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# Visual Exploratory Data Analysis Methods to characterize Student Progress in ILEs

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# Outline of Talk

- ▶ **Betty's Brain a Learning by Teaching Environment**
  - Teaching: self-directed, open-ended process
  - Concept Maps and Causal Reasoning in science domains
  - Preparation for future learning through Self Regulated Learning & Metacognition
    - Social interactions with two agents
      - Betty – metacognitive awareness
      - Mr. Davis – metacognitive strategies
- ▶ **Bringing the teachers into the learning process**
  - Two representations
    - Learning performance
    - SRL behavior analysis from students activity data
- ▶ **Summary**



# Learning by Teaching

- ▶ Literature (e.g., Bargh and Schul, 1980)  
“Teaching is a powerful way to learn”
- ▶ Tutor benefits as much as tutee (Graesser et al., 1995; Chi et al., 2001)
- ▶ Students more motivated to learn and teach than learn and take a quiz (Biswas, Schwartz, and Bransford, 2001)
- ▶ Teaching involves many constructive activities (McAlpine)
  - Planning to teach – research, create representations, organize
  - Teaching – presenting, explaining, interacting
  - Analyzing and reflecting on students’ responses & feedback during and after teaching



# Teachable Agents

## Our approach



- ▶ **Students teach computer agent**
- ▶ **Agent performs based on what she is taught**
  - **Characteristics:**
    - Student who does not forget or learn new content on her own (no machine learning algorithms drive our agent)
    - Answers questions, explains answers using speech and animation (intelligence comes from ability to reason)
    - Can explain reasoning processes step by step
    - Shows metacognitive awareness
- ▶ **Students reteach agent so that they may do better, (and in that process they learn)**
  - ▶ Self–other effect
- ▶ **Scaffold student’s learning & teaching processes**



# Betty's Brain




Teachable Agents Group at Vanderbilt University


Betty'sBrain

Pointer  
 Teach Concept  
 Teach Link  
 Teach Theme  
 Reverse Link  
 Edit  
 Delete  
 Erase Colors  
 Cleanup

Themes



Ask Mr. Davis



Ask Explain  
Quiz Repeat

```

    graph TD
      solar[solar energy] -- provides (+) --> absorbed[absorbed light energy]
      precipitation[precipitation] -- feeds (+) --> vegetation[vegetation]
      vegetation -- absorbs (-) --> carbon[carbon dioxide]
      carbon -- contributes to (+) --> greenhouse[greenhouse effect]
      greenhouse -- prevents (-) --> heat[heat radiation]
      heat -- lowers (-) --> global[global temperature]
      global -- raises (+) --> absorbed
      global -- melts (-) --> sea[sea ice]
  
```

Talk Log Resources Quiz Notes Panel

| Icon | Question  | Answer       | Action 1        | Action 2     |
|------|---|--------------|-----------------|--------------|
| ✗    | If sea ice increase, then what happens to absorbed light energy?    | I don't know | Re-ask question | Get feedback |
| ✓    | If precipitation increase, then what happens to sea ice?            | increase     | Re-ask question | Get feedback |
| ✓    | If vegetation increase, then what happens to sea ice?               | increase     | Re-ask question | Get feedback |
| ✗    | If global temperature increase, then what happens to precipitation? | I don't know | Re-ask question | Get feedback |
| ✗    | If sea ice increase, then what happens to global temperature?       | I don't know | Re-ask question | Get feedback |



# Self Regulated Learning



Goal: “prepare students for future learning” (Bransford & Schwartz)

- ▶ **Encompasses Cognitive, Metacognitive, and Motivational skills people employ in directing their own learning** (Pintrich, 2000; Zimmerman, 1990, 2002; Winne & Hadwin, 1995; Schraw, Crippen, & Hartley, 2006)
  - Cognitive processes (e.g., understand, create, analyze, evaluate)
  - Strategies (e.g., elaborate, organize, plan, monitor, regulate)
  - Contextual and conditional application of strategies (e.g., when to apply a cognitive process (analyze) or a strategy (monitor))
  - Self-knowledge or awareness (one’s strengths and weaknesses)



# How do students learn in TA environment ?

- ▶ **Preparing to Teach – self directed activity**
  - Read the resources
  - Understand
  - Organize knowledge as entities and causal relations
- ▶ **Teaching agent is a social process**
  - structuring knowledge by building concept map
  - Take responsibility – is agent learning ?
    - Can query and quiz agent (self–other monitoring)
  - Reflect – why is agent not getting this answer right ?
    - Self explanation, read resources, ask agent to explain answer
- ▶ **Scaffolding by Mentor agent**
  - Mentor helps TA and the student self–assess their knowledge (grades quizzes)
  - Provides feedback on strategies that help in learning and monitoring one’s learning



# Experimental Studies

- ▶ From 2003 on in 5<sup>th</sup>, 6<sup>th</sup>, 7<sup>th</sup>, and 8<sup>th</sup> grade (Middle school) classrooms
  - ▶ Example: 3 versions of system
    - LBT: Baseline Learning by Teaching
    - SRL: Learning by Teaching + self-regulated learning feedback
    - ICS: Intelligent coaching (Control condition)
  - ▶ More recently, focusing on relevant feedback to support student learning
- Typically students take pretest, intervention, then posttest; work on multiple units



# Data collected



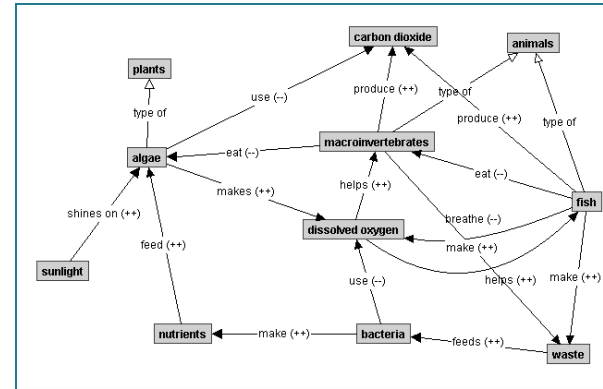
## ▶ Pre-Post Tests

- Multiple Choice
- Free Response

*Betty's science teacher told her that interdependence among things in the river is very important for river ecosystems. What is interdependence in a river? Please give examples.*

## ▶ Concept maps

- Score concepts and links
- Per student per session



## ▶ Log files (student activities on system))

- Students' actions (edit map, query, quiz, explain, read)

|      |                    |    |                                |        |
|------|--------------------|----|--------------------------------|--------|
| 5008 | main_1             | 13 | map_edit_qualitative_concept   |        |
|      | macroinvertebrates |    | macroinvertebrates             |        |
| 5008 | main_1             | 14 | map_add_qualitative_concept    | algae  |
| 5008 | main_1             | 15 | map_delete_qualitative_concept | algae  |
| 5008 | main_1             | 16 | session_end                    |        |
| 5008 | main_2             | 1  | session_start                  |        |
| 5008 | main_2             | 2  | map_delete_causal_link         |        |
|      | macroinvertebrates |    | bacteria                       | eat -- |
| 5008 | main_2             | 3  | map_delete_qualitative_concept |        |
|      | macroinvertebrates |    |                                |        |
| 5008 | main_2             | 4  | map_delete_qualitative_concept |        |
|      | bacteria           |    |                                |        |



# Student's Learning performance (2005–06)

- ▶ Pre-post + concept map score (final map score - day 1 map score) gains

| Gain Score      | Conditions |            |            |  |
|-----------------|------------|------------|------------|--|
|                 | ICS        | LBT        | SRL        |  |
| Multiple Choice | 0.4 (2.4)  | 1.1 (3.1)  | 0.4 (1.5)  |  |
| Free Response   | 1.9 (3.0)  | 4.3 (3.2)  | 4.8 (4.7)  | SRL > ICS ( $p < 0.1$ )                      |
| Map Concepts    | 8.1 (2.4)  | 7.3 (2.7)  | 10.4 (3.1) | SRL > ICS ( $p < 0.05$ ); LBT ( $p < 0.01$ ) |
| Map Links       | 12.2 (3.8) | 12.7 (5.3) | 16.2 (4.4) | SRL > ICS ( $p < 0.05$ ); LBT ( $p < 0.1$ )  |

- ▶ Correlations among gain scores

| Gain Score      | Free Response | Map Concepts     | Map Links        |
|-----------------|---------------|------------------|------------------|
| Multiple Choice | .16           | -.07             | .13              |
| Free Response   | --            | .35 <sup>a</sup> | .41 <sup>a</sup> |
| Map Concepts    |               | --               | .54 <sup>c</sup> |

<sup>a</sup> $p < .05$ . <sup>b</sup> $p < .01$ . <sup>c</sup> $p < .001$ .



# Technology in the Classroom

- ▶ How do we make technology relevant to classroom instruction?
  - Must involve the teacher
- ▶ Where can technology have a great impact?
  - Formative assessment
- ▶ Where can a teacher get good help from technology?
  - Keep track of student progress through assessments e.g., ASSISTMENT system (Feng and Heffernan, 2006): structured learning environment

Formative assessments for individual students & groups of students (class as a whole) for open learner environments

How do we do this in Betty's Brain?



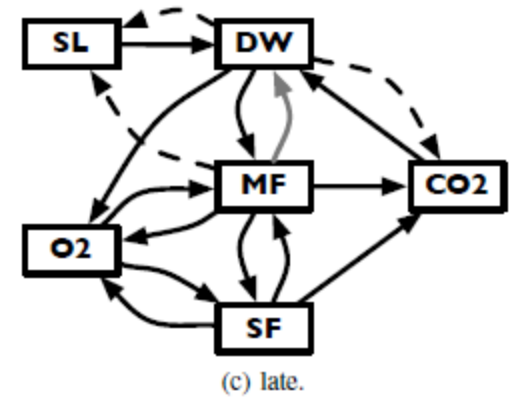
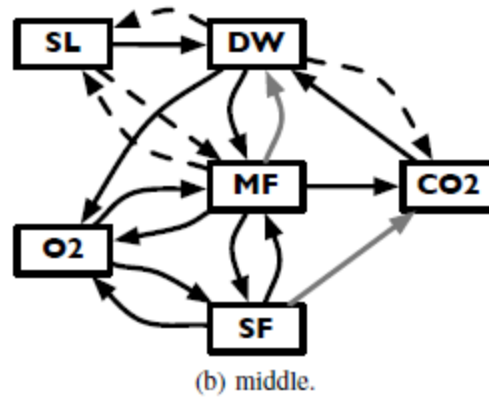
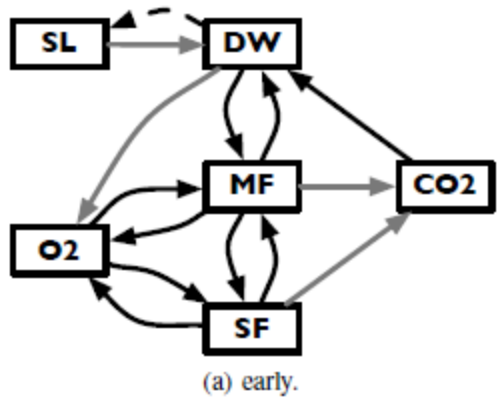
# Summarizing the knowledge construction process for teachers

- ▶ Visualization and animation of concept map construction process
- ▶ Two methods
  - Animation of student's concept maps over time
    - For individual students and groups of students
    - Animation steps synchronized with edit actions
    - Tool enables one to play map progress as a movie
  - Individual student progress over time
    - Number of correct links
    - Number of incorrect links
    - Overall progress of student (# correct – # incorrect links)

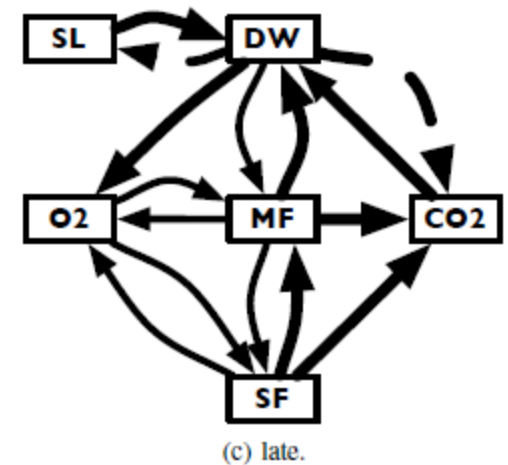
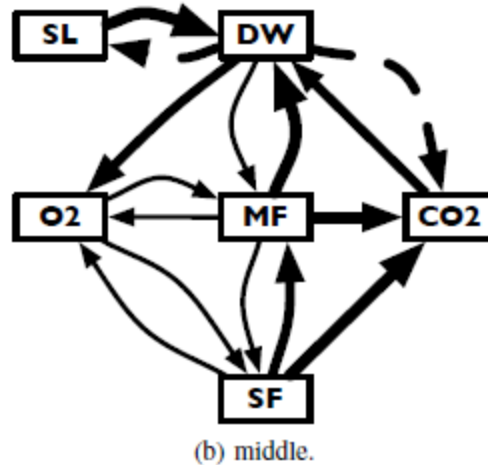
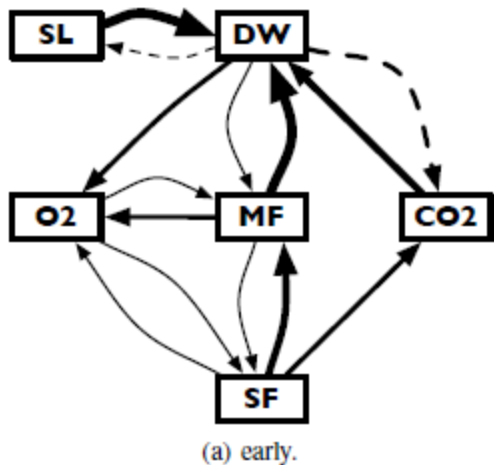


# Concept Map Animations

## ▶ Individual student

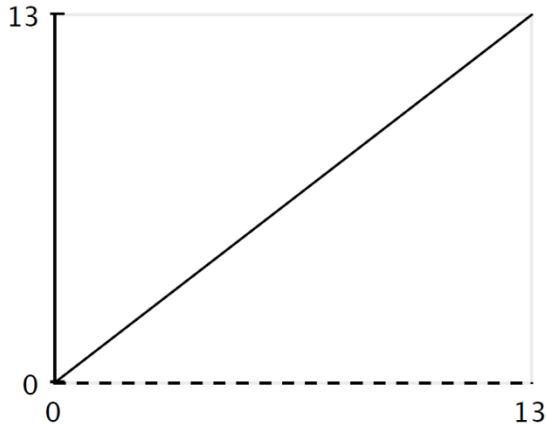


## Aggregate visualization for class

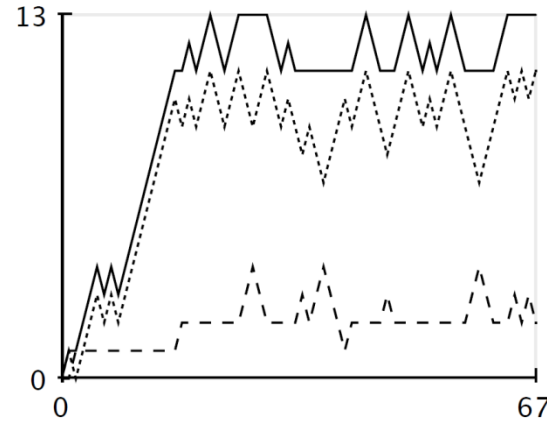




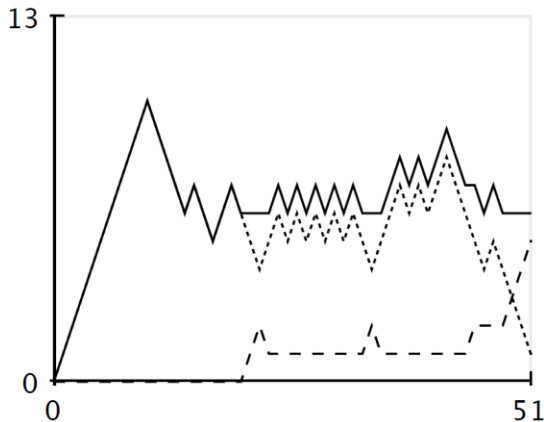
# Tracking Individual Student Progress



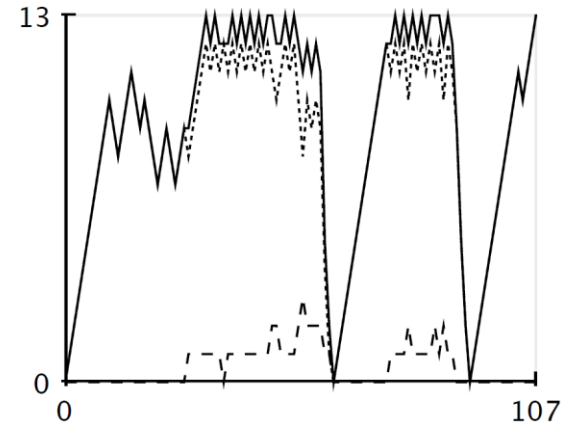
Student 1: Linear progress



Student 2: Linear progress, then stuck



Student 3: Linear progress, then oscillates, ends up on wrong track



Student 4: Linear progress, stuck oscillate, delete map, start again, finally correct



# Summary

- ▶ Visualizations much more informative than numerical summaries
- ▶ Can identify missing knowledge, misconceptions
- ▶ Helps teacher discover student problems as they occur, address them through feedback – formative assessment
- ▶ Tool for researchers and teachers to work together initially, and for teacher's to work with independently later: Teacher's dashboard
- ▶ More work to be done – use data mining techniques to develop better understanding of patterns



# Analysis of Student Interactivity Patterns



- ▶ Student behavior extracted from log files and coded into sequences
  - Five primary activities
    - Editing activities (add, delete, modify concept or link)
    - Ask Query
    - Take Quiz
    - Read Resource
    - Check Explanation
  - Also, off–topic activities



# Analyzing Behavior Sequences

## ▶ Hidden Markov Models of student Behavior

