ADAPTIVE LEARNING ENVIRONMENTS:

L6: Qualitative Modelling and Betty's Brain

Qualitative Models

Concern with reasoning in qualitative terms about the causal structure of world.

Allow reasoning about dynamic processes.

Not necessarily same as cognitive fidelity but does aim for it.

QUEST: White and Frederiksen (1986,87)

The domain is electrical circuits.

Internal representation uses causal calculus: basically component-oriented, but incorporates some higher-level concepts guiding evaluation of component states.

Progressions of mental models: model changes as the students' understanding of the domain progresses

"modelling possible evolutions in students' reasoning about electrical circuits as they come to understand more and more about circuit behaviour"

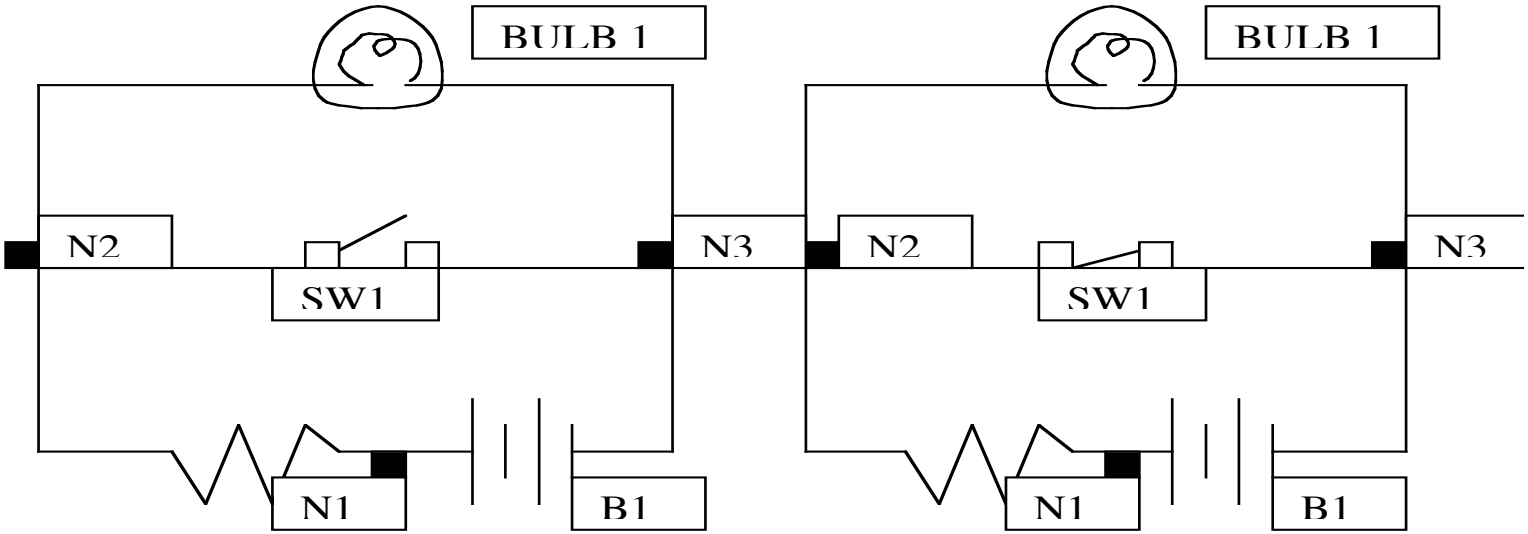
Focus on using model progressions: helps students learn:

a. to predict and explain circuit behaviour, and

b. to troubleshoot by locating opens and shorts to ground in series-parallel circuits

The more advanced the student's understanding, the higher level the model

QUEST: a circuit amenable to zero-order qualitative reasoning (White & Frederiksen, 1986)



- "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. Since the switch has no resistance, there is no voltage drop across the switch. Thus, there is no voltage drop across the light, so the light will be off."

De Kleer's ENVISION Theory, 1983

Mechanistic Mental Models (= causal/qualitative)

Reasoning about physical devices

Causal model of buzzer = envisionment:

links components with respect to behaviour;

- describes device in terms of component states, changes in states and consequences for other components

Model can be run on specific inputs to yield predictions.

Envision theory attempts to provide modelling framework for reproducing causality from structure

Models expert/scientist's knowledge

Construction of a causal model for a buzzer: (adapted by Wenger, 1987, from de Kleer and Brown, 1983)

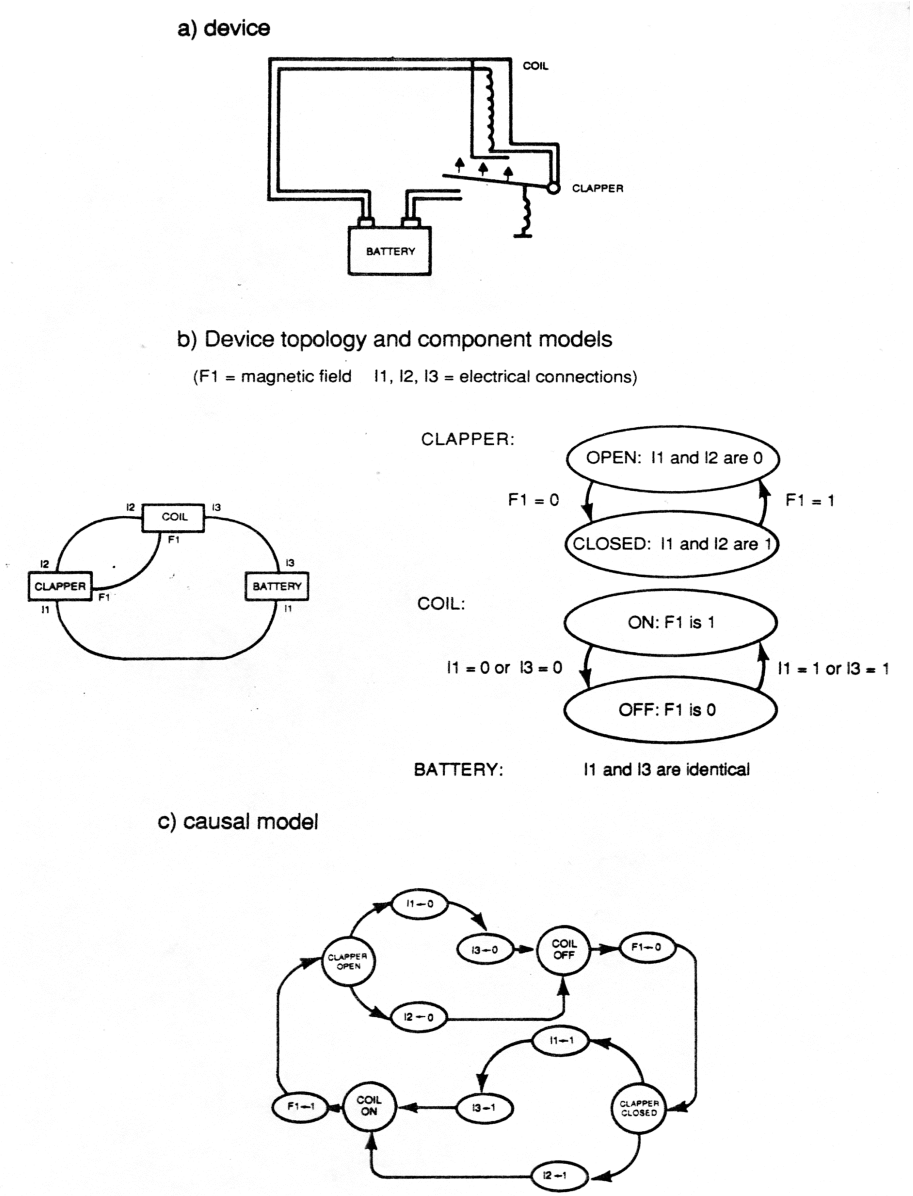


Figure 4.10 Construction of a causal model for a buzzer

Adapted from "Assumptions and ambiguities in mechanistic mental models," by J. de Kleer and J. S. Brown, in *Mental Models*, Hillsdale, NJ: Erlbaum. ©1983 Lawrence Erlbaum Associates, Inc., reprinted with permission.

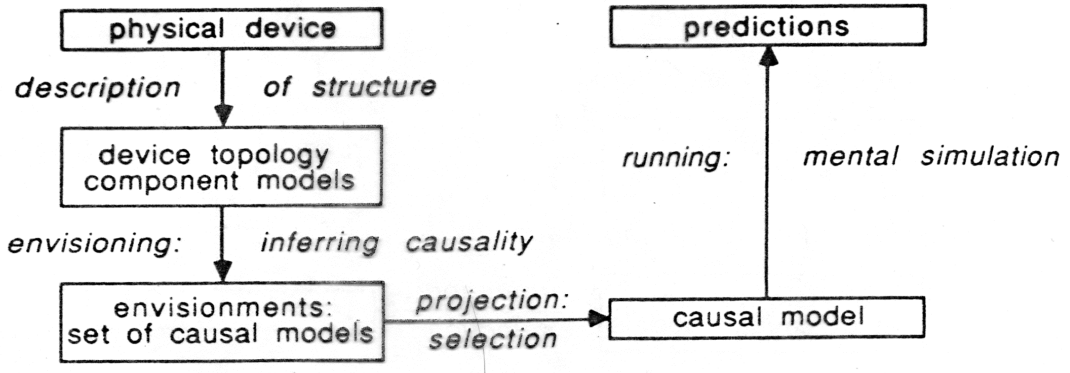


FIGURE 2.15 The development of a qualitative simulation according to deKleer & Brown. *Note.* Adapted from *Artificial Intelligence and Tutoring Systems: Computational and Cognitive Approaches to the Communication of Knowledge* by Etienne Wenger, 1987, Los Alto, CA: Morgan Kaufmann, Publishers, Inc. Adapted by permission.

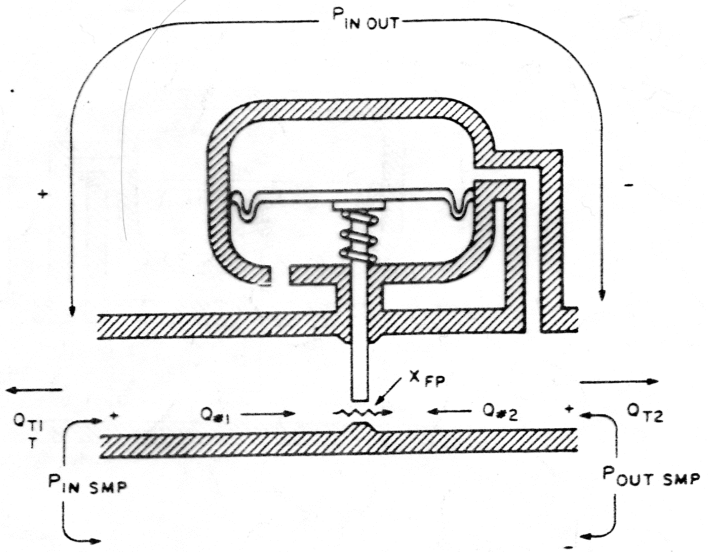


FIGURE 2.16 DeKleer & Brown's (1984) representation of a pressure regulator. *Note.* From "A Physics Based on Confluences" by J. deKleer & J. S. Brown, 1984, *AI Journal*, 24(1-3), pp. 7-83. Copyright 1984 by North Holland Publishing Co. Reprinted by permission.

De Kleer and Brown, 1984 (figures from Wenger, 1987)

Qualitative Process Theory - Forbus, 1984

Reasoning about processes

Attempts to provide a language for encoding causality as perceived by people (more like “naive physics”)

Qualitative Process Theory: description of a process of heat transfer, (from Wenger, 1987, after Forbus, 1984)

Lot of later work in Qualitative Reasoning followed from these, and also got used as the basis for other tutoring systems

Process heat-flow

Individuals:

source: an object, Has-Quantity(source, heat)

destination: an object, Has-Quantity(destination, heat)

path: a Heat-Path,Has-Connection(path,source,destination)

Preconditions Heat-Aligned(path)

Quantity Conditions

A [temperature (source)] > A [temperature (destination)]

Relations

Let flow-rate be a quantity: A [flow-rate] > ZERO

flow-rateaQ+(temperature(source)-temperature(destination))

[temperature (source)aQ+ heat(source)]

[temperature (destination)aQ+ heat(destination)]

Influences:

I- (heat(source), A[flow-rate]) I+ (heat(destination), A[flow-rate])

Qualitative Ecological models

Qualitative modelling used for various domains

e.g. Ecological modelling of ecosystems

Tree, plant and grass growth models in cerrado (Brazil)

- Explore models, run them and look at impact
- Explore causality
- Generation of explanations

Causal model for the Cerrado communities (Salles et al, 1997)

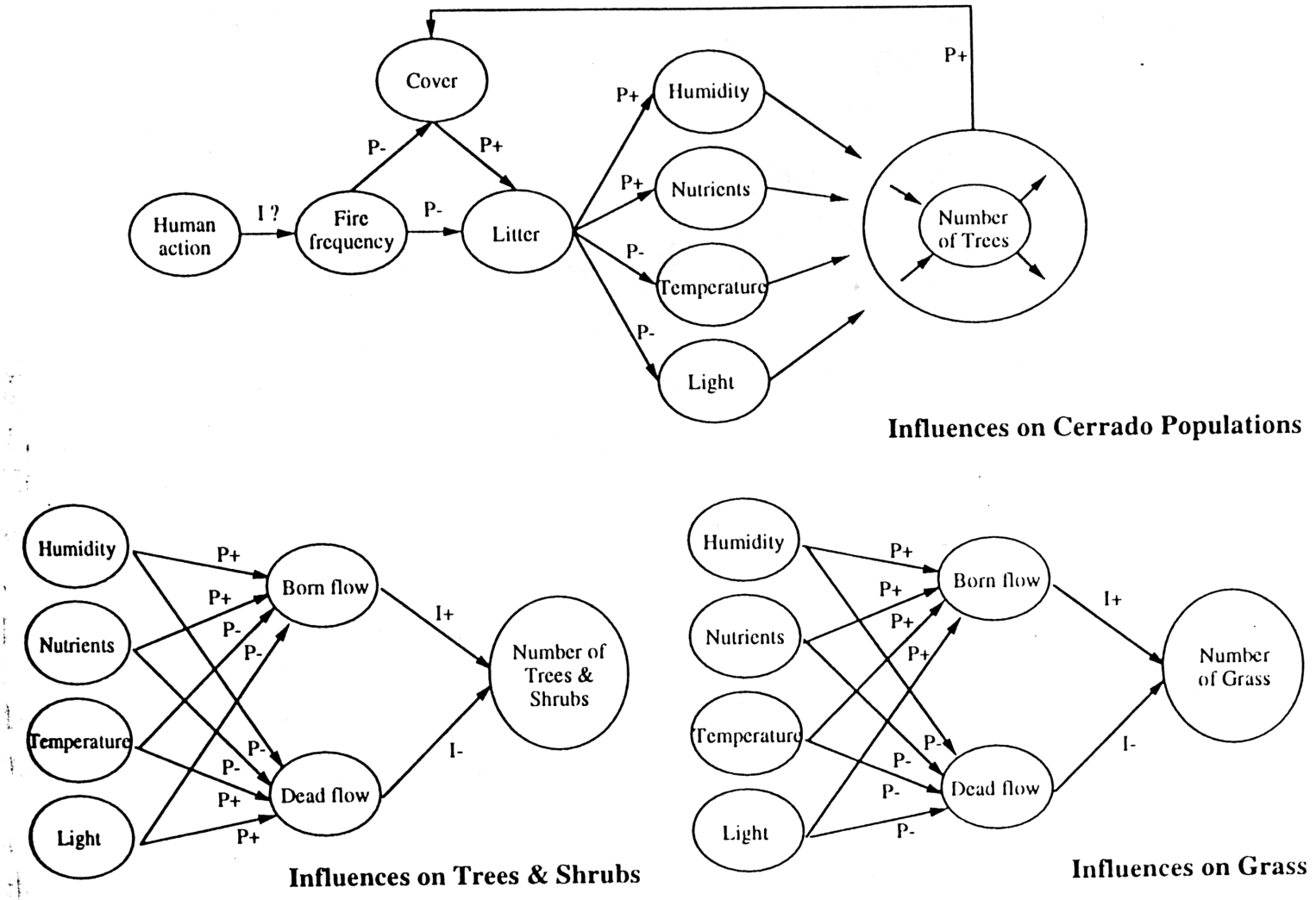


Figure 1: Causal model for the cerrado communities

Deriving Explanations from Qualitative Models

In answering questions, the discourse planner will eventually combine the Primitives in the example question presented above, concerning the propagation of change of the decreasing frequency, this may result in an explanation as the following:

[context]
[remind basic concept]
You know: There is a cerrado referred to as cerradol
[remind quantity]
You know: cerradol has a quantity fire frequency referred to as fire-frequencyl. It has currently the value plus and is decreasing.
[new information]
[explain causal dependency]
The decrease in fire-frequencyl increases the litter1
[explain quantity]
litter1 is the quantity litter of cerradol.
It has currently the value plus and is increasing.
[signalling]
The increase in litterl has four effects:
[explain causal dependency]
1. The increase in litterl increases the moisturel
[explain causal dependency]
2. The increase in litterl increases the nutrientl
[explain causal dependency]
3. The increase in litterl decreases the lightl
[explain causal dependency]
The decrease in lightl decreases the born-f low3
[explain quantity]
born-f low3 is the quantity born-flow of grassl. It has currently the value plus and is decreasing.
[explain causal dependency]
The decreasing amount of born-f low3 decreases the number-of3
[explain quantity]
number-of3 is the quantity number-of of grassl. It has currently the value max and is stable.
[explain causal dependency]
The decrease in lightl increases the dead-f low3
[explain causal dependency]
The increasing amount of dead-f low3 decreases the number-of 3
[explain causal dependency]
[explain similar]
4. The increase in litterl decreases the temperaturel
[refer same]
This propagates the same way as lightl

Betty's Brain (BB)

An example of a "teachable agent" system

Target users: US middle school students (~age 12-13 years), mainstream schools

Original domain: River ecosystems, but has now expanded

Led by researchers at Vanderbilt University, Stanford and McGill

Betty's Brain - The Teachable Agents Group @ Vanderbilt University

Nicola

Start Conversation

Mr. Davis

Mr. Davis: Well hi there, ALE-class! Welcome back to Betty's Brain. Now um...what were we supposed to do today?

Continue

Mr. Davis

Start Conversation

Add a note

Causal Map | Science Book | Notes | Quiz Results | Teacher's Guide

- Introduction
- Introduction
- Concepts
- Wolves
- Deer
- Hunters
- Grass
- Cows
- Rainfall

Introduction

Forests contain many different living things, such as wolves, deer, and grass.

Other factors can affect these animals. Hunters kill the wolves and deer. The amount of rainfall can affect the grass.

creatures of the forest

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Betty's Brain: Qualitative Modelling

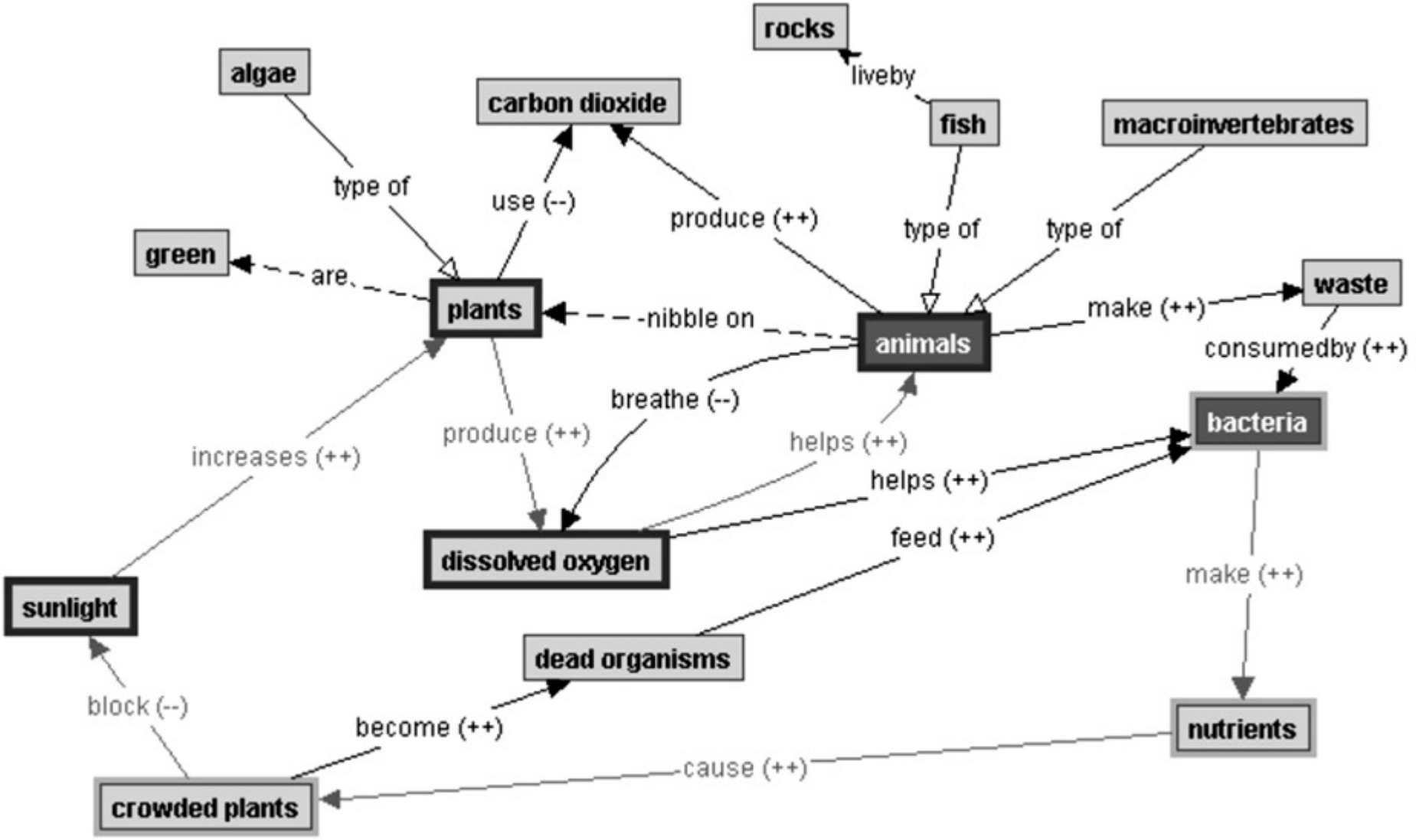
Representation in concept map is a type of qualitative modelling

QUALITATIVE MODELS: Concern with reasoning in qualitative terms about the causal structure of world

e.g. uses "more" vs. "less" rather than quantitative relationships

Allow reasoning about dynamic processes/systems– like an ecosystem

Not necessarily same as cognitive fidelity (i.e. exactly how humans do it) but aims to be close.



BB concept map example, reproduced from Biswas et al., (2005), p. 371

Teachable Agents

"Teachable agents are computer agents that students teach, and in the process, learn themselves"*

A type of ***pedagogical agent***

- virtual or embodied characters that support learning
- may play multiple roles, e.g. peer, tutor (as in Autotutor)

or **here, a student**

Agent as **beneficial metaphor** - taps into **schemas** of:

- interacting with other people, about educational settings, about learning/teaching

** Biswas et al. 2005, p. 364*

Pedagogic goals
(see Biswas et al 2005)

1. **Help students develop networks of knowledge**
   - Connected items, with explanatory value
   - Potential for application to new situations

2. **"Prepare for future learning":** Students to take responsibility for their own learning, in other situations outside tutor (or outside formal education!)

Pedagogic goals, contd.

3. Help students to develop metacognitive skills

- In short: Thinking about own thinking
- Monitoring own knowledge and learning processes

→ ***Metacognition is a big topic!***
We will return to it in more depth later

Learning by teaching (LBT)

Exactly what it sounds like: **The student is also a teacher.** To impart material, you must know it!

Some key research findings:

Those who learn with the goal of teaching may learn more, or more deeply, than those learning for themselves *(Bargh and Schul, 1980)*

Early TA study by Biswas et al. (2001) recorded students saying they felt responsible for Betty, and needed to learn more to help her.

--> A methodology that the BB researchers believe will support the pedagogic goals

Learning by teaching (LBT)

"Instruction that spoon feeds students does not work as well for future learning as does instruction that helps students take on the responsibility of exploring and inventing their own solutions before they receive the canonical answer (Schwartz and Martin 2004)."

from Biswas et al, 2005

Betty's Brain: workshop in place of Friday lecture

Based on the BB workshop, how would we say the system models the student knowledge?

Why might it use that method?

Work in seminar groups

The list of BB "workshop" questions is on a hand-out, linked online from the course schedule

Activity: Trying Betty's Brain

1. Read the questions first, so you know what type of information on which to focus
2. Step through the tutorial. *Ignore Mr Davis dialogue if you can...*
3. Go to your assigned domain module . You will need to close and then re-start BB
4. Teach Betty at least part of the material, so that you can quiz her (etc.)
5. Guide your group's exploration with the list of questions-- *up to you how to organise group, how to record, what you think "counts" as evidence!*