Evaluation of the SimForest Inquiry Learning Environment

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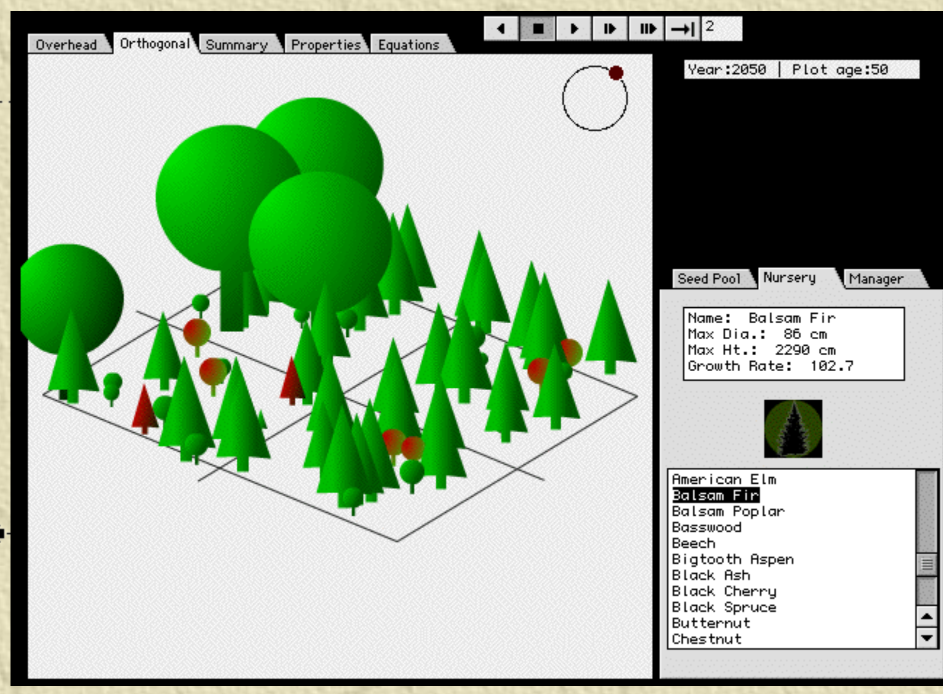

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Supported by NSF CCLI grant # DUE-9972486
and NSF LIS grant # REC-9720363

SimForest Project

- Learning goals: inquiry skills; botany/ecology; epistemology/beliefs about science
- Grades: 7-12, undergrad (& graduate)
- Project Phases:
  1. Software development
  2. Class and lab tests with undergraduates
  3. Curriculum Development
  4. Teacher Education (Summer Institute)
  5. Classroom support and assessment
- Evaluation: inquiry skills; teaching methods, professional development
- Glass-Box version of SimForest (prototype)

SimForest Project Evaluations

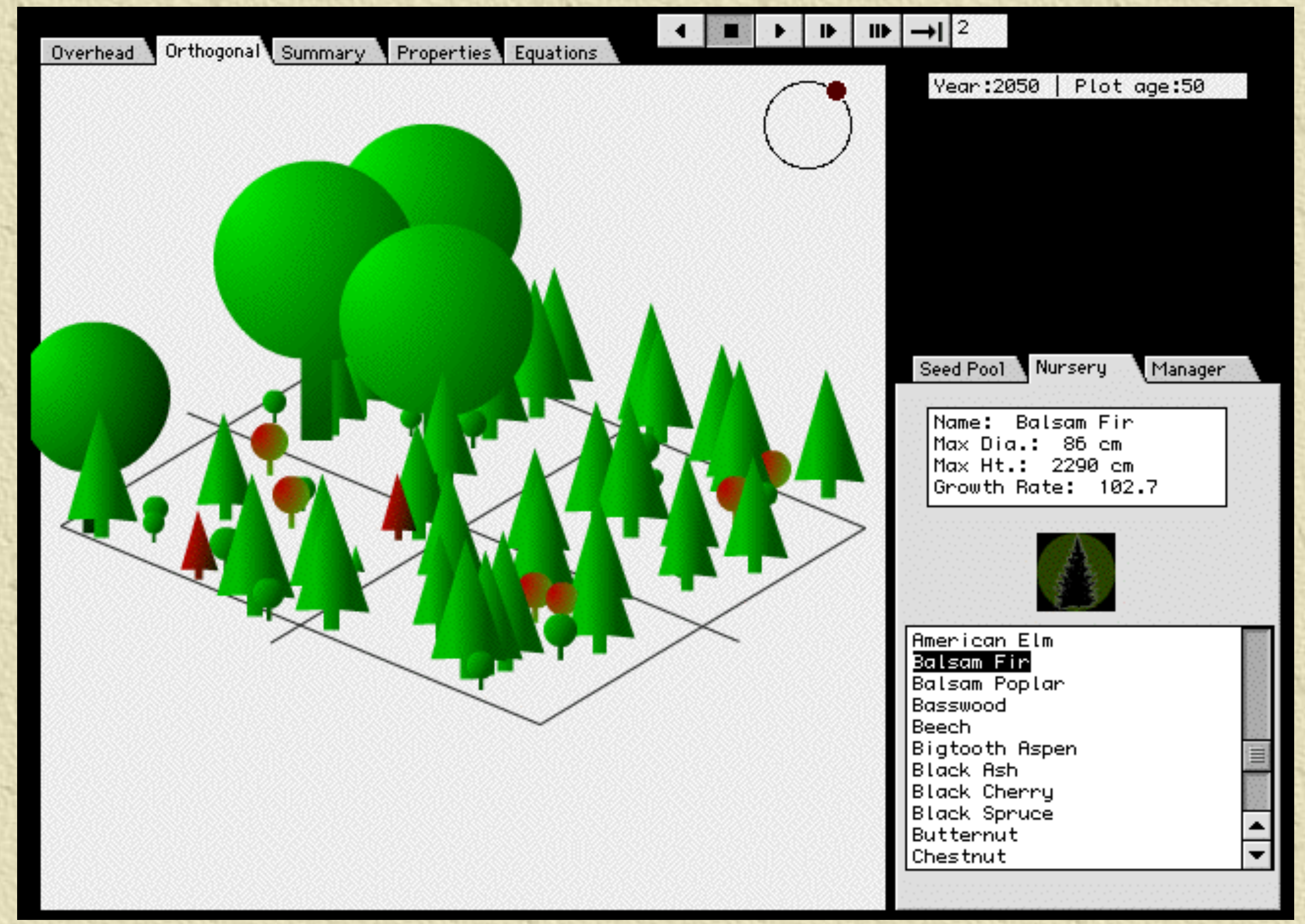
- Undergrad: 51 college students;
  14 instructional sessions of 1-2 hours ea.
  - Inquiry cycle and sub-skill analysis in one activity
  - Instructional cycles: multiple activities during a class
  - Analysis of expert teacher "best practice"
- Middle school students:
  - Inquiry skill improvement (pre/post test)
- Middle school teacher professional development
  - Lessons learned
  - Case studies

Overview:

focus on college trials

- 1. Characterization of the inquiry process while using SimForest
  - A. Do we observe inquiry sub-skills?
  - B. How long are inquiry cycles?
  - C. How many inquiry cycles in a typical class?
  - Reason: pilot some new evaluation methods, get rough estimate of time-factors
- 2. Characterize some "best practice" classroom methods for using inquiry-based learning environments.

SimForest Demonstration



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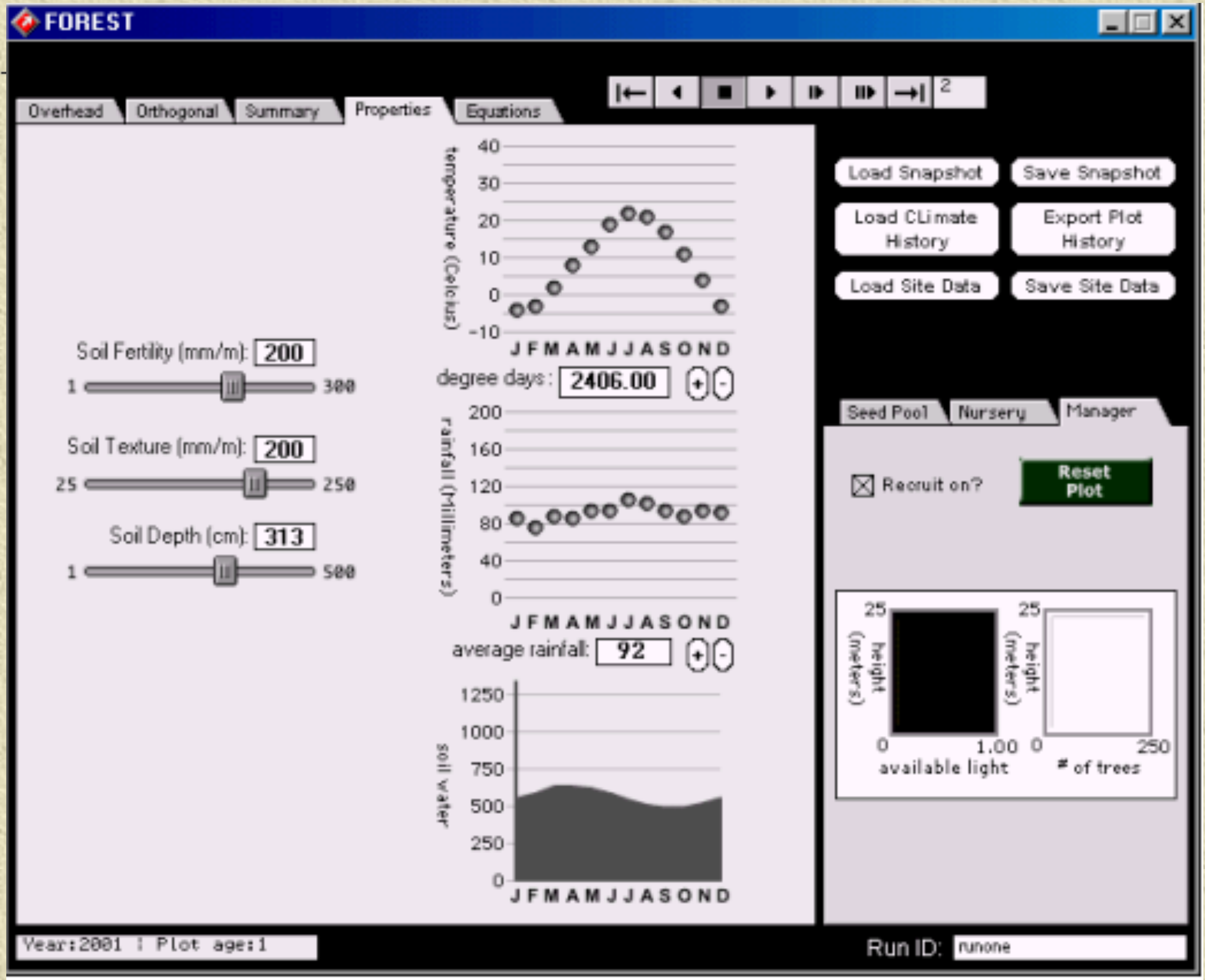
Site Properties Tool



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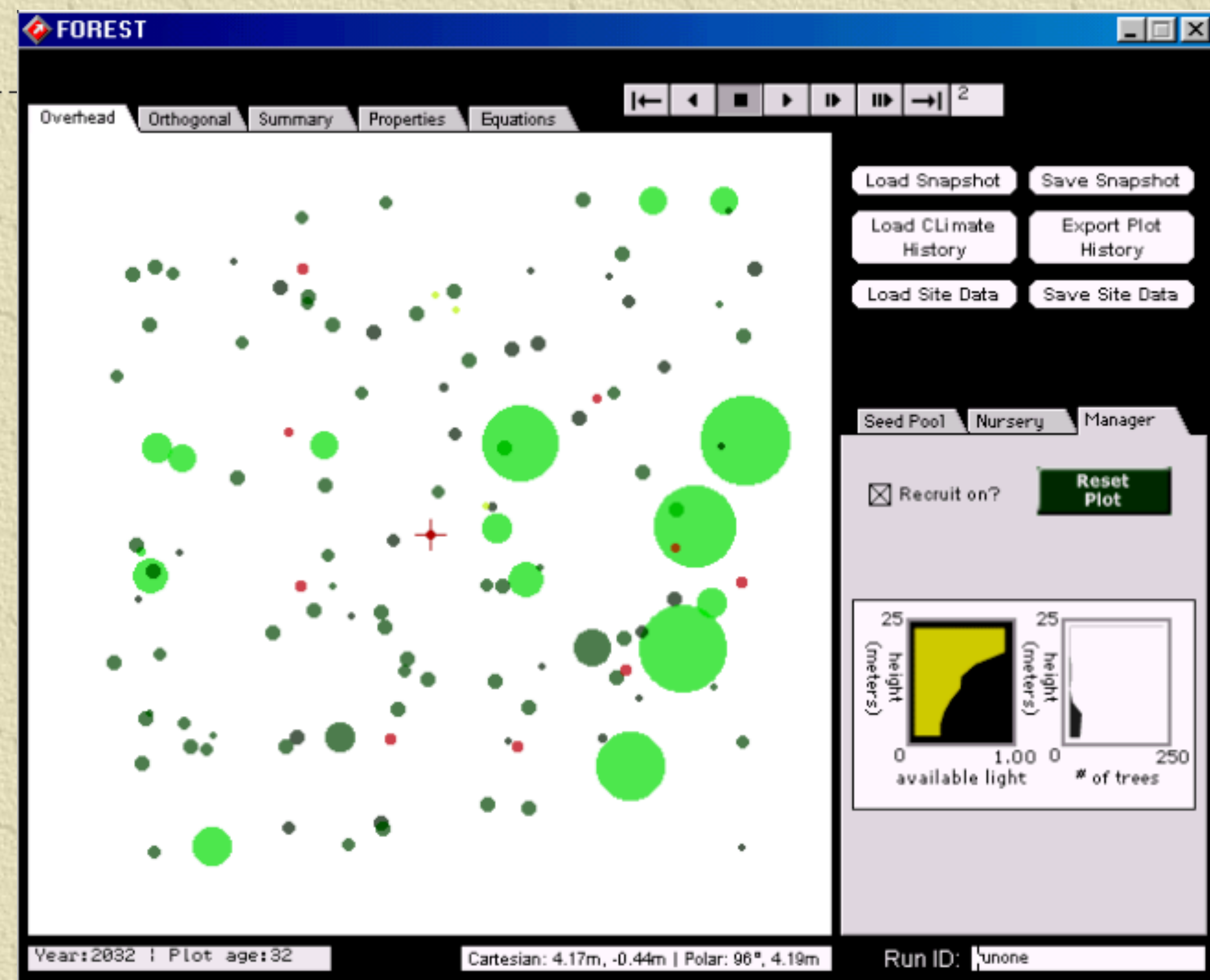
Overhead View



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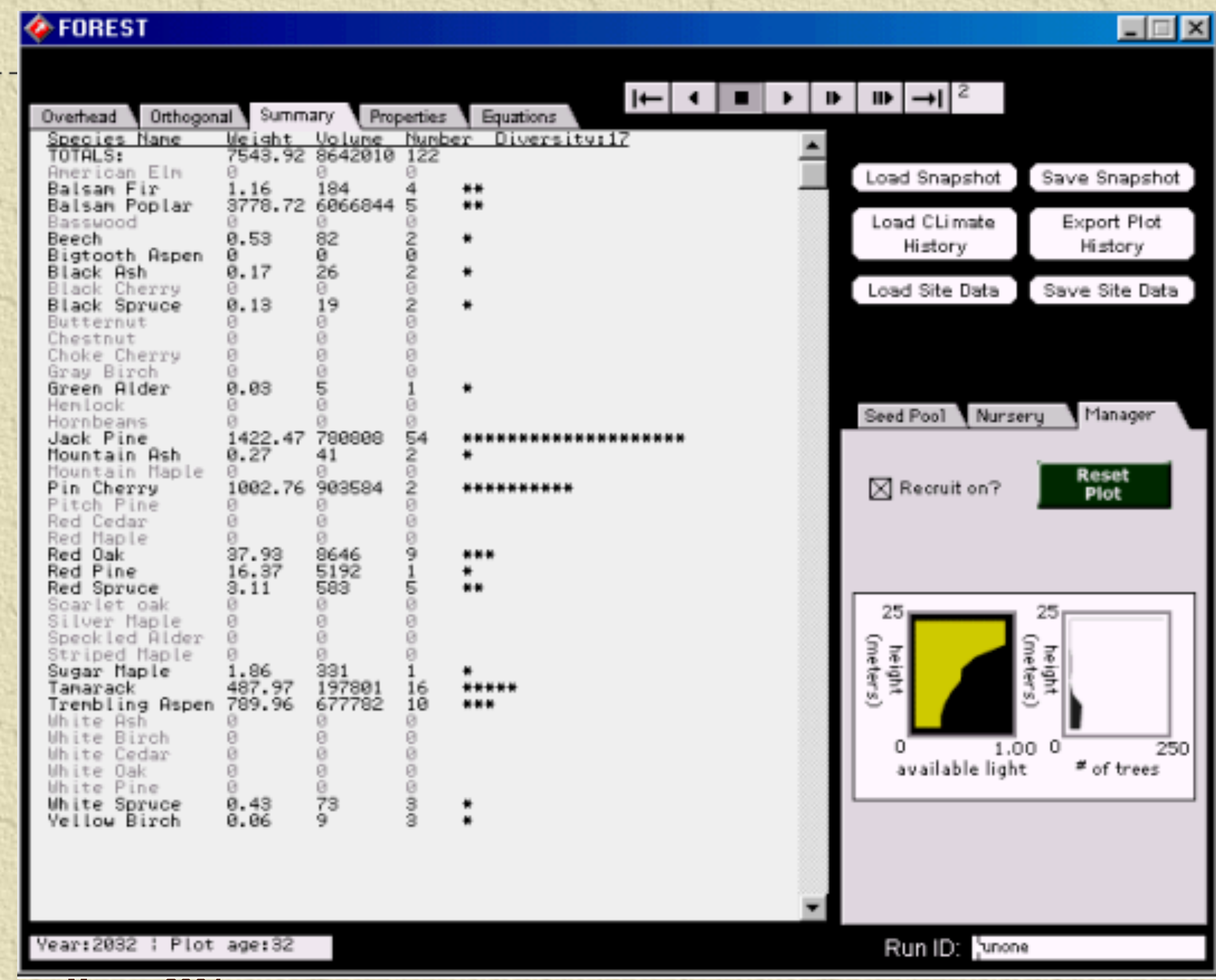
Summary View



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Tracking the inquiry cycle

(from video tape analysis)

Episode-->	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
SESSION A:																														
Ask question		x																												
Refine question		x																												
Make hypothesis			x																											
Plan experiment				x																										
Set-up experiment					x					x				x				x												
Run Simluation						x					x				x				x			x								
Record data																														
Verbal observations							x					x				x				x			x							
Refine Method									x				x				x													
Data analysisi	x							x													x			x						
Summarize																									x					
SESSION B:																														
Ask question	x															x														
Refine question																														
Make hypothesis										x							x													
Plan experiment																		x												
Set-up experiment																			x											
Run Simluation		x			x			x				x								x			x				x			
Record data																														
Verbal Observations			x			x			x				x								x			x				x		
Refine Method				x			x				x											x				x				
Data analysisi														x											x				x	
Summarize															x															x

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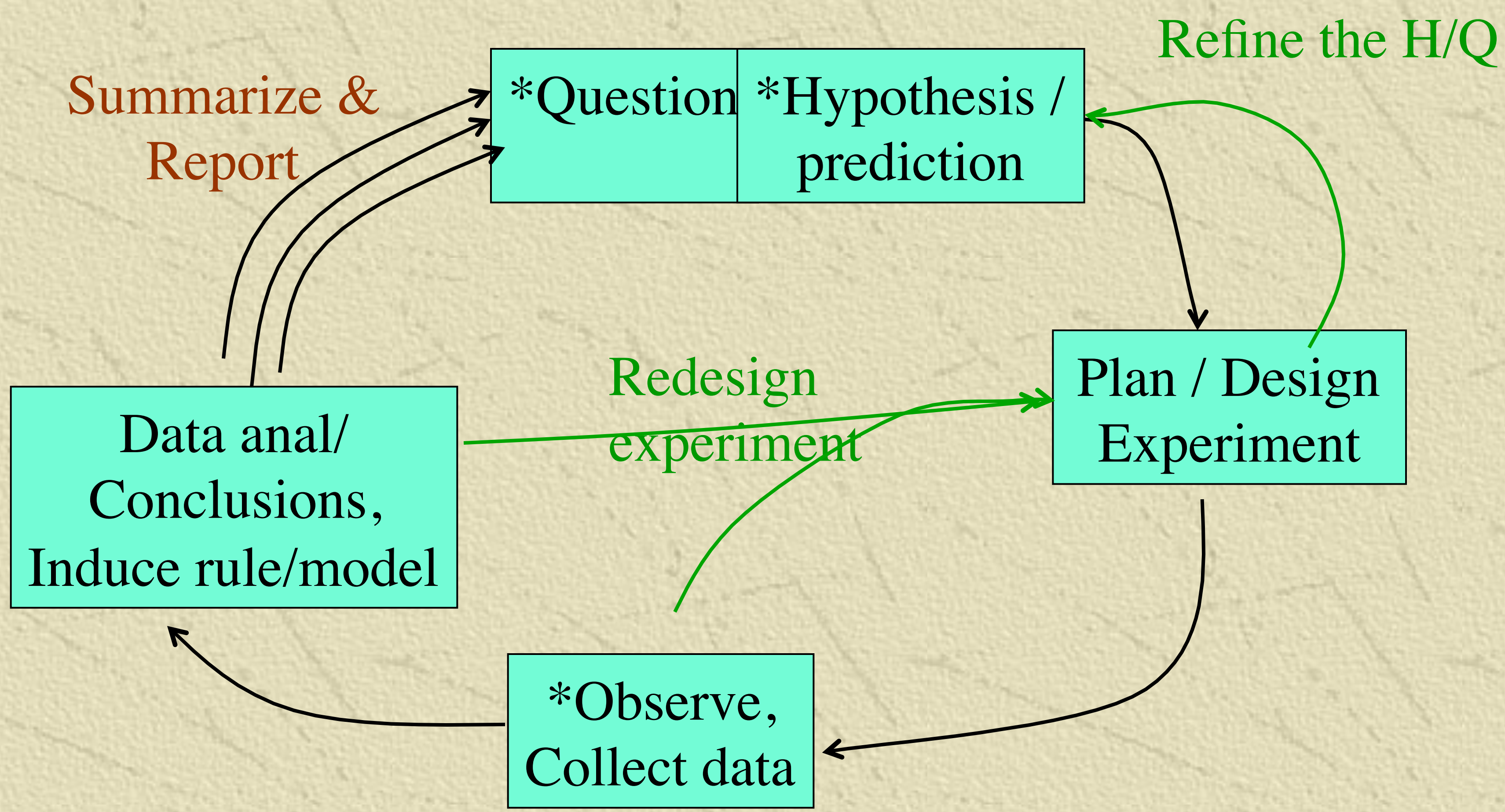
Inquiry Cycle Variations



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Evaluating Inquiry Cycles

- 1. Video tape analysis of student pairs
- 2. “Ethnographic” style observation/ analysis of classroom teaching

Inquiry Cycle Results

- Local (inquiry sub-skills): Average cycle about 10 minutes; partial and sub-cycles observed
- Global (several activities per class): 1.5 hour class; ave. of 4 cycles; ave.20 minutes each
  - Cycles of convergent and divergent work
- 10-35 min. activities with 2-4 inq. Cycles
- Students did ave. of 3 cycles per activity
- Measure of scaffolding/freedom
- * Many more cycles than “wet labs”

Characterizing best-practice classroom methods:

- Scaffolding individual students (and entire class)
- Scaffolding collaborative inquiry & problem solving

Characterizing best-practice classroom methods: Collaborative inquiry & problem solving

- Alternating **convergent & divergent** activities --individual/ group and whole-class
- **Additive knowledge --** class given same open ended task, e.g. "run the simulation and note what you observe;" reconvenes & compare, synthesize
- **Multiple student-created tasks --** ea. student/group poses question; reconvene for breadth in issues discussed; e.g. What happens if there is global warming of 3 degrees?
- **Collaborative hypothesis confirmation -** groups test alternate student hypotheses; e.g. "I think rain is good for oaks"
- **Unsystematic exploration --** explore a parameter space randomly sampling values; e.g. What makes white maples grow?
- **Jigsaw method** (state space search) **--** e.g. systematic exploration of a multi-variable space of temperature, soil quality, and rainfall

Other observed classroom tactics

- **Leading questions** and Socratic dialog
- **Emergent curriculum** and question/need-based dialog
- **Pre-telling** ("you will soon discover that..."), **pre-asking** ("How can we answer this question using the simulation?"), **post-telling** ("what you just learned is..."), and **post-asking** ("What can we learn from what we just saw?")
- **Opportunistic flow** of activities. Dynamically creating or choosing activities based on the following: student questions, student need to know, results of a previous activity, and unexpected problems with the software.
- **Committing to a hypothesis**. Asked students to pose a hypothesis or guess at an answer before starting an investigation.

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SimForest Characteristics & Issues

- Rich context for many types of activities, questions, students: age, topic, background…
- Relates to experience and authentic curiosity
- Multiple dependent & independent variables
  - Allows focus on many inquiry sub-skills
  - Can generate rich hypothesis & personally relevant hypotheses
  - What/how to measure/observe?
  - Observation skills; diff between observation and inference

Pedagogy Guidelines

- Start outside! -- connect with real trees
- Make predictions & debate
- Alternate convergent and divergent activities:
  - Free play with simulation
  - Solicit Qs
  - Open inquiry --> regroup & summarize
  - Systematic inquiry (jigsaw method)

Sample Lesson: How does temperature affect...?

Goals	Other Questions
Students will be able to **describe** the effects of temperature on a forest's , as it is demonstrated in SimForest. Students will be able to **design experiments** to **predict** possible effects of on New England forests, using SimForest. Students will be able to **compare** and **contrast** different predictions (simulated by SimForest) of the effects of global warming.	How does the composition of a forest change with a decrease in temperature? Is there and increase or decrease in diversity? How does the composition change with an increase in temperature? Is there an increase or decrease in diversity? How might global warming affect local forests? Which New England species would be lost if the temperature rose 2 degrees, 4 degrees, 10 degrees? Does the speed of the warming matter? One concern about global warming is that the temperature will increase more quickly than the seeds of southerly species can migrate north. How could you model this using SimForest?

Teaching Tips and Background Information

The first two questions in the other questions *list deal purely with examining the effects of temperature on forest composition and diversity and involve relatively simple manipulations of the temperature graph.*

Subsequent questions become more complicated, which is fitting as they involve a complicated issue, Global Warming. The questions listed here are examples of the types of questions that could be explored using SimForest within the topic of global warming. We do not expect that any group of students would investigate all of them.

You may want to provide students with scientific literature on global warming so that they will have something on which to base their experimental design.

There are a number of ways to structure an investigation of global warming using SimForest.
For example, students could

- *Begin with an empty plot and compare a plot grown in current local conditions to a plot grown in warmer conditions.*
- *Begin with a climax forest grown in current, local conditions, increase the temperature once, and then observe how the forest changes (and compare this to the way that the forest changes after reaching climax if the temperature does not increase).*

....(cont...)

A-la-carte Lesson Outlines

- Give teachers suggestions and resources--let them modify/reconstruct lessons to:
  - Student grade/academic level
  - Previous knowledge
  - Classroom dynamics and learning styles
  - Topical context (e.g. location, season, travel...)
- Table of concepts/skills vs. lessons
- List objectives & student inquiry Qs

Selected Curriculum Lessons

- **Unit One: Tree Trunks Leaves and Branches**
  - How Does a Tree Make Wood?
  - If Wood is Made of Sugar, Why Can't We Eat It?
  - How Old Is a Tree's Trunk?
  - […..]
- **Unit Two: Trees in the Forest**
  - How Do You Measure the Size of a Tree?
  - How Do You Map a Plot?
  - [….]
- **Unit Three: Forest Growth and Change**
  - How Does a Forest Change Over Time?
  - Does the Simulation Always Yield the Same Results?
  - Can We Simulate the Plot We Surveyed?
  - How Does Temperature Affect Forest Composition?
  - How Do Human Made Disturbances and Management Techniques Affect Forests?
  - How Do "Natural" Disturbances Affect Forests?
  - Is the Simulation Valid?

Three Evaluation Transfer Tasks: Worms, Fish, & Flowers

- Description of situation and question

1. State a prediction
2. Describe an experiment
3. Reflect on the experiment
4. Construct a graphical representation of the prediction
5. Reflect on uncertainty in science
6. Critique an experimental design

A. Stating a prediction

- Implicit or no prediction
  - I think that earthworms prefer most soil rather than dry soil
- Clear relationship between two variables
  - I think that the more water, the more worms

Coding Rubric:

Step B Describe your experiment

a) Systematic variation of the independent variable.

b) Measures the dependent variable.

c) Holds other things constant.

d) Is feasible to do.

e) Is specific and quantitative (measure how often; how many fish?).

f) Deals with random variation ($n>1$, e.g. ave. over 10 fish in each tank; ave. over repeated experiment)

B. Describing an experiment

- Weaknesses in manipulation of independent variable or measurement of dependent variable
  - Independent: Get … a square container … fill it with dirt … add lots of water to one side & none to the other. Put a few worms on each side.
  - Dependent: See which side they like better.

Experiment (continued)

- Systematic manipulation of independent variable. Clear measurement of dependent variable. *Fairly unreflective about control. Don't score unfeasibility.*
  - Get 3 boxes … fill 1st with 300 ml of water, 2nd 500 ml, & 3rd with 1 L. … pour dirt into each box … put 20 worms in each … wait 1 month and see how many worms are still alive.

C. Reflecting on experiment

- No explicit reference to general principles, i.e. no evidence of metacognition. [Note that the writing is excellent here.]
  - My experiment is a good way to test my prediction because it clearly shows if the worms prefer dry, moist, or really wet soil.

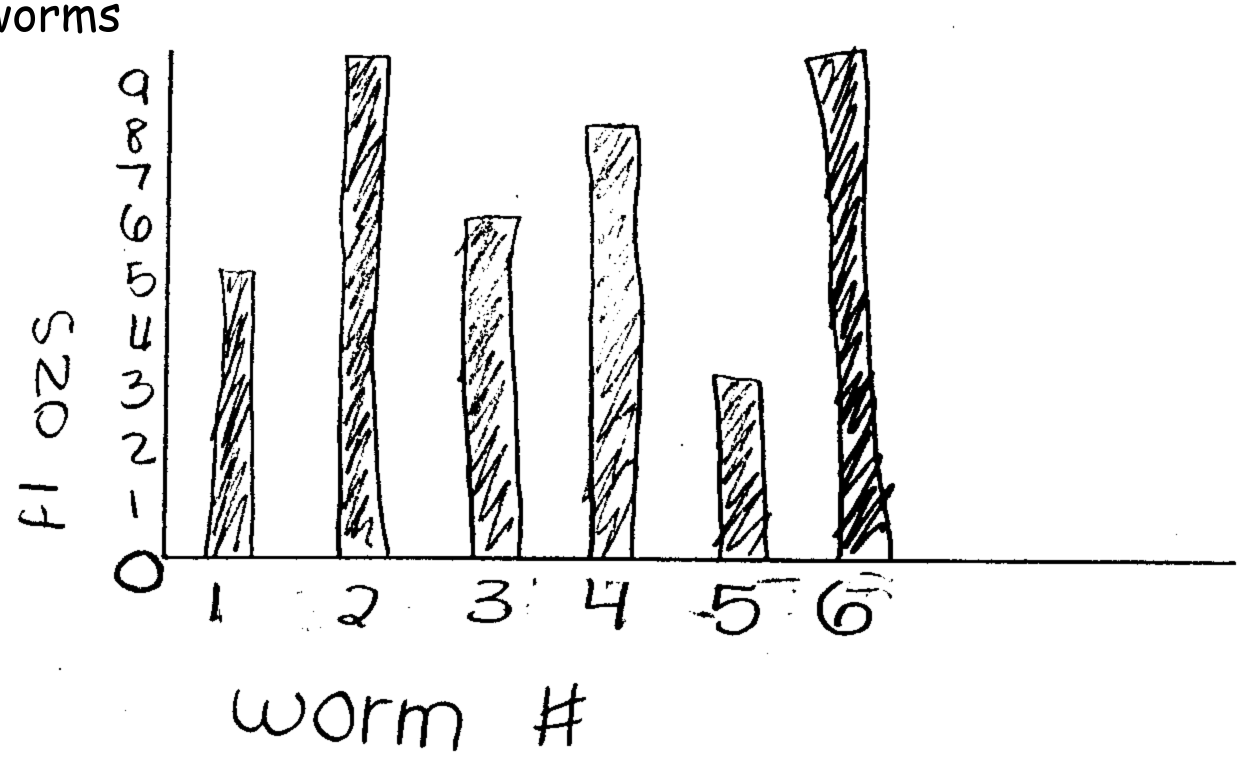
Reflection (continued)

- Some reference to general principles; some evidence of metacognition. [Note the experimental design here is not the best.]
  - My experiment is a good way to test my prediction because it is using two similar pots, each with a different amount of water. This variable can help you to determine if your hypothesis is correct by testing the final outcome under different conditions.

D. Graphical prediction example

Problems with correspondence to prediction, axes, or data plotting

I think that the more water, the more worms



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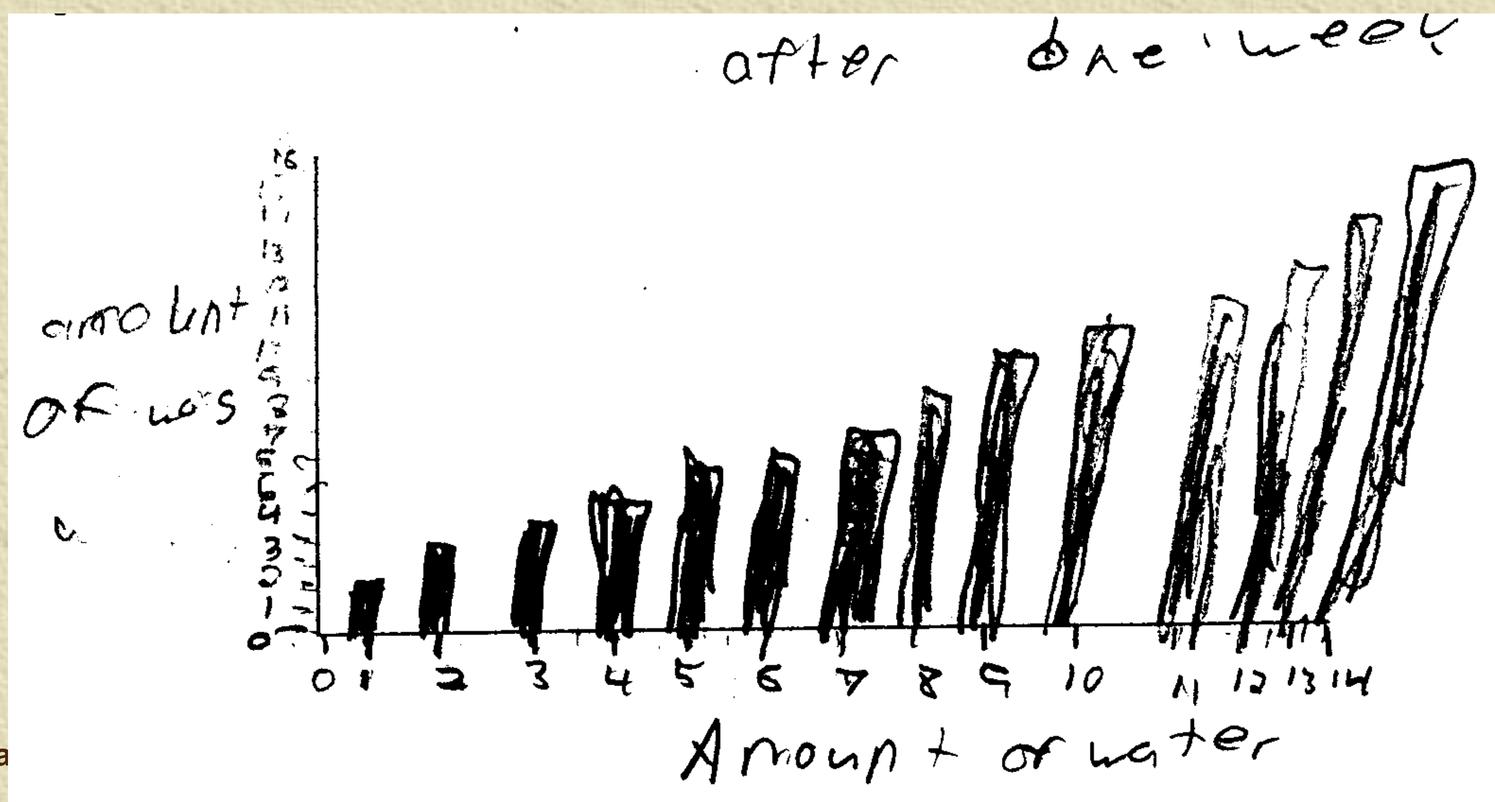
D. Graphical prediction example (continued)

Good axes & plotting. Clear relation to prediction.

I think that the more water the more worms



E. Reflecting on uncertainty

- Not very explicit. Not more than one or unusual other variable mentioned. General principles not mentioned.
  - Maybe some of the worms did not need that much water.

Uncertainty (continued)

- Clear mention of other variable(s). Mentions measurement error or random variation in a reflective way. Mentions general principles.
  - You could have used different soil or but you could have had different lighting
  - The surrounding temperature could have been different, and more or less water could have evaporated.

F. Confounded experimental design

Amount Of Water (Liters)	Amount of Clay (Kilograms)	Number of Worms
2	1	20
4	5	40
6	9	60
8	13	80
10	17	40
12	21	10

Task F data

- No one sees the confounded variables
  - I don't think it dropped from 40 to 10. And they should redo the last part of the experiment.
  - I thought that there was no problem. The did show the amount of water clay and worms.
  - I think the problem is that they're putting in too much water. It might drown the worm. You could fix this be stopping after 8 liters.

Prof. Devel. Lessons Learned

- Resource-focus: a-la-carte lesson outlines
- Plenty of time to PLAY with simulation
- Talk about what and how they teach
- Too BUSY to spend much time on email
  - meetings were important
- Address state science frameworks
- Time during institute to work on lessons
- Lessons: Demonstrate -> Create -> Pilot -> Discuss

Learning Goals

- Higher order skills
  - Inquiry skills
  - Modeling concepts
- Content concepts, facts
  - Botany (trees)
  - Ecology (forests)
- Attitudes and scientific epistemology
  - Computer simulations in society: approximate
  - How scientists use complex simulations

Factors making curriculum adoption difficult

- State frameworks
- MCAS
- Demand from administration
- Demographics of school
- Class structure, academic level of students
- Length of class time
- Number of meetings per week
- Number of students in class
- Accessibility to computers, class time etc.
- Timing—does it fit into unit?
- Student motivation and interest
- Student learning
- Ease of activity to prepare
- Comfort and ability of the teachers' understanding of subject
- Creating real behavioral and understanding improvements in teachers through hands on Professional Development workshops

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Teacher Training and support

- 1 week summer institute in 2001
- 8 participants: grades 7-11 (6 schools)
- 6 science teachers, 2 ed-tech teachers
- Fall 2001 & spring 2002; 2 or 3 3-5 day lessons
- Stipends and P.D.P.s
- Web site; email list
- 4-hour Saturday meetings every 3 months
- Classroom observations and feedback

Summary of Data Types

- **Teacher Questionnaires:** Pre SI, Post SI, January Meeting
- **Daily Session Evaluations:** During Summer Institute
- **Personal Interviews:** Pre Institute, During Institute, Post Institute
- **Teacher Journals:** Written after each class they taught on SimForest
- **Teacher Retrospectives**: Written at the end of their unit
- **Classroom Observations**: Conducted by myself and Tom Murray
- **Informal Conversations**: From ongoing dialogue with myself and the teachers

Teacher Questionnaire

Given Pre SI, Post SI, Jan 2002, (Nov 2002)

Scale: 1. High, 2. Good, 3. Moderate, 4. Low, 5. Poor

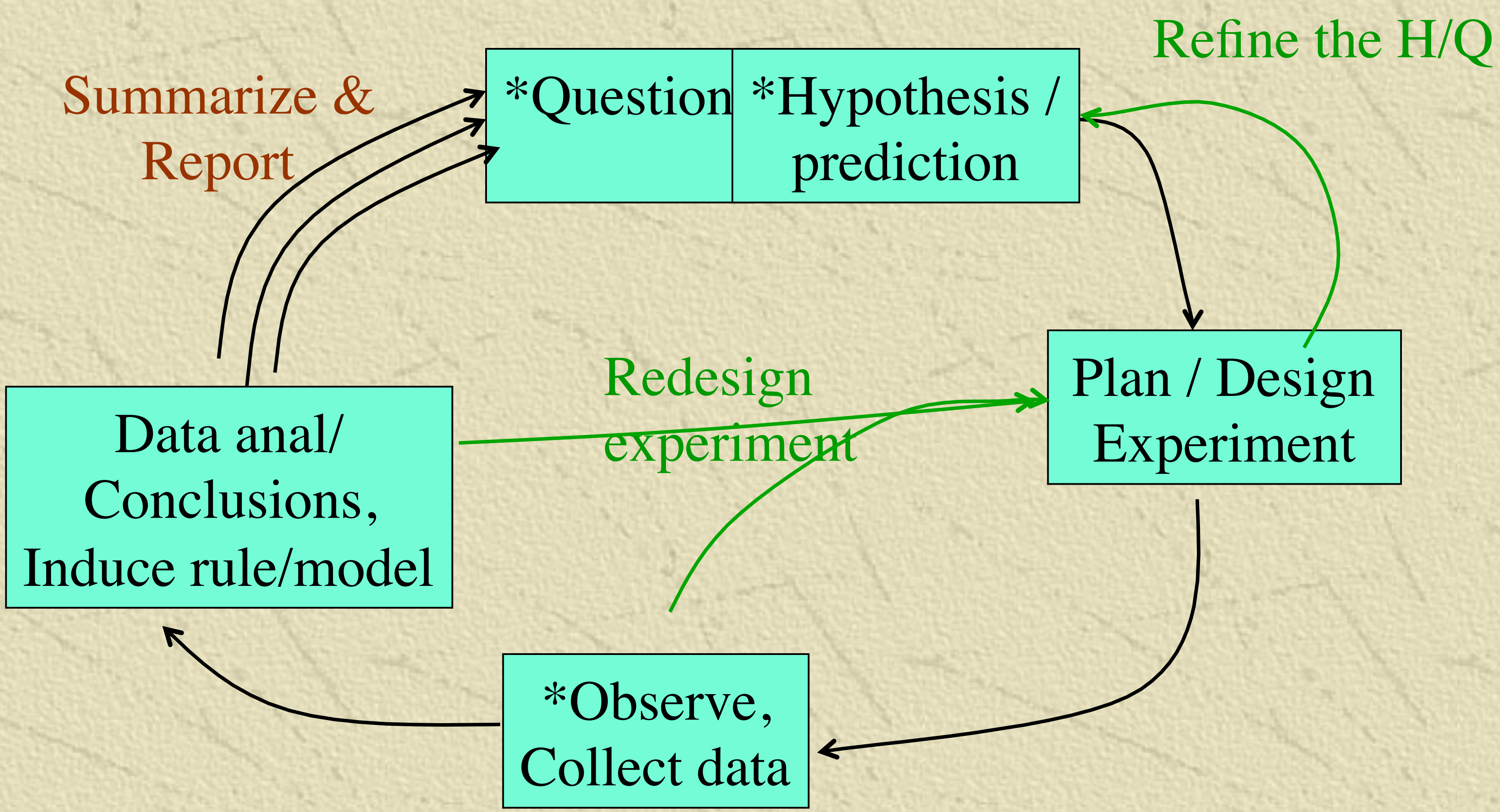
1. Teaching scientific inquiry skills (in general)
2. Using simulation-based software in your classes (in general)
3. Teaching botany and ecology content related to your classes
4. Designing and using student assessments in your classes.
5. Using SimForest in my classes
6. Using or Adopting SimForest curriculum for my classes

For each above rate;

A . Comfort & Confidence

B. Understanding & Skill Level

Inquiry Cycle Variations



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Some Inquiry Sub-skills

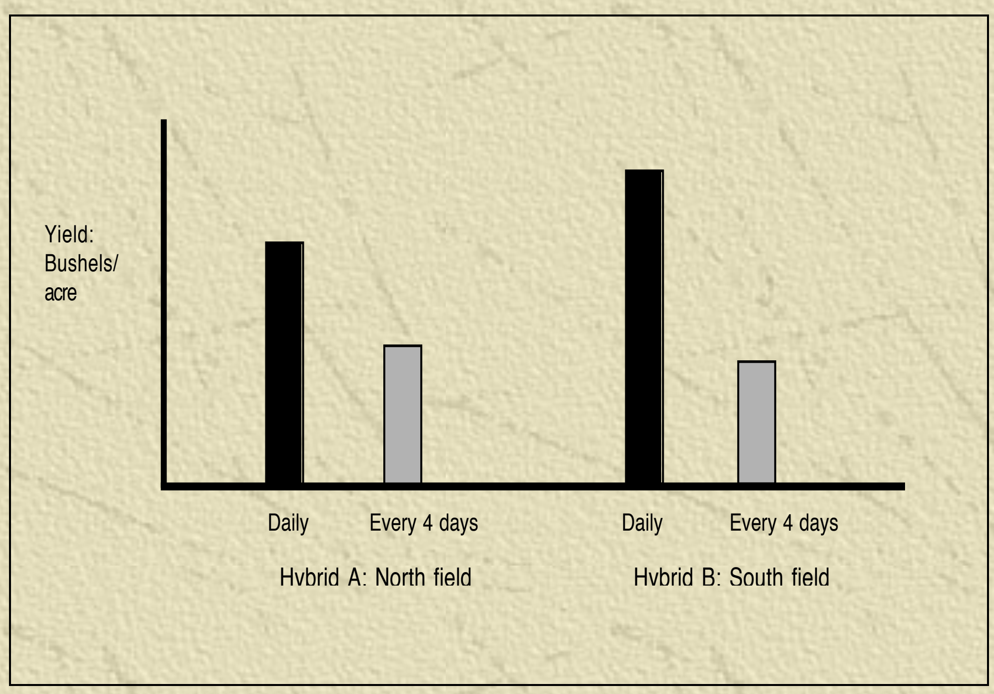
- **Unbiased observations**: separate data/observations from inferences and make
- Pose **valid questions and hypotheses** (clear, confirmable)
- Clear **argumentation**: Supporting hypotheses and providing sources; chains of reasoning
- Shift between brainstorming or **divergent** work/thinking and focusing or **convergent** work/thinking
- **Systematicity** and representativness of data set (exploring data space)
- **Organizing** data and looking for patterns, trends, categories
- Dealing with errors, **noise, and outliers** in the data
- Avoiding "**confirmation bias**;" considering counter examples & data
- **Data analysis**. Many skills--graphing, statistical analysis, etc.
- **Metacognition**: Reflection, self-monitoring, evaluation, revising

Example task

- A farmer wanted to compare two corn varieties and their responses to varying amounts of water. She believed that Hybrid B would produce a better yield than Hybrid A, and she believed that daily watering would increase yields. She planted her North field with Hybrid A and her South field with Hybrid B. She watered one half of each field daily, while the other half of each field was watered once every four days. The resulting yields at harvest are shown below in a table and also in a graph.

Yield in bushels per acre

	Watering interval 1 day	4 days
Hybrid A: North field	108	63
Hybrid B: South field	138	55



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Example task (cont.)

- A. The farmer had two hypotheses: (1) that hybrid B would produce a better yield than hybrid A; and (2) that daily watering would increase yields. Do the data support these hypotheses? Explain your answer in terms of the data.
- B. Did the farmer make any assumptions in setting up the experiment? List any assumptions that you can identify.
- C. Can you suggest any improvements in the design of the farmer's experiment that would provide more evidence concerning the two hypotheses? Describe what you would do.

Scientific Epistemology

- Sophisticated beliefs about the **nature of science**
  - Science is not just experts accumulating facts using a fixed method
  - Understand theory-evidence relations in science
  - Understand uncertainty, change, and disagreement
- Student's epistemology is explicit and reflective
- Student's epistemology is associated with lower-level science knowledge
- Student's epistemology functions as a metacognitive control structure in thinking about science

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Acknowledgements & Participants

- Supported by NSF CCLI grant # DUE-9972486 and NSF LIS grant # REC-9720363
- PIs: Tom Murray, Larry Winship, Neil Stillings
- Software: Ryan Moore, Roger Bellin & Matt Cornell, GravitySwitch Inc.
- Curriculum: Ester Shartar
- Classroom impl. and tchr. trng. research: Ayala Galton
- Consulting: Laura Wenk, Paul Zachos
- Teachers: Peter Shaughnessy, Pam Novak, Karen Cousland, Cynthia Gould, Susan Pease, Deirdre Scott, Patricia Tarnauskas, Jeff Weston
  (Amherst, Northampton, Turners Falls, Athol/Leominster, Chicopee, and Longmeadow)

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Supporting Inquiry --#1

- **Scaffold inquiry process** -- templates; activity sequencing; inquiry / hypothesis notebook
- **Supporting arguments** (chains of reasoning) -- justif. and critique links, argument graphs
- **Data collection** -- search tools; data tables
- **Data analysis** -- calc. tools, graphs, meta-phenomena meters, concept maps,

Supporting Inquiry --#2

- **Understanding content** -- multiple representations, field guides, model evolution.
- **Reflection** -- templates and collaboration
- **Planning** -- goal space visualization, plan notation
- **Coaching** -- argument analysis; hypothesis analysis; data collection analysis
- **Collaboration**- MUDs, email, etc., document annotations, human resource data bases
- **Peer Evaluation and Reporting** -- templates, email,..

Inquiry Learning Software Research Projects (#1)

* == software available

- *Belvedere (LRDC, Suthers)
- *Model-It (U. Mich., Solloway)
- *SimQuest/SMILSE (de Jong & Joolingen)
- *ThinkerTools (White & Frederiksen)
- Smithtown (LRDC, Shute, Glaser, et al.)
- *CISLE/Knowledge Forum (Scardemalia)
- CoVIS (NWU, ILS; Gomez, Edelson)

Inquiry Learning Software Research Projects (#2)

- *Agent-Sheets (U. Colorado, Repening, Fisher)
- *Exploring the Nardoo (U. Wolongong: Harper, Hedberg, Fasano)
- *ISIS (Instr. Sci. inq. Skills), Maestro (AFRL Brooks: Shute, Steuck, Meyer, Rowley…)
- And: (Georgia tech/Guzdial & Kolodner,...)
- *Misc. software: Sim-City, Ant, earth; Stella,...

SimForest-G (Glass Box)

SimForest-B (black box, MM Director)

- More "Graphically appealing"

SimForest-G (glass box, Java)

- Model Inspector, Model Editor, Graphing Tools

SimGlass (Java)

- Generic architecture for glass box simulations

Variations in Inquiry Software

Data Source	Data Collection	Analysis	Results
Real world, Source Docs, Simulation, Modeling	Observe, Measure, Find	Graphs/Tbls, **Hypoth. Tools**, Coaching, Arg. Graph, Concept graph	Presentation, **(Report Genres)**, Argument, Model/law, Pattern/trend, Simulation

Inquiry Environment Activities

WHAT IF?	X VS Y	WHY	MODELING	MODEL VALIDATION
Specific values: 1) explore (open ended) 2) Hypothesis testing (goal oriented)	How does X effect Y? What is relationship between X and Y?	Why does X effect Y?	1. Understand the model more deeply 2. Parametric: fixed equation, change parameters 3. plug in sub-models/equations (by indiv. equ or by type/factor) 4. Alternate theories 5. Creator/god (invent new laws)	Compare with **real** data 1. validate systems/teachers model 2. validate student's model
(and see model changes)	(infer a part of the model; vs. whole model is multivariate)	From **outside** the model; more "fundamental" question or sub-model		

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Black-, Glass-, and Empty-Box Simulations

Black Box Simulations Ex: SimCity	Glass Box Domain-Specific Simulations Ex: SimForest	Free-box Modeling Systems Ex: Logo, Stella

- Start with full working, realistic model
- Domain specific conceptual support for each equation

The "meta-model" problem

← Answering 'Why' questions: ←

Assumptions, Sub-Theory e.g.: chemistry	→	MODEL e.g.: biology	→	Emergent Behaviors e.g.: ecology
Canned Text		Equations		Analysis tools (Graphs, etc.)

Sub-Theory and Emergent Behaviors: NOT modeled but ARE learning goals

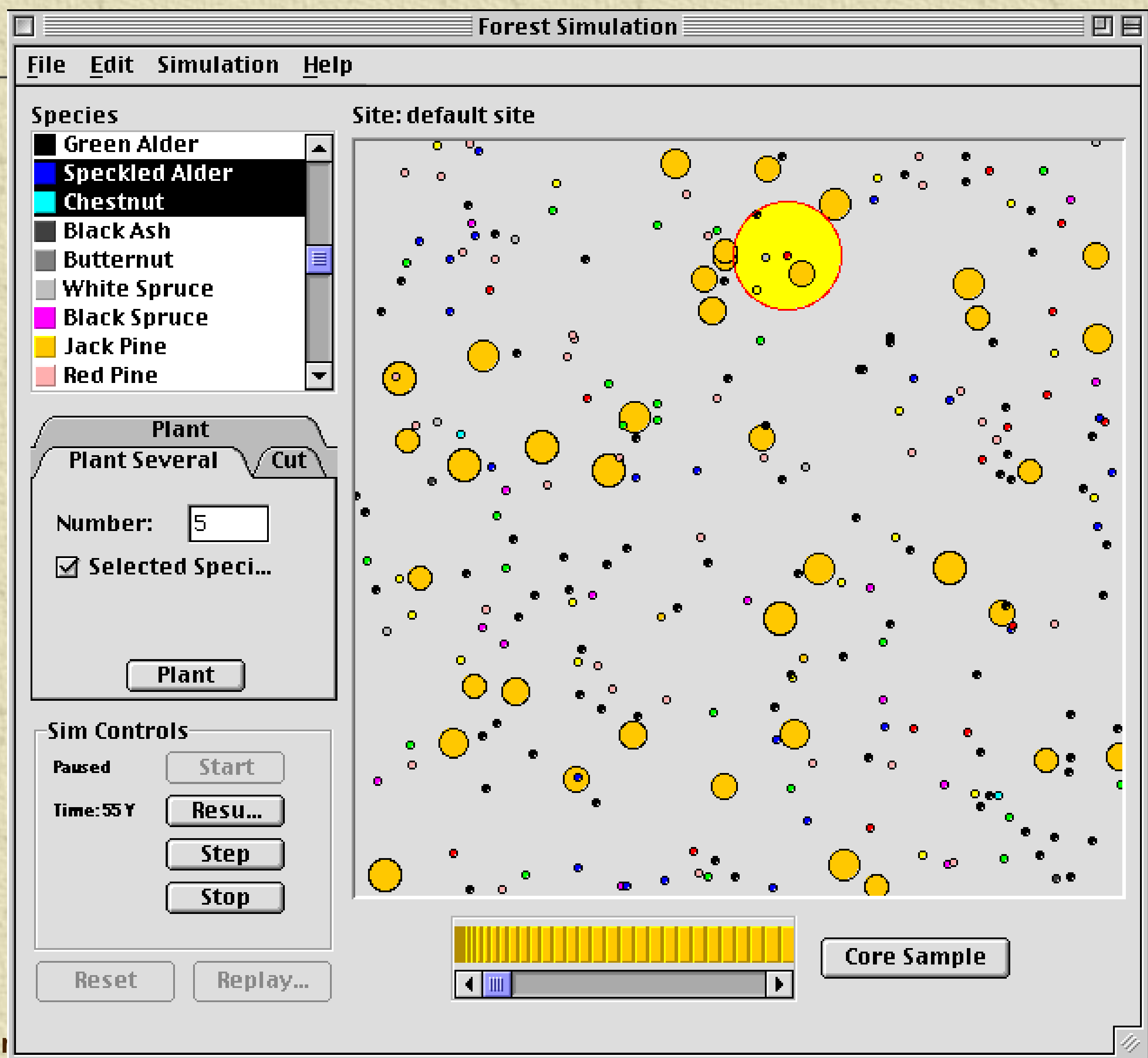
Model Inspector Information

Equation	SQI = (1-BAR)/BAMAX
Textual representation of the equation	Soil Quality Index = (1 -Total Basal Area)/Maximum Plot Basal Area
Description	SQI is soil quality index, which determines how the intrinsic fertility of the site limits the growth of trees. It is a measure of … [text book or URL reference].
Units	(The units in which the variable is measured)
Graph of relationship	Picture showing qualitative shape of relationship
Referents	SQI is referred to in these equations: … SQI refers to these variables: …
Assumptions, simplifications, and limitations to the equation	The equation assumes that tree circumferences are perfect circles.
Alternative equations	For a more complex equation that takes into account circumferences that are not perfect circles, see …

Levels of Questions/Hypothesis

Question/Hypoth. Level	Example	Action to Answer/Test
1. Concrete/Situational ("What if?")	"What would happen if I started a forest with almost all birches and just two maples?"	Run it and observe
2. Relationships ("How?")	"How does soil quality affect species diversity?"	Scientific Inquiry; Graphs
3. Explanatory ("Why?")	"Why does increased soil quality decrease tree diversity?"	Look at equations; Canned explanations in Model Inspector
4. Modeling	"What would happen if we replaced the Basal Area equation with a more complicated one that takes tree density into account?"	Inquiry in the model space; Model Editing

SimForest-G


Forest Simulation
File
Edit
Simulation
Help
Species
Site: default site
Green Alder
Speckled Alder
Chestnut
Black Ash
Butternut
White Spruce
Black Spruce
Jack Pine
Red Pine
Plant
Plant Several
Cut
Number:
5
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Plant
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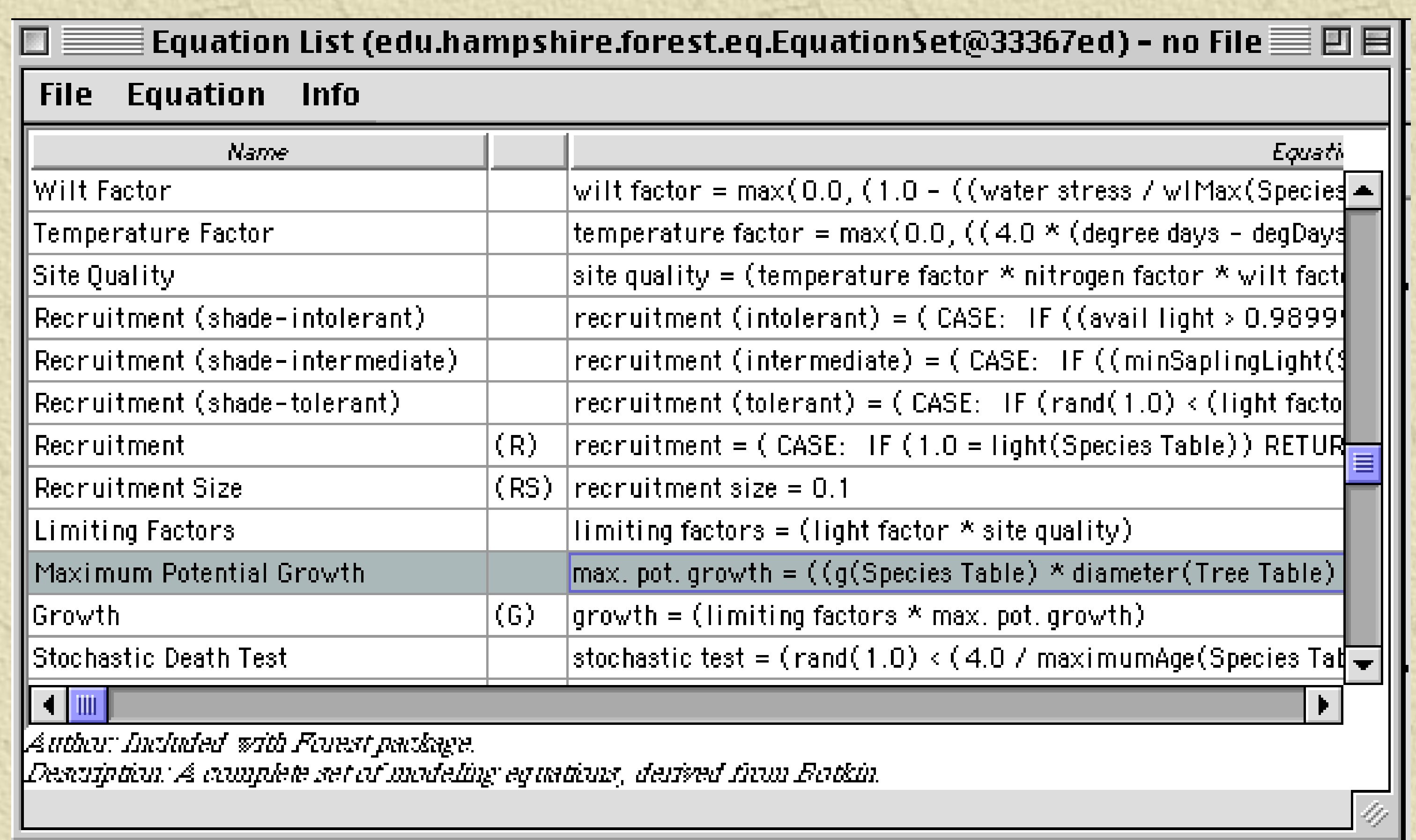
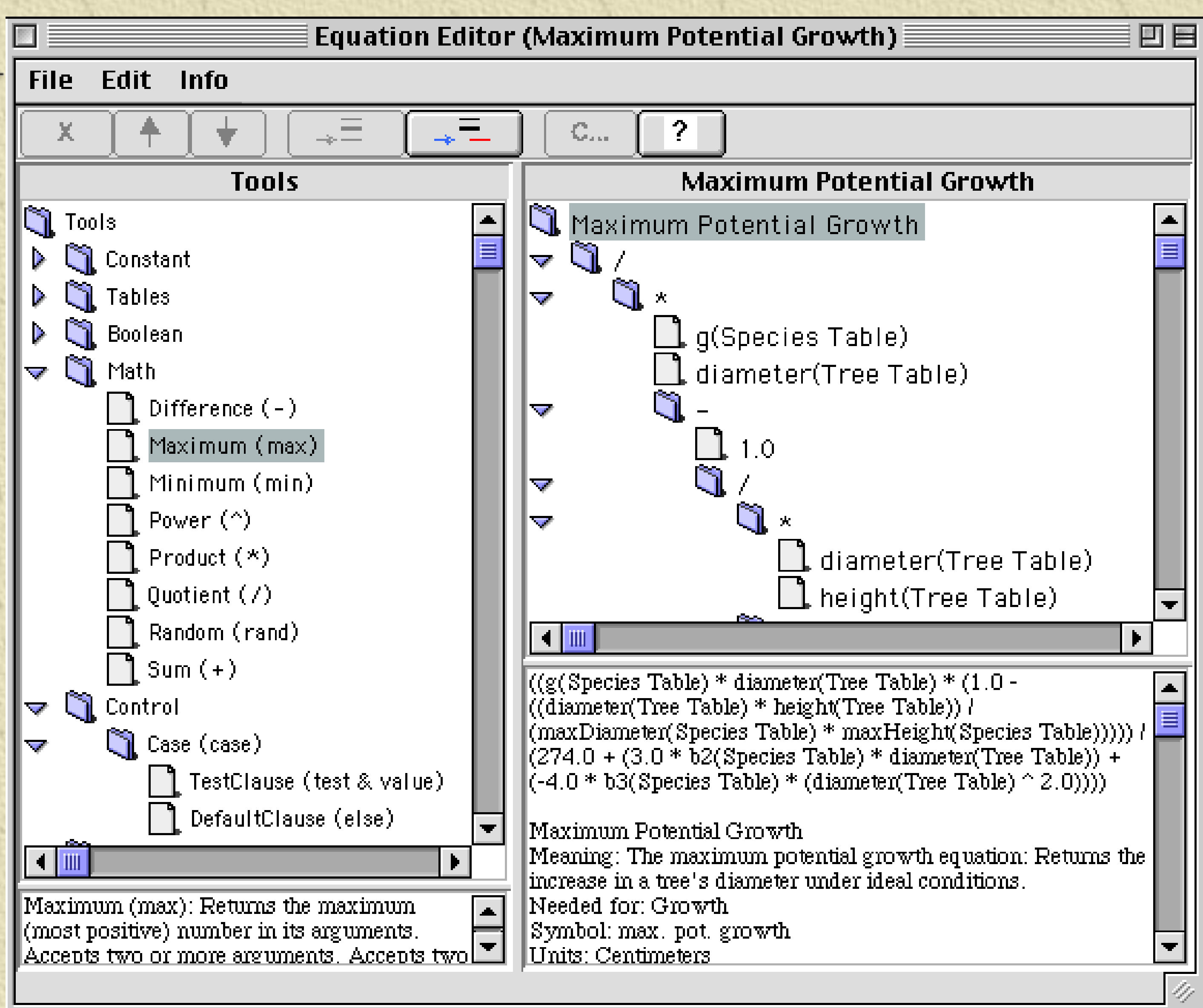
Time: 55 Y
Resu...
Step
Stop
Reset
Replay...
Core Sample

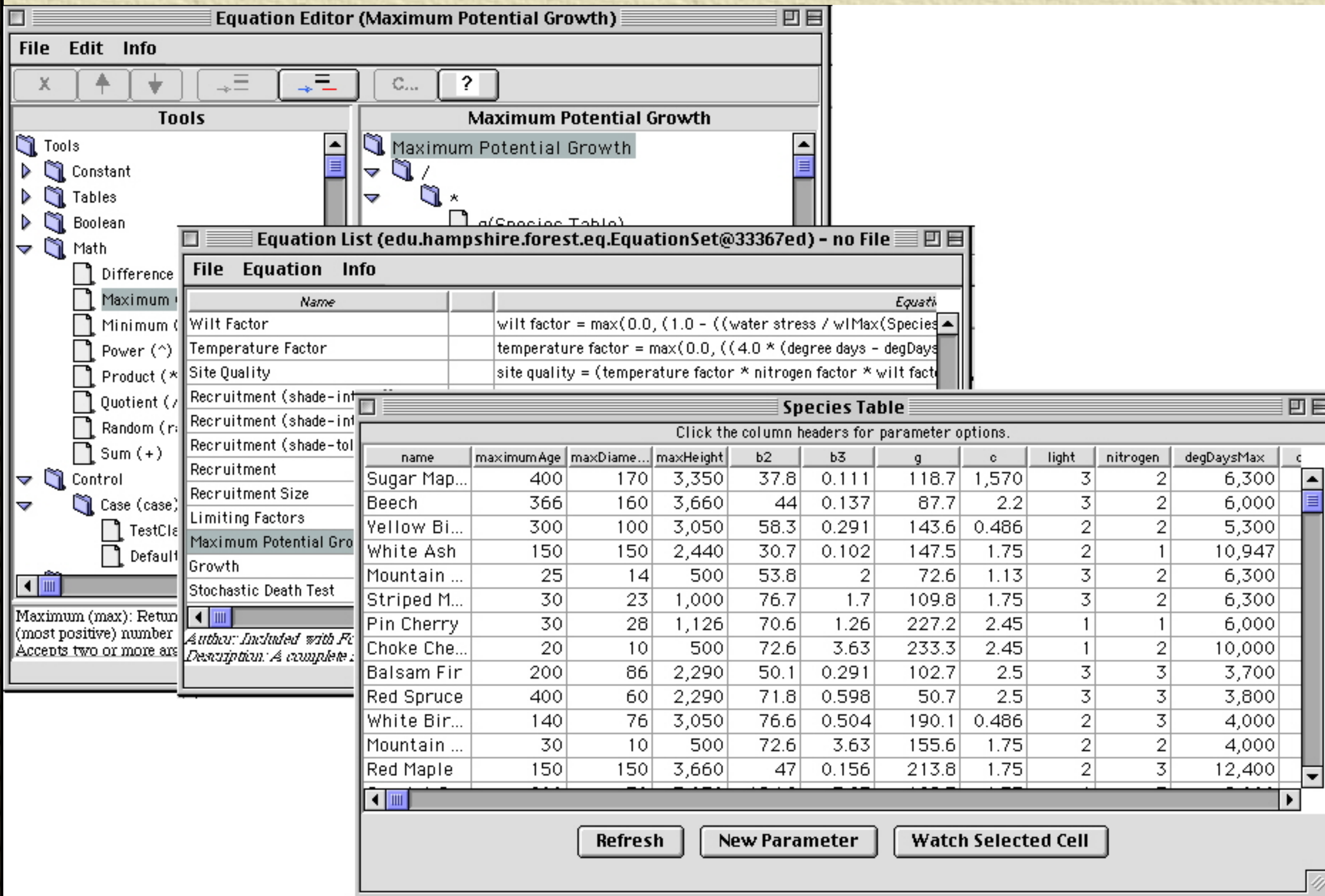
SimGlass Equation List



SimGlass Equation Editor



SimGlass-Table Editors



name	maximumAge	maxDiame...	maxHeight	b2	b3	g	c	light	nitrogen	degDaysMax
Sugar Map...	400	170	3,350	37.8	0.111	118.7	1,570	3	2	6,300
Beech	366	160	3,660	44	0.137	87.7	2.2	3	2	6,000
Yellow Bi...	300	100	3,050	58.3	0.291	143.6	0.486	2	2	5,300
White Ash	150	150	2,440	30.7	0.102	147.5	1.75	2	1	10,947
Mountain ...	25	14	500	53.8	2	72.6	1.13	3	2	6,300
Striped M...	30	23	1,000	76.7	1.7	109.8	1.75	3	2	6,300
Pin Cherry	30	28	1,126	70.6	1.26	227.2	2.45	1	1	6,000
Choke Che...	20	10	500	72.6	3.63	233.3	2.45	1	2	10,000
Balsam Fir	200	86	2,290	50.1	0.291	102.7	2.5	3	3	3,700
Red Spruce	400	60	2,290	71.8	0.598	50.7	2.5	3	3	3,800
White Bir...	140	76	3,050	76.6	0.504	190.1	0.486	2	3	4,000
Mountain ...	30	10	500	72.6	3.63	155.6	1.75	2	2	4,000
Red Maple	150	150	3,660	47	0.156	213.8	1.75	2	3	12,400

SimForest-G Species Table

Species Table

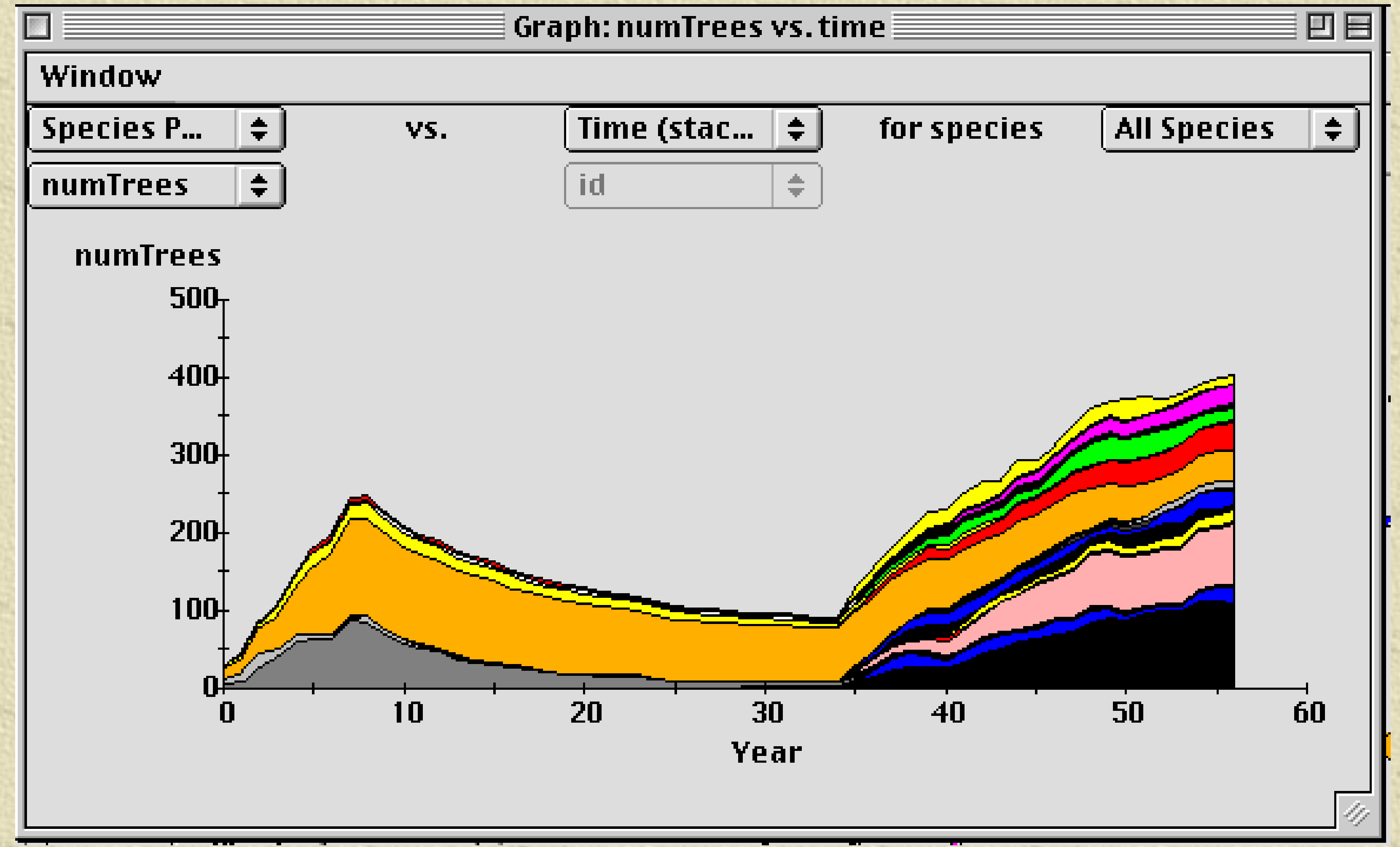
Click the column headers for parameter options.

name	maximumAge	maxDiame...	maxHeight	b2	b3	g	c	light	nitrogen	degDaysMax
Sugar Map...	400	170	3,350	37.8	0.111	118.7	1,570	3	2	6,300
Beech	366	160	3,660	44	0.137	87.7	2.2	3	2	6,000
Yellow Bi...	300	100	3,050	58.3	0.291	143.6	0.486	2	2	5,300
White Ash	150	150	2,440	30.7	0.102	147.5	1.75	2	1	10,947
Mountain ...	25	14	500	53.8	2	72.6	1.13	3	2	6,300
Striped M...	30	23	1,000	76.7	1.7	109.8	1.75	3	2	6,300
Pin Cherry	30	28	1,126	70.6	1.26	227.2	2.45	1	1	6,000
Choke Che...	20	10	500	72.6	3.63	233.3	2.45	1	2	10,000
Balsam Fir	200	86	2,290	50.1	0.291	102.7	2.5	3	3	3,700
Red Spruce	400	60	2,290	71.8	0.598	50.7	2.5	3	3	3,800
White Bir...	140	76	3,050	76.6	0.504	190.1	0.486	2	3	4,000
Mountain ...	30	10	500	72.6	3.63	155.6	1.75	2	2	4,000
Red Maple	150	150	3,660	47	0.156	213.8	1.75	2	3	12,400

Refresh | New Parameter | Watch Selected Cell

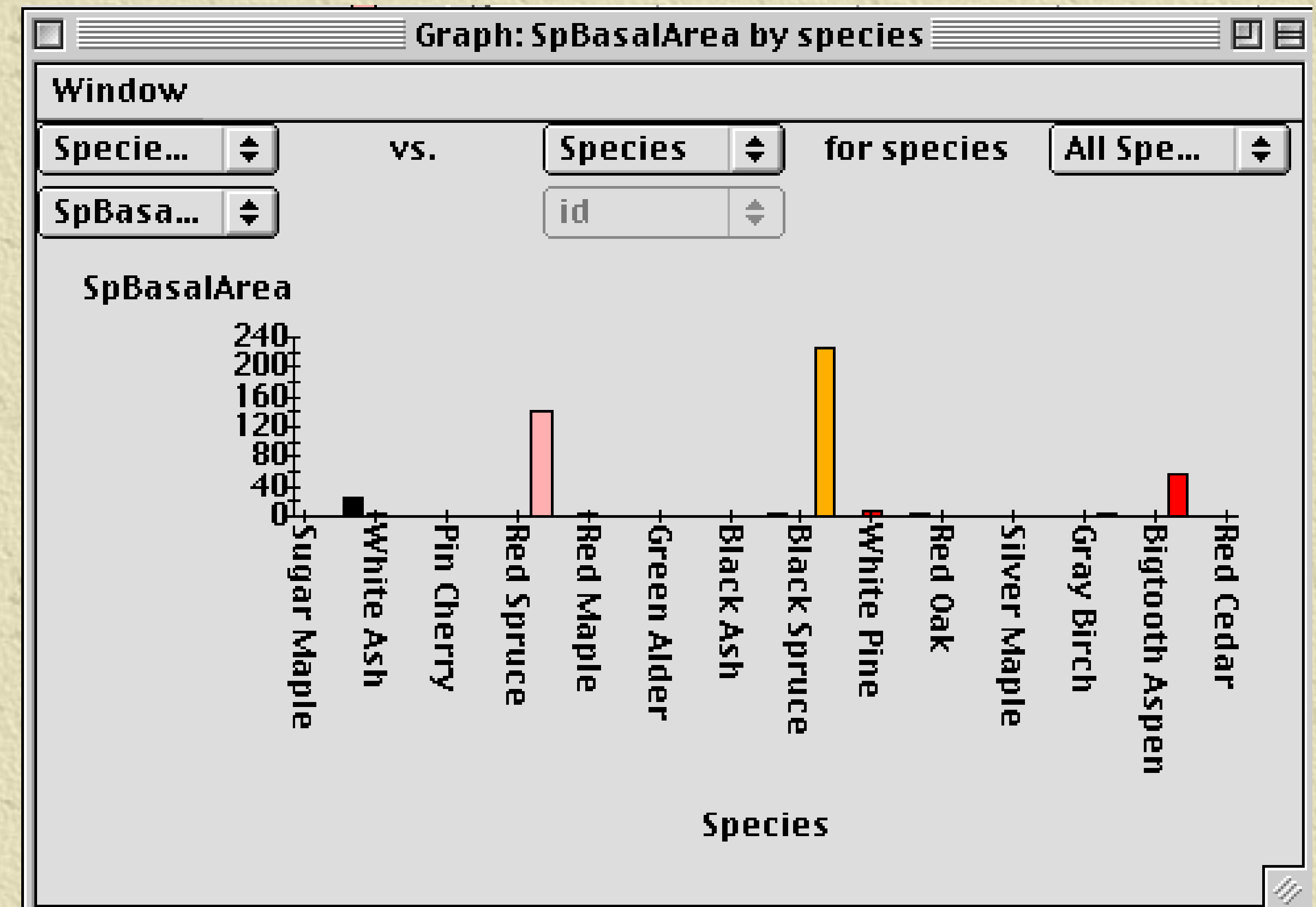
Murray 2004

Tree Count Time Series



Murray 2004

Basal Area Bar Chart



The Growth Equation

$$dD = G * D * (D_{max} - D) / D_{max} * Lf * Tf * Wf * Sf$$

- ***dD*** = change in diameter over time
- G = optimal growth rate (specific to species)
- D = diameter
- D_{max} = maximum diameter(specific to species)
- Lf = light factor
- Tf = temperature factor
- Wf = water factor
- Sf = soil nutrient factor

Coding scheme

for class observation and video analysis

Teacher and Student Moves	Session Properties
Teacher Questions: O (open); C (closed); L (leading); R (rhetorical) **Teacher Lectures**: M (motivating); C (content); S (summary); E (example); A (analogy); T (assigns a task)	**Locus of Information**: S->T student to teacher T->S teacher to student S->S student to student S->C student controls computer (TG) (with teacher guiding)
Student: U (software usability question); M (subject matter question); P (student performs task)	**Inquiry Cycle Steps**: Q - question, predict, or hypothesize P - plan A - analyze or model C - conclude/communicate

Murray 2004

Student Problems/Issues -- #1

- Can't manage one's 'agenda:' open Qs, hypotheses, partial conclusions, sub-goals, process reflection (Floundering, inefficiency; non-systematic)
- Can't keep track of or organize: notes & ideas; data and relationships
- Too many tools, options, choices; how and when to use them?
- Lost in Hyperspace: Where am I? How do I get to __? Where was I? How do these pages relate?
- Can't decide: when I have enough info. to conclude; what to look at next

Student Problems/Issues -- #2

- Problems finding ‘good questions’
- Not enough background knowledge
- Observations: unbiased; attention to detail
- Overcoming strong preconceptions and misconceptions
- Can’t understand or visualize: important patterns or relationships
- Can't generalize what's learned in lab to real world experience
- Can't communicate what is learned, found, induced