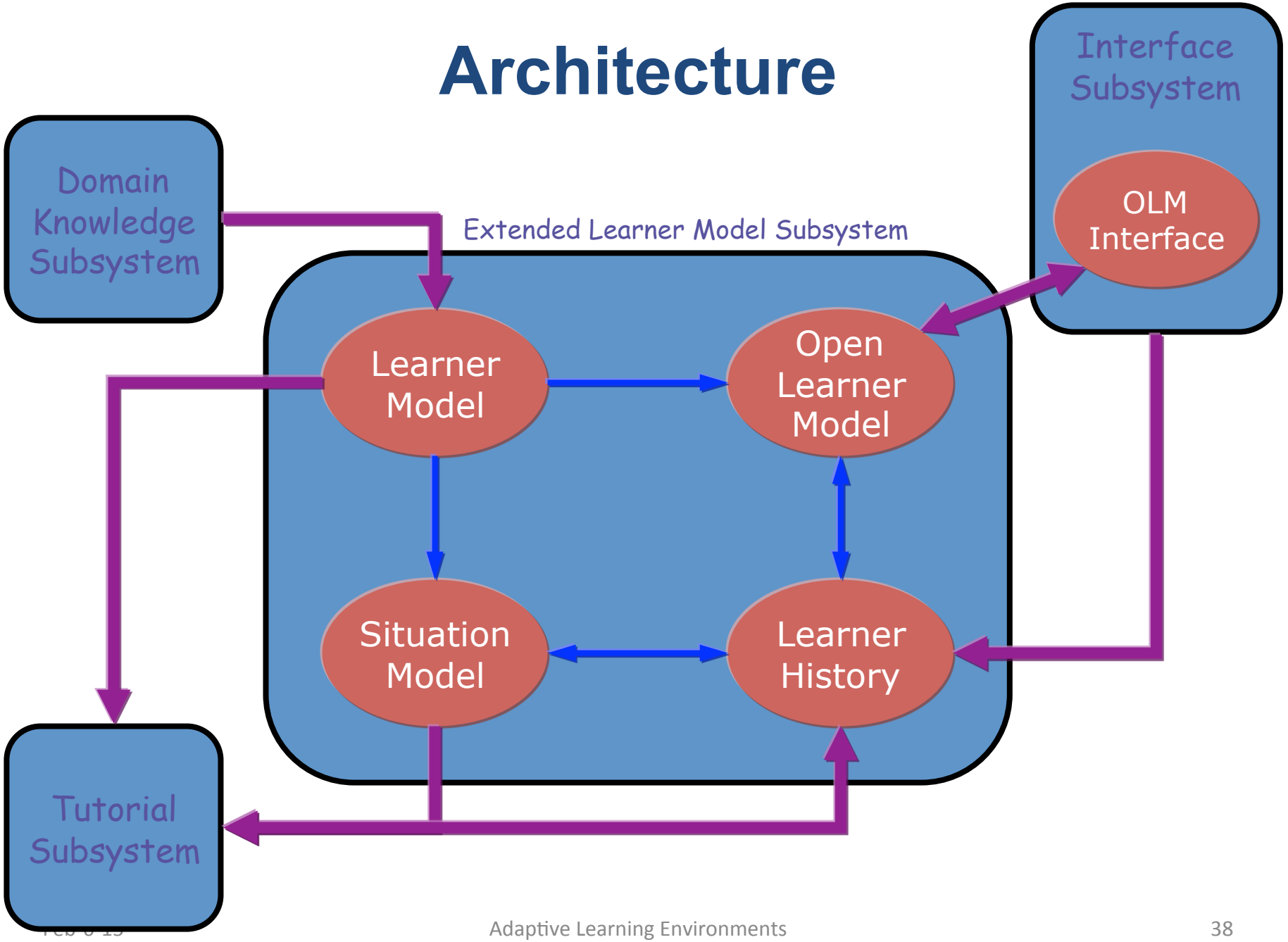
- performance on system (e.g. *you scored 70%*)
- and on value judgements (e.g. *you did well*)

OLM "suggestions" to the Tutorial Component

– Belief revision may highlight need for learner to do an exercise, study an example, etc.

A dedicated Graphical User Interface

Architecture



Learner Model Content

Domain Knowledge (e.g. derivation rules, function, chain rule)

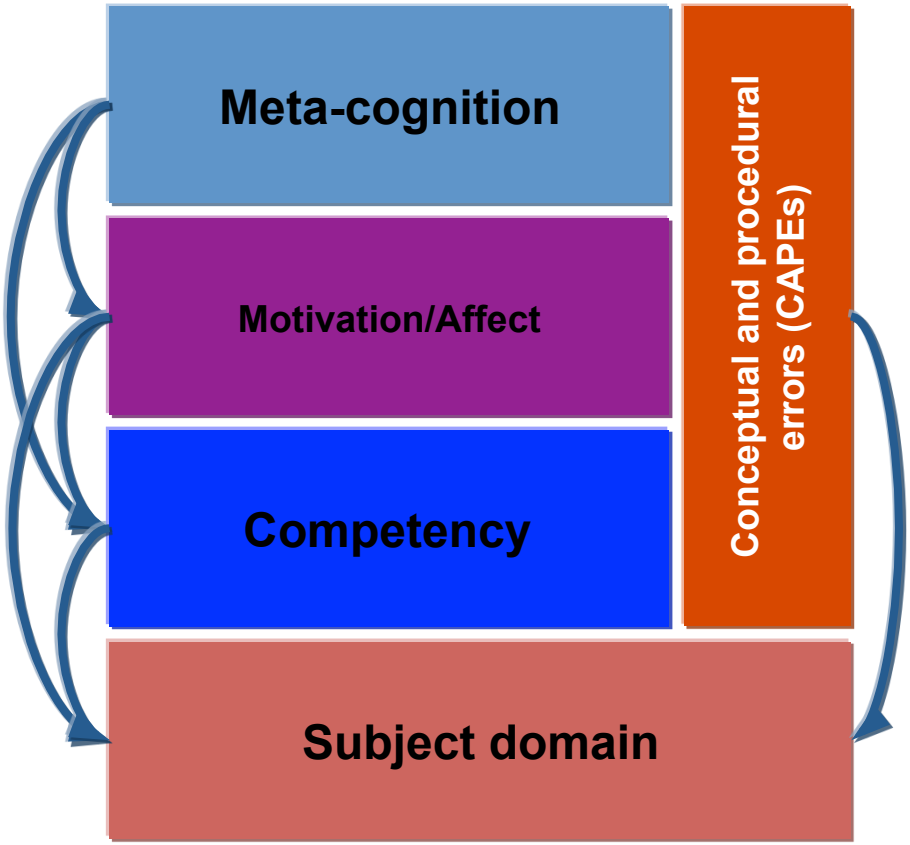
Competencies (e.g. reasoning mathematically, handling mathematical symbols and formalisms)

Meta-cognition (e.g. student believes that they understand chain rule)

Affect and Motivation (e.g. frustrated, interested, puts effort)

Conceptual and performance errors (incorrect derivative for negative power function, expanding brackets incorrectly)

Learner model structure



- Dimensions are piled up in layers
- Bottom layer is the subject domain, as a *ground* dimension
- Beliefs are placed in the upper layers only
- Beliefs are about higher layers *applied* to lower layers

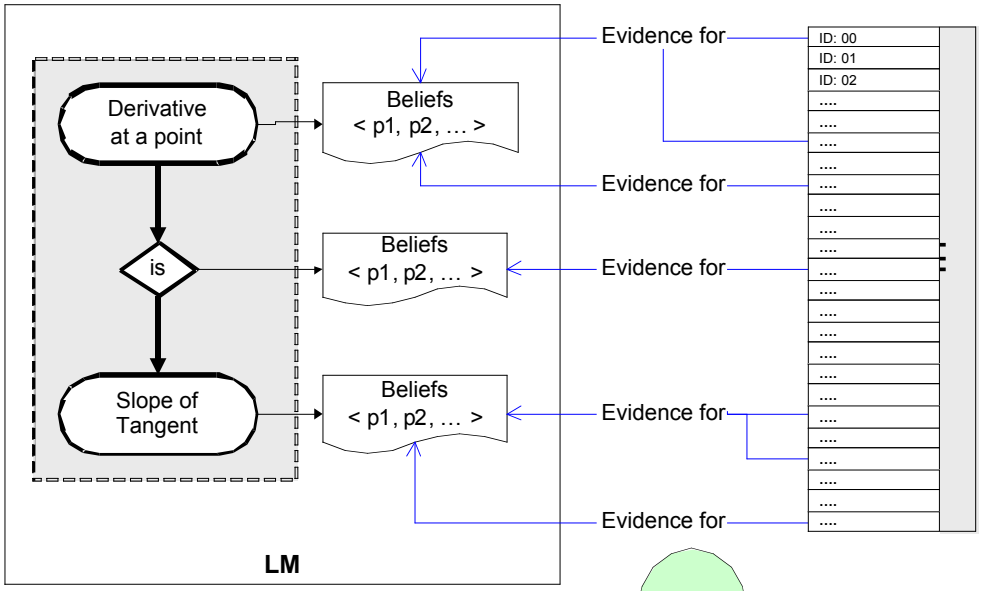
Example: **a belief on learner awareness of her motivation at following a proof of the chain rule for derivatives**

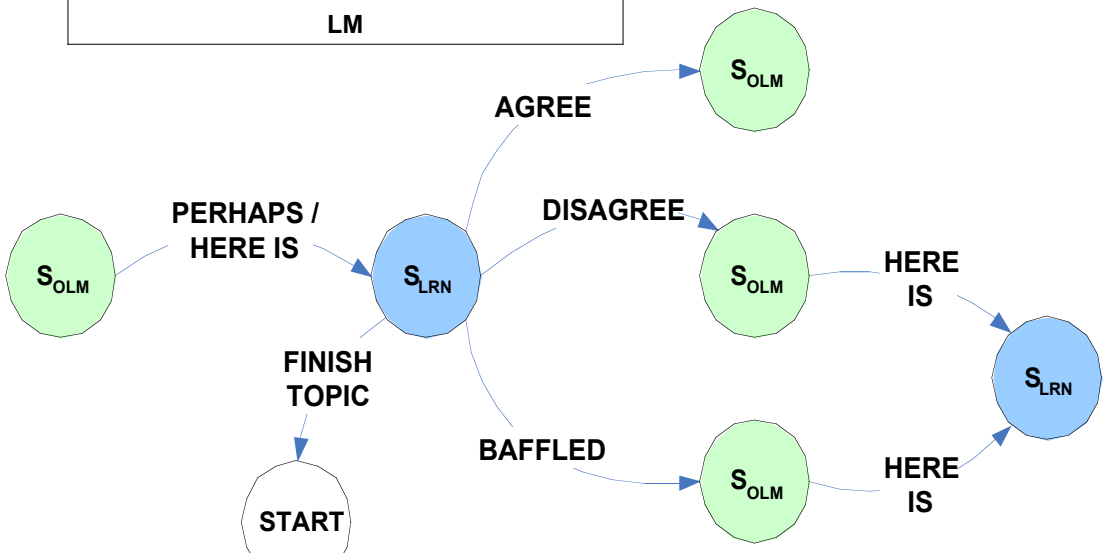
Open Learner Model: Specification

Belief and Evidence
Link the model to the direct actions and activities that the user may recall (i.e. as stored in the Learner History)

Interactive diagnosis
Dialogue moves as language for learner and OLM to use to communicate and argue about beliefs and performance

Deployed by graphical widgets with NLG support





Inference/Diagnosis: Dialogue Moves

Learner's Moves

SHOW ME:	Show me what you think **I know** about differentiation Show me **how competent** you think I am in terms of learning
I DISAGREE:	I don't think **I know** the chain rule (but you seem to think I can)
I AGREE:	Yes, I am **very confident** about my understanding of differentiation
I DISCONFIRM:	I cannot accept that **I understand** the chain rule **quite well**
I'M BAFFLED:	I do not understand how **you reach your conclusion**
LET'S MOVE ON:	I **never** want to revisit this topic

OLM's Moves

PERHAPS:	Perhaps you are **quite confident** about **using the chain rule**
HERE IS:	Here is the **evidence** I have about what you can differentiate
CAN I CONFIRM:	So **we agree** that you understand the chain rule **well**
UNRAVELLING:	I believe you are **quite good** at mathematical modelling because you **told me so yesterday** and your performance is **as good as yesterday**
FINISH TOPIC:	So we **agree to differ** about your competence at mathematical modelling - we **move on but will revisit** some time soon

OLM and NLP

- Templates used for transcription of dialogue between OLM and learner
- Templates for every dialogue moves
- Reference to LM and OLM elements mapped into the templates (i.e. **Belief descriptor**, **TAP nodes**)
- Value judgement mapped to every LM belief (i.e. **Level**, **Performance**)
- Internationalisation easily supported

OLM Welcome my dear **toto**. What brings you here today?

toto I don't know what to do now.

OLM Perhaps you should explore **[derivative, , think, , ,]**.

toto Yes, why not.

toto Show me what you think I know about **[derivative, , think, , ,]**.

OLM I think your are **Level I** about **[derivative, , think, , ,]**.

toto I don't understand why you think **Level I**.

OLM Here is the evidence for me to think you are **Level I**.

toto I don't understand why you think **Level I**.

OLM Here is the evidence for me to think you are **Level I**.

toto I don't understand why you think **WARRANT_2**.

OLM Because you did this **easy** exercise with a **0.0** performance.

toto I disagree with **WARRANT_2**.

OLM In this case, what is your own judgement about the situation?

toto Let's change the topic of discussion, please.

OLM Fine, but we will have to come back to this issue later.

If want more on this…

Common types of student modelling not discussed here:

- Constraint-based modelling
- Plan recognition
- Expert-system model

see Woolf (2009) Chapter 3, required reading

A totally different idea of the roles models can play: **Lifelong learner modelling** *(see reading list)*