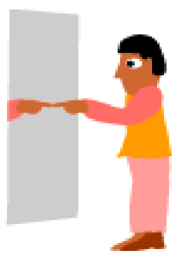
Interactivity and Learning

Daniel Schwartz

Stanford University



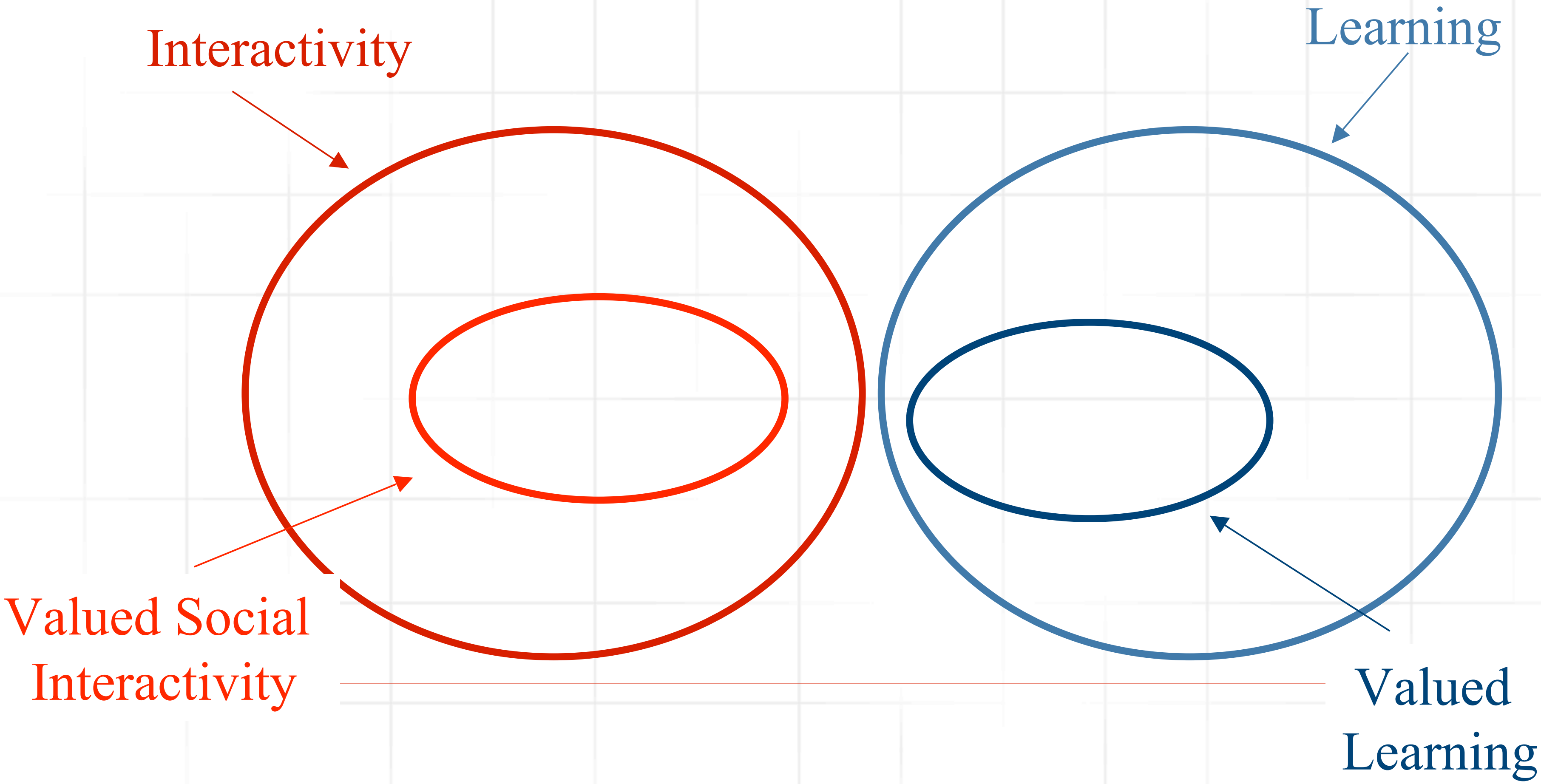
Greetings

- Honored. I did take a few AI courses in graduate school and got A's.

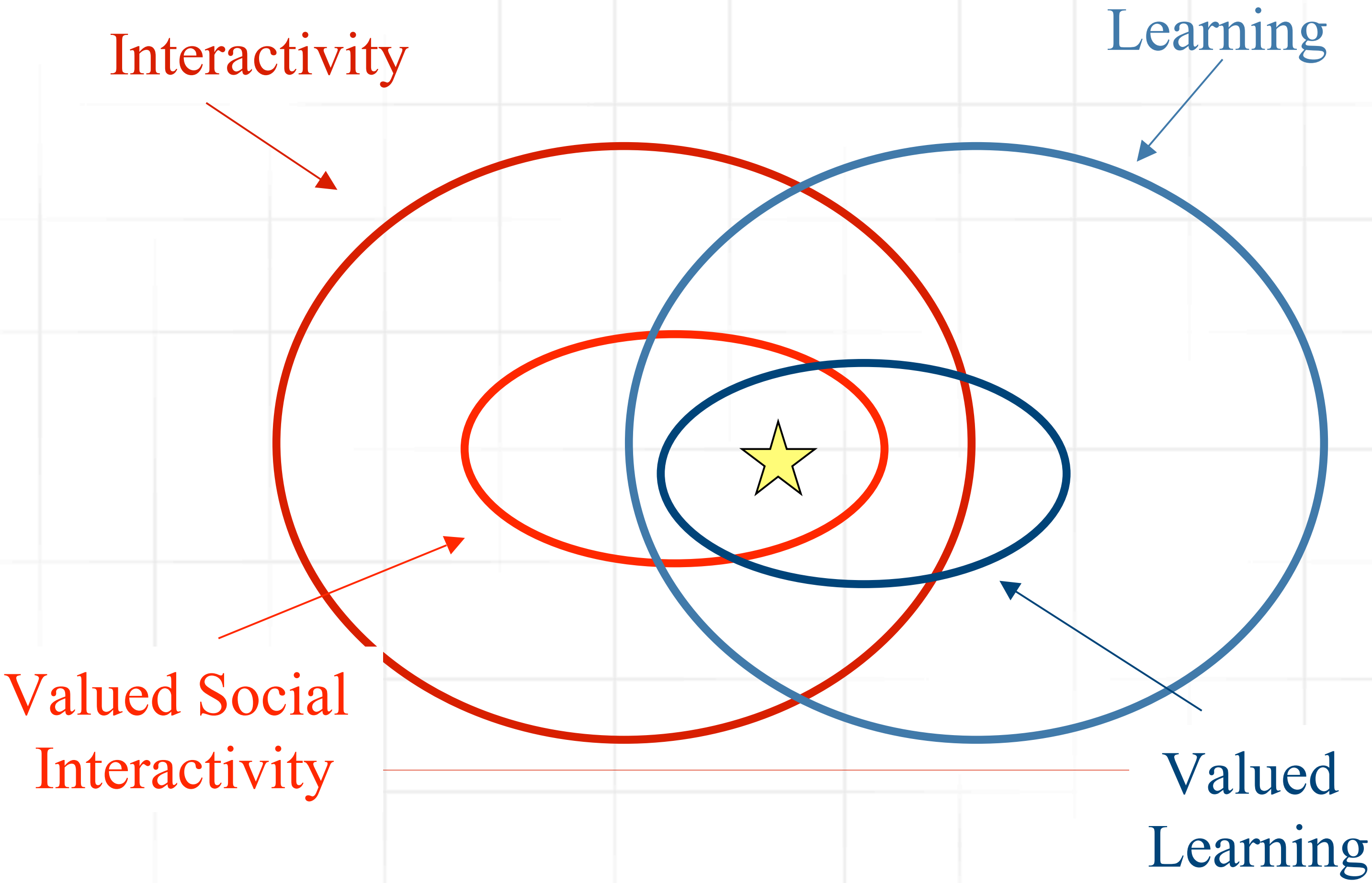
Artificial Intelligence in Education

- Two main capacities of interest:
  - **Social Interactivity**
    - Artificial intelligence, but real (social) interaction.
    - Tutors, coaches, learning partners, advisors, conversational agents, politeness, story telling, question asking, turn-taking…
  - **Learning**
    - Math, science, and other things that can be modeled well.
    - As we model additional domains, they can be added.

Goals of Social Interaction and Learning



Honor the goals of each and find the "sweet spot" of overlap.

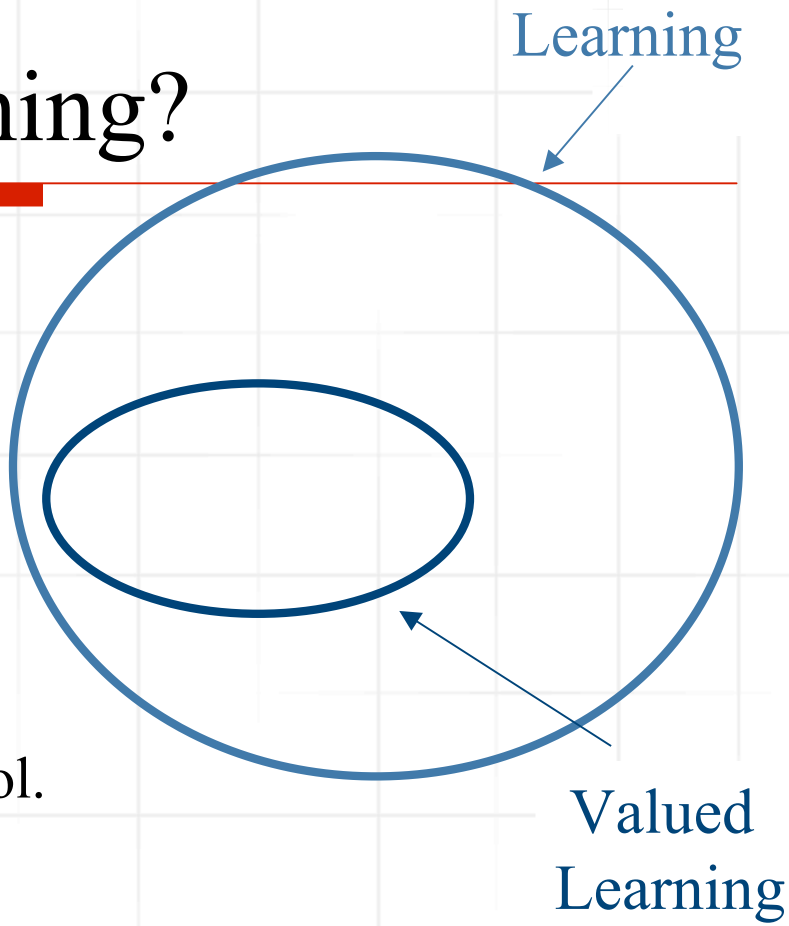


Interactivity and Learning

- → What is valued learning?
- What is valued social interaction?
- Enhancing social interaction for learning
- Teachable Agents
- Relevant Evidence using the Agents
- Sweet Spot of Social Interaction and Learning

What is valued in learning?

- People always learning.
  - What learning do we want?
- Asked Superintendents
  - Students who can adapt and continue to learn after school.
- Transfer literature should be relevant.
  - Use of prior learning in new situation.



What is valued transfer?

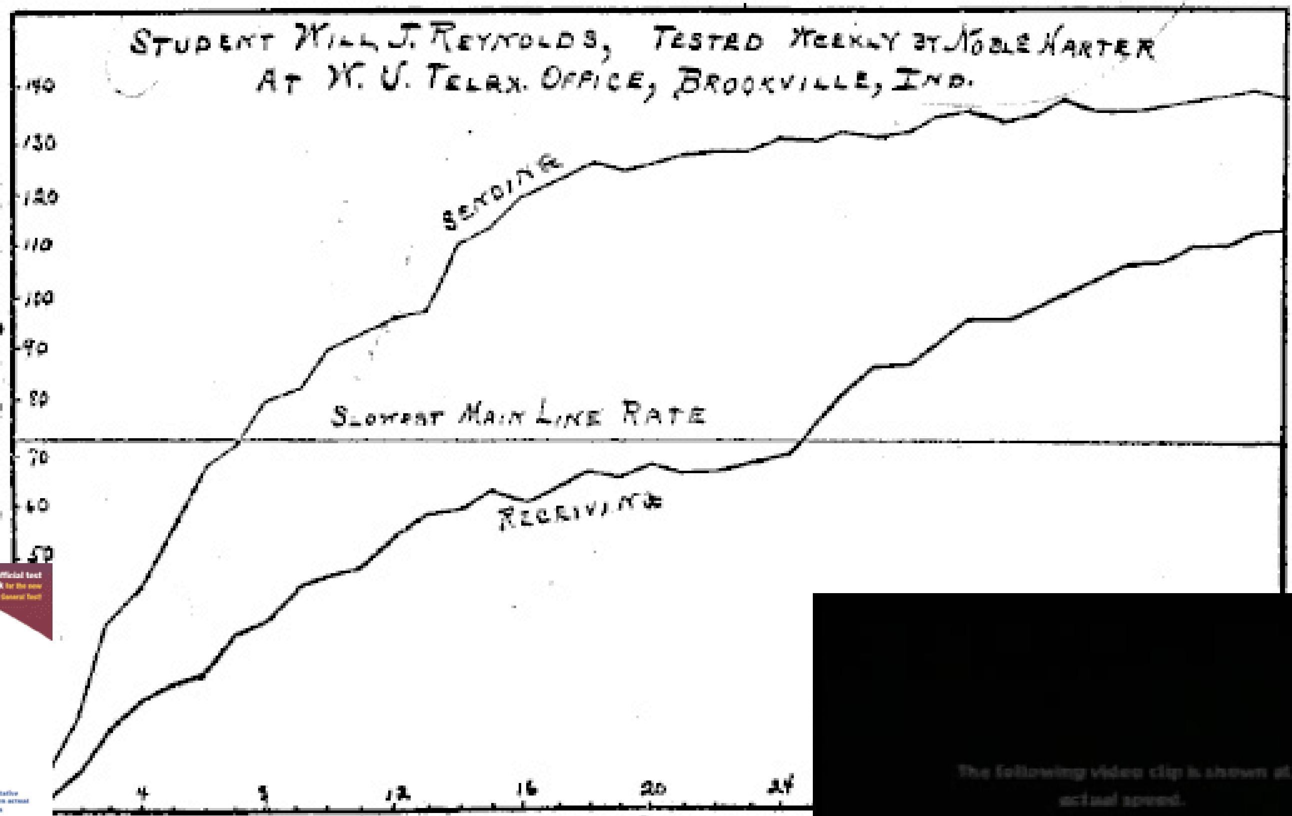
(w/ John Bransford)

- Detterman from Transfer on Trial.
  - "…most studies fail to find transfer …and those studies claiming transfer can only be said to have found transfer by the most generous of criteria and would not meet the classical definition of transfer."
- Classical definition: "stimulus generalization"
  - Replication of old behavior in a new situation.
- But, superintendents wanted to improve student abilities to adapt and change, not just repeat old behavior.
- A confusion between research on transfer and valued learning.
  - Try to clarify the source of this confusion.

“Classic generalization” view emphasizes efficiency of knowledge application.

- Much of the psychological literature on learning has emphasized efficiency
  - Faster and more accurate retrieval and application of previously learned behaviors.
- Efficiency emphasis has a long history…

Fig. X



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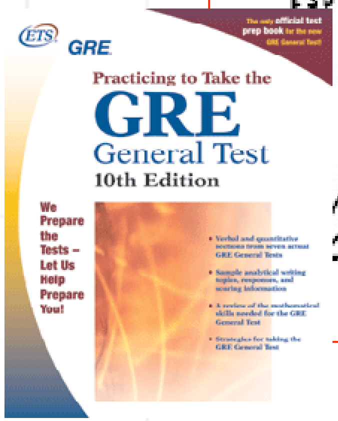
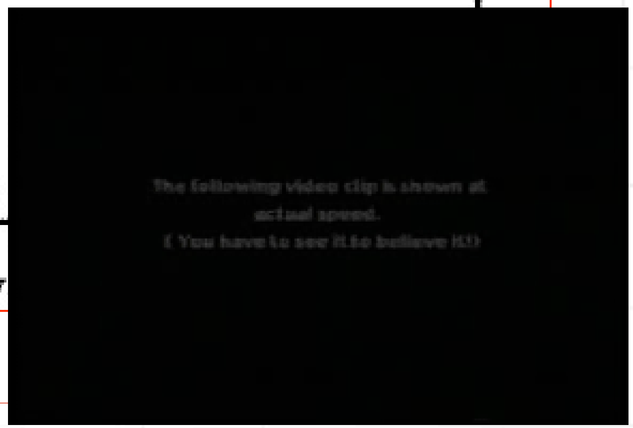


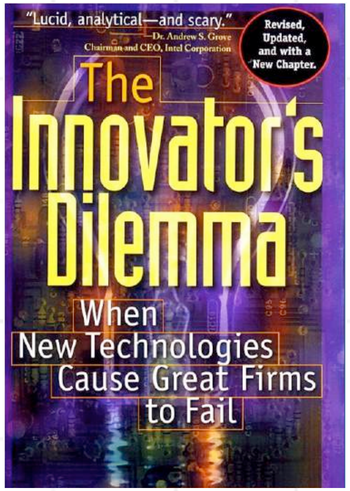


Efficiency should be emphasized.

- 99.9% = failure for orchestral musician.
- Improved efficiency frees up cognitive resources.
  - Efficient word decoding enables reading for understanding.
- Important for routine tasks.
- Most learning assessments are about efficiency
  - Speed, accuracy, consistency, 1st-try positive transfer

Issues with Efficiency

- Businesses worry that too much emphasis on efficiency reduces innovation.
- For novel learning, efficiency can interfere
  - Assimilate to efficient schemas and miss what is new.
    - Children interpret _ **of 8 pieces** as 1 and 4 pieces.
    - Use their efficient natural number schema.
  - Sometimes need to "let go" to see new possibilities.

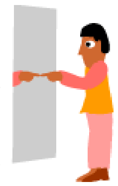


Innovation

- Innovation involves generation of new ideas
  - Rather than refinement of pre-existing ones.

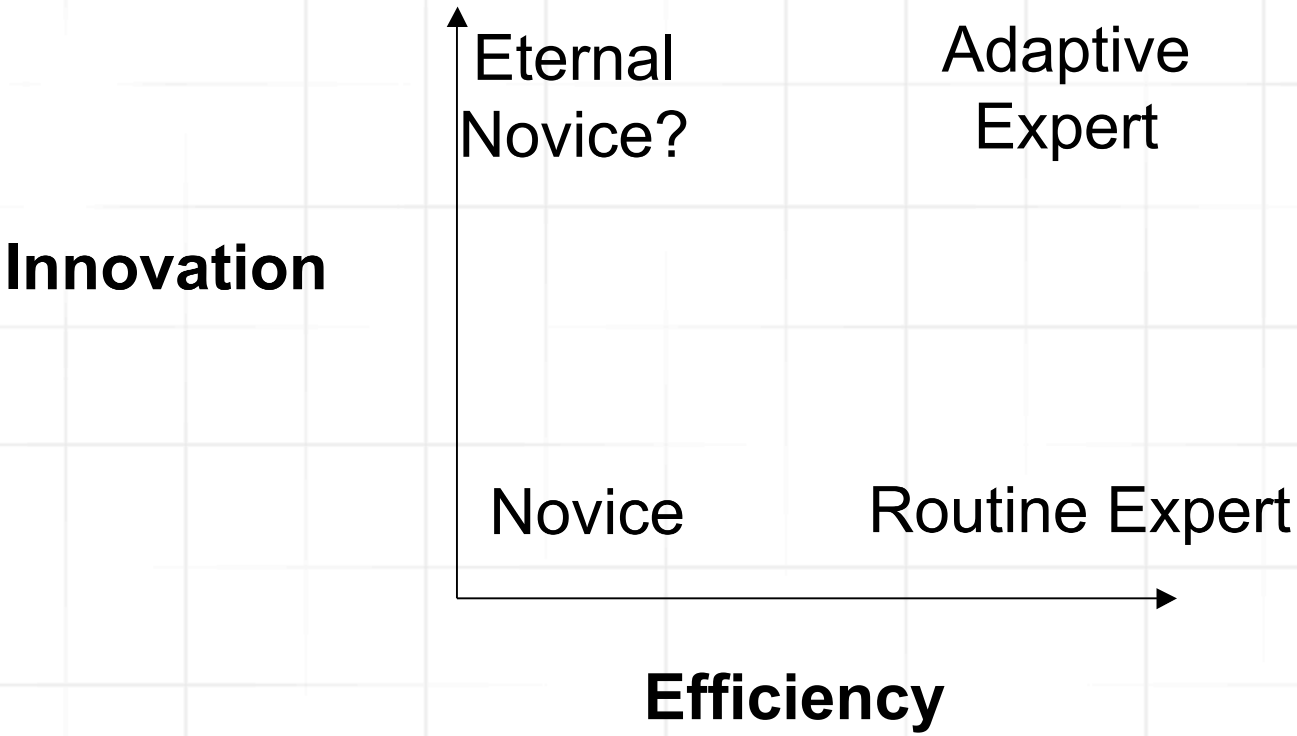
- Innovation and efficiency are not opposites.
  - Myth of creative person versus drone.
  - Myth of discovery versus direct instruction.
  - Different processes involved in the two, so they can co-exist.

Adaptive Experts

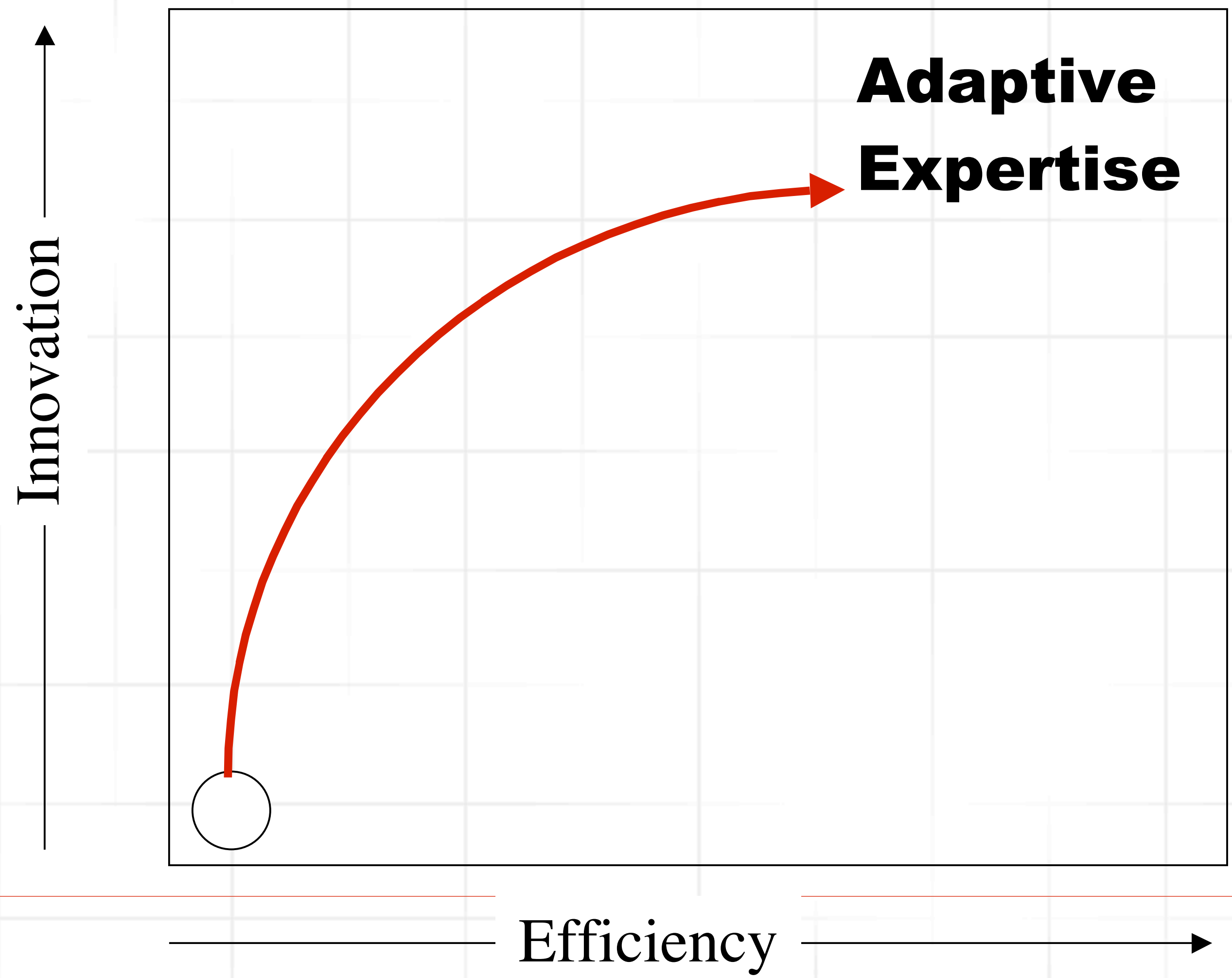


- Adaptive experts are presumably high on both (Hatano & Inagaki, 1996).
  - A strong set of efficient schemas to draw upon.
    - Ericsson's 10-year latency to innovation.
  - But, able to recognize when it is time to "let go," adapt, and learn new ideas.
  -
- Adaptive experts sound more like what superintendents were after than the ability to repeat the same behavior in a new context.

Efficiency & Innovation



Optimal Trajectory for Learning?

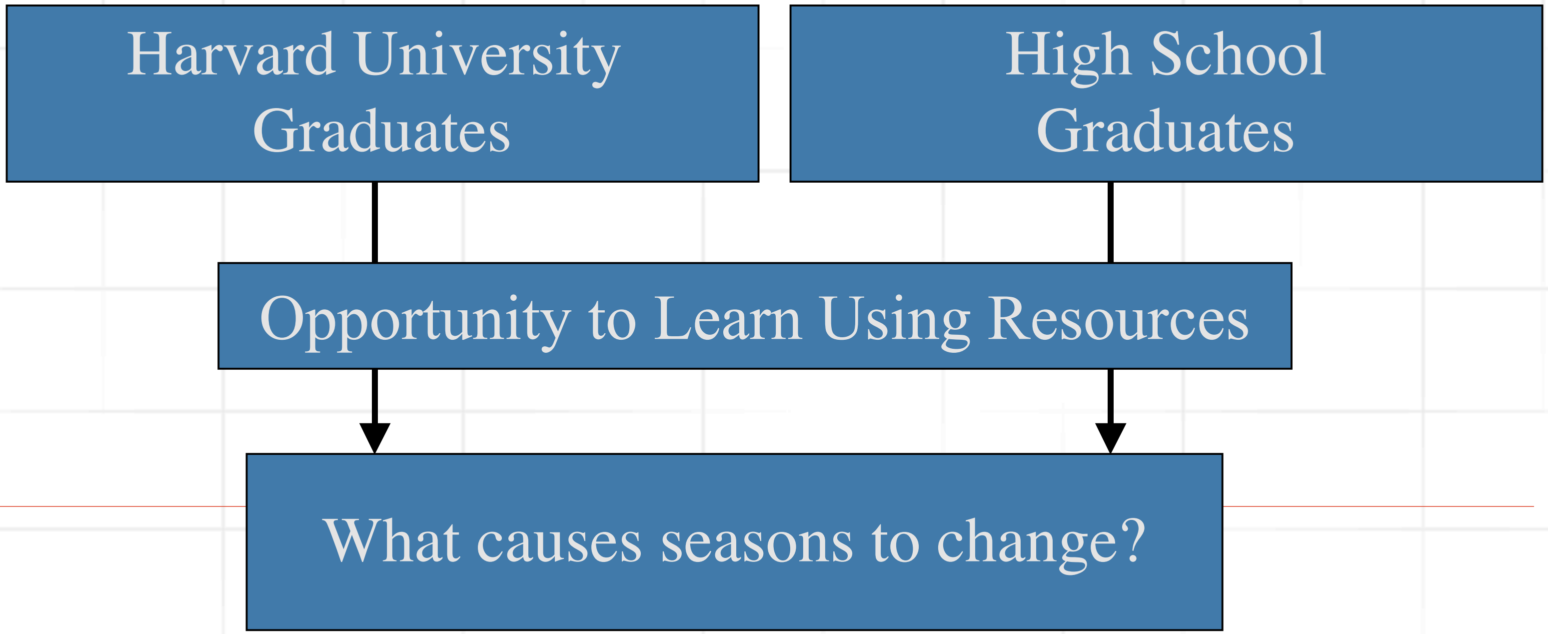


How do we assess whether students are learning?

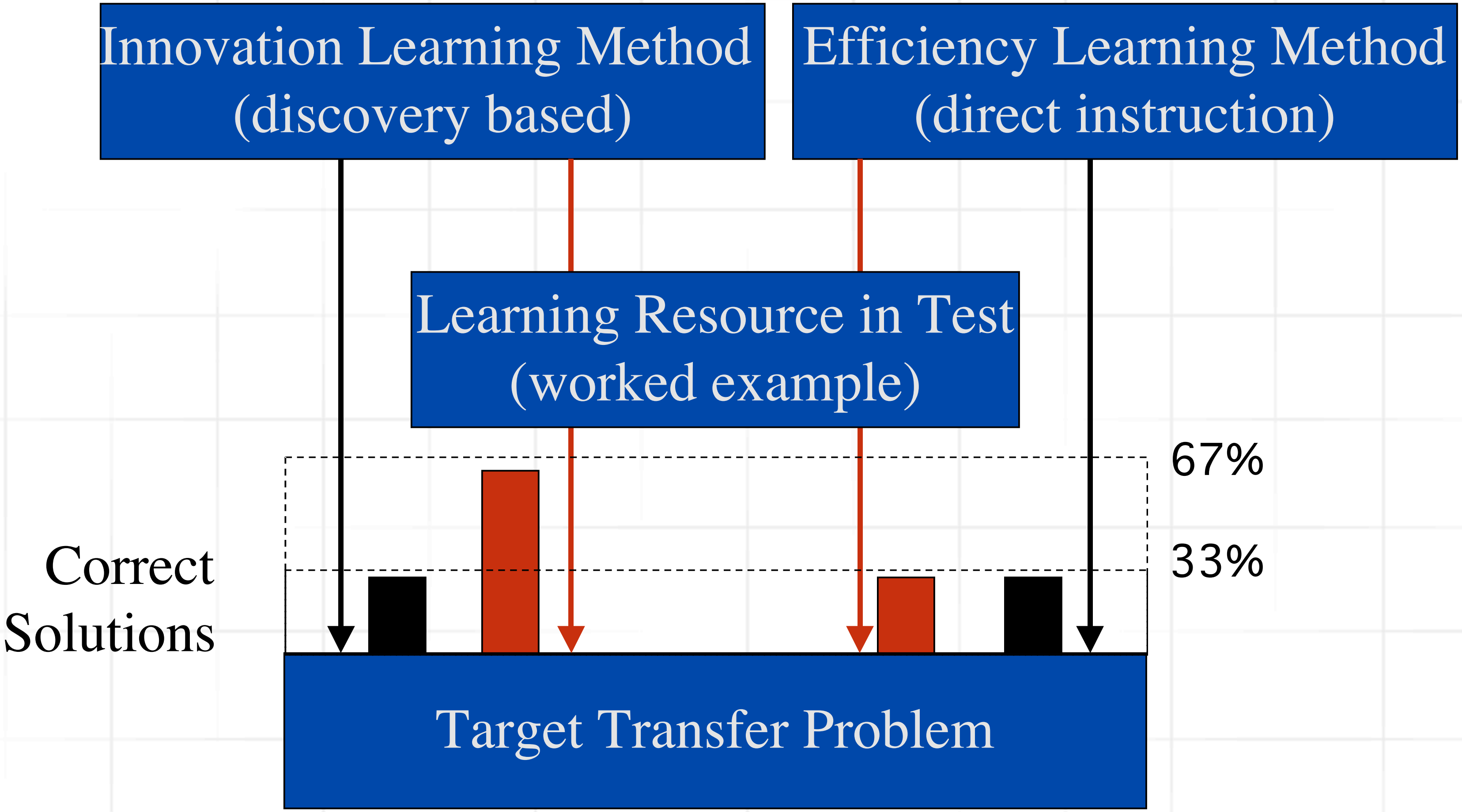
- Instructional approaches that include “innovation” often evaluate with efficiency assessments.
  - A measurement mismatch.
  - Often fails to find strong effects.
  - Leads to: “Why not just tell them the answer… wouldn’t that be more efficient?”

Need appropriate assessments

- Assessments of efficiency
  - Sequestered Problem Solving (SPS)
- Assessments of adaptiveness.
  - Preparation for Future Learning (PFL)



Study with 100's of high school students learning statistics



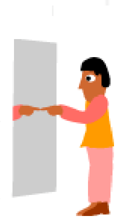
Summary on Learning

- Goal is not simply for student to “learn.”
  - Too undifferentiated for effective applications.

- Need to decide what is valuable to learn.
  - This is more than just deciding what content.
  - It includes deciding on form of desired behavior.

- One form of valued learning prepares students to transfer their knowledge to learn new ideas and adapt.
  - Trajectory towards adaptive expertise.
  - Not just repeat old behaviors in new settings.

Summary of Learning



- Requires efficiency and innovation experiences.
  - Efficiency-only and Innovation-only experiences did not greatly help students solve the transfer problem.
  - Students needed innovation experiences plus opportunities to learn efficient solution afterwards.
- Need the right learning assessments.
  - Had we not measured students preparation for future learning (by including the worked example) the two instructional approaches would have looked the same.
  - We would have missed the “hidden value” of innovation experiences.

Interactivity and Learning

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- → What is valued social interaction?
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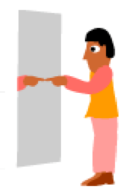
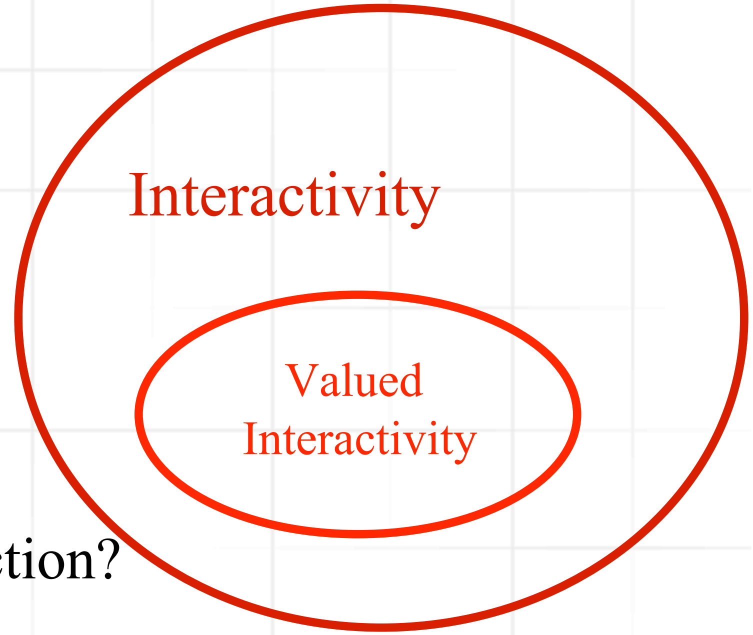


Social Interaction

- Often, beliefs about what counts as a valued social interaction. Researchers choose their favorite and build designs to promote it.

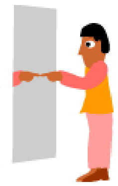
- The proximal goal is to promote that type of interaction.



- Two issues:
  - Does design promote valued interaction?
  - Does design also lead to learning?

Cooperation Research

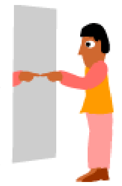
Early example of designing valued social interaction.



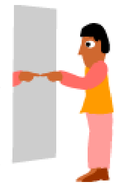
- Research in response to WWII
  - The goal was conflict resolution and cooperation
  - Morton Deutsch, 1973

    "I started my graduate career not long after Hiroshima and Nagasaki, and my work in social psychology has been shadowed by the atomic cloud ever since. The efforts reported in this book reflect my continuing interest in contributing to the understanding of how to prevent destructive conflict and initiate cooperation."

Successful for Promoting Valued Interactions.



- Two key variables have been highly effective in promoting valued social interactions:
  - **Mutual Interdependence**
  - **Individual Accountability**
- Do these variables also support learning of math, reading, etc.?
- Variables derived from assumption of potential conflict or withdrawal.
  - Not such a bad assumption for many school settings (in U.S.).
  - If students work cooperatively, they might improve their learning.



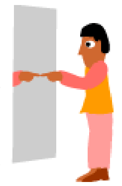
Applications to learning.

- Slavin's (1996) meta-analysis on cooperative learning:
  - MI or IA = +.07 effect size
  - MI & IA = +.32 effect size

- Unfortunately, only 25% of teachers who are trained implement both conditions (Antil et al., 1998)

- Students evidently are not inclined to do it either for the school activities (otherwise Slavin would not have found any effects).

- It would be nice to find a type of interaction that students (and we) spontaneously value <u>and</u> that leads to learning.



In summary

- Valued Interactions and Learning
  - Developing valued social interactions is a very important goal.
  - Using them to squeeze out content learning is another matter.
- When techniques for creating valued interactions borrowed by education, leads to a model:
  - Motivation → Valued Interactions (→ Hopefully Learning)
  - The conditions are for interactions, and not learning
- Prefer a situation where valued interactions have a more direct relation with learning.

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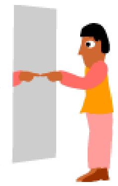
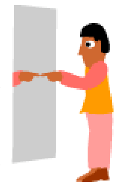
Valued Interactions for Learning



- The umbrella of valued interactions (Deutsch)
  - "A cooperative process is characterized by open and honest communication of relevant information among participants. <u>Each is interested in informing, and being informed by, the other</u>."
- What creates these conditions for learning?

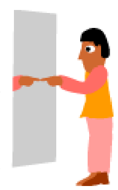
Two dimensions

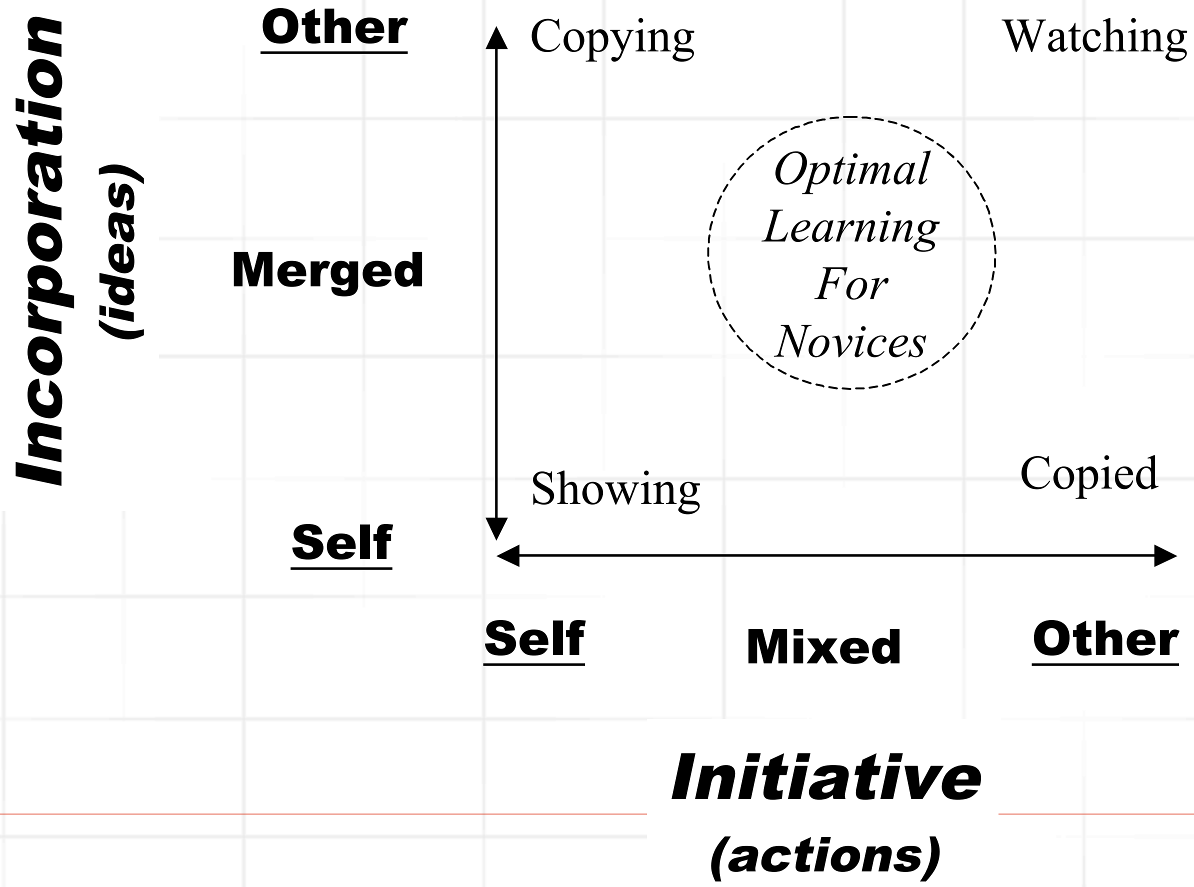


- Many conditions important for creating effective social computer interactions:
  - Timing, familiarity of input/output, visual appearance…
  - These often depend on the specific application.

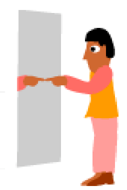
- Identified two general conditions.
  - **Incorporation of Ideas**
    - The degree to which participants' ideas are taken up.
  - **Initiative in Action**
    - The degree to which all participants' can initiate actions.

Interactivity Space for Novice Learning in Motivating Collaborations





A classic positive example



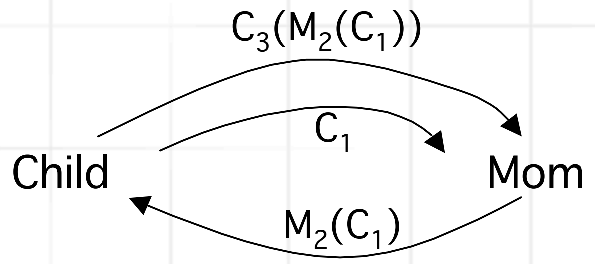
- Mother-child speech.

  Child: *Ball*

  Mother: *Ball, you want me to get the ball?*

  Mother: *That is the doll.*

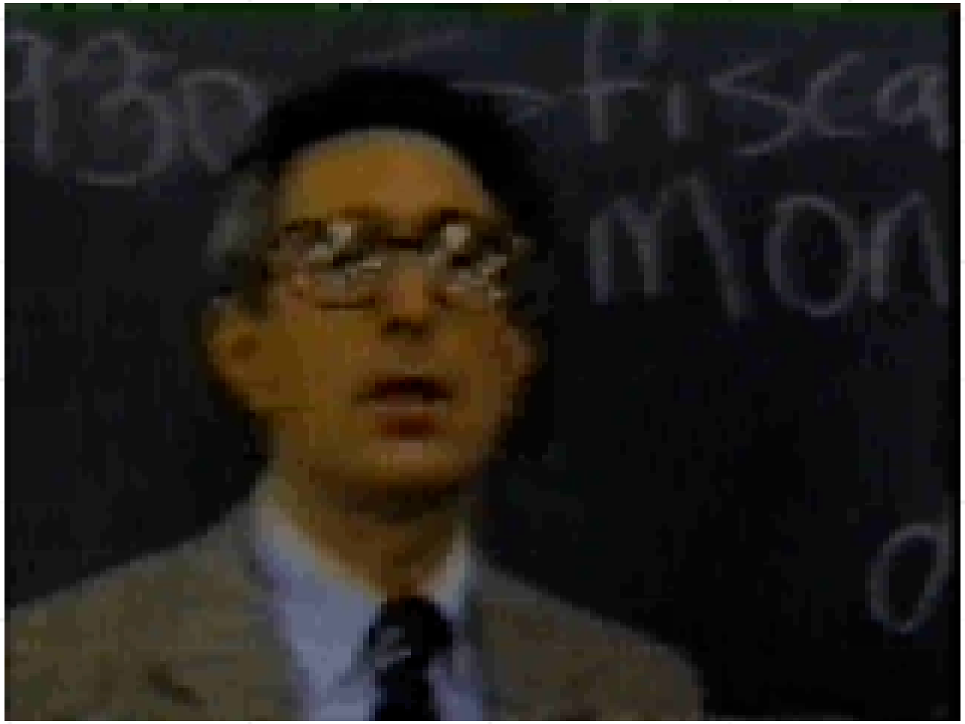
  Child: *Doll?*



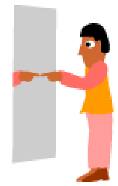
- New information is more comprehensible to child:
  - **Merged** (Incorporation):
    - Mother incorporates and builds on child's ideas.
  - **Mixed** (Initiative):
    - Mother's action relevant to child's own; shows implications of child's initiative.

- Learning object names is better when mother moves into child's space compared to dragging child into hers (Tomasello & Farrar, 1986).

A classic negative example



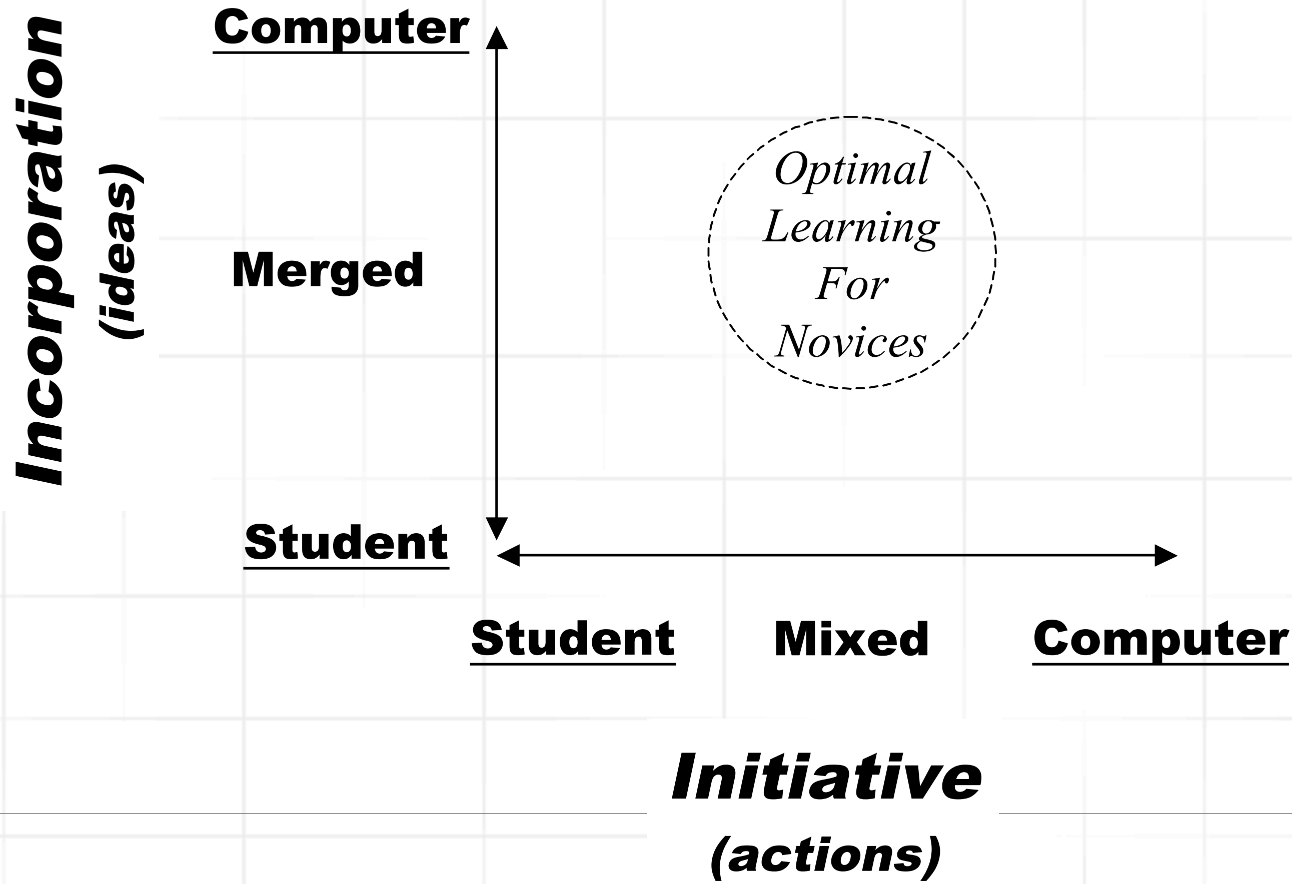
More subtle cases:



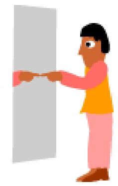
- Chess programs?
  - Good on mixed initiative
  - Low on balanced incorporation.
    - Program is responsive to your moves.
    - But, it explicitly hides ideas.
    - Difficult for novices to learn.
      - Ideas not in the “joint space” and students cannot incorporate.

- Cognitive Tutors?
    - Responsive to student moves.
    - But does not “take them up” – it looks for deviations from its own.
    - Interesting story of Graesser’s AutoTutor

Explore space in context of computer applications



Interactivity and Learning



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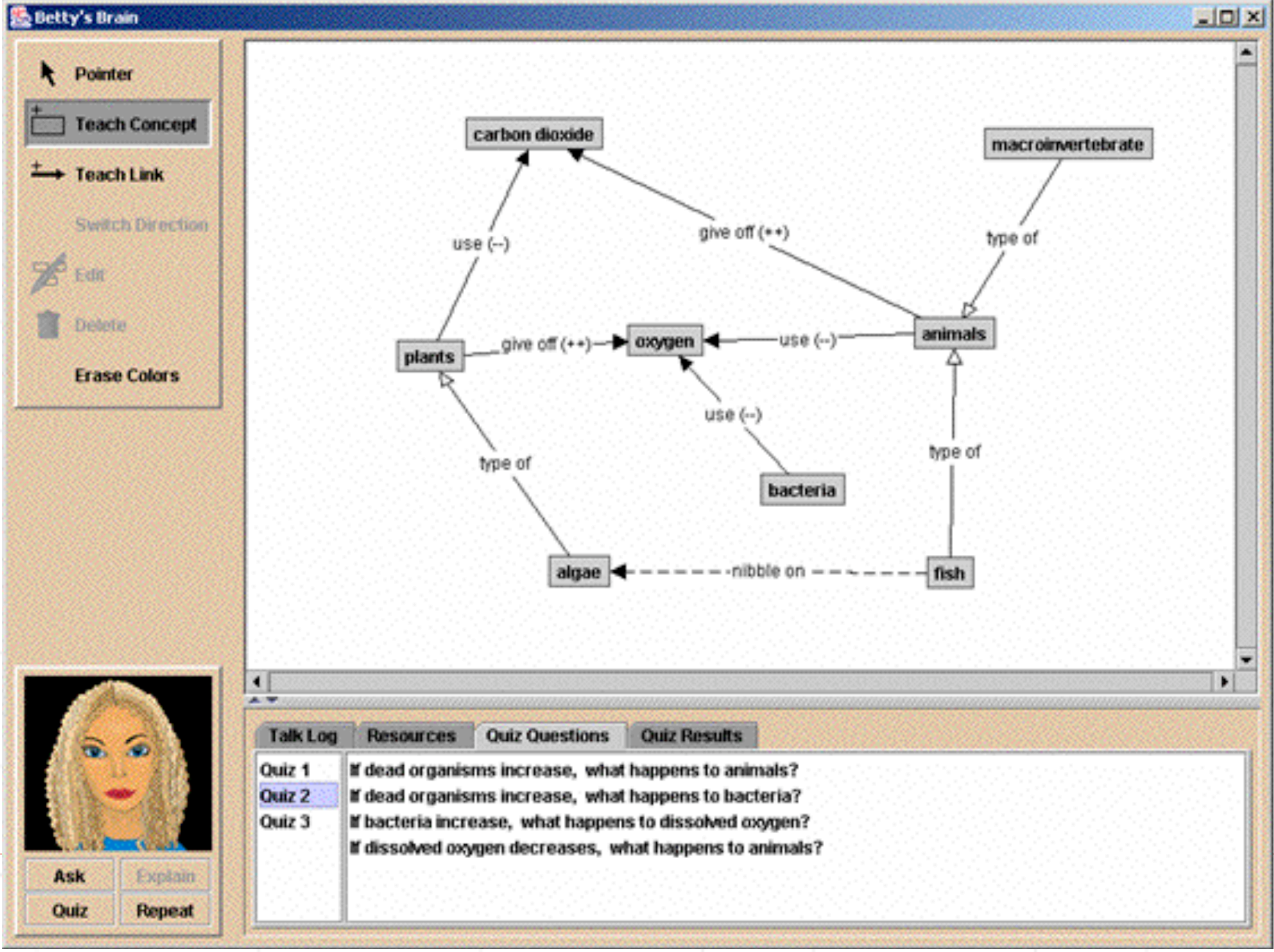
Teachable Agents

- Learning By Teaching
  - Common wisdom
    - people “really” learn when they teach.
  - Empirical findings
    - Students who prepare to teach learn more than students who prepare to take a test. (Bargh & Schul,1980; Biswas, et al., 2001)
- Built computer agents that students teach
  - A natural social interaction students know well
    - Teach – Test – Remediate

Betty: A Teachable Agent



Basic Teaching Interaction

- Not machine induction; students must explicitly teach.

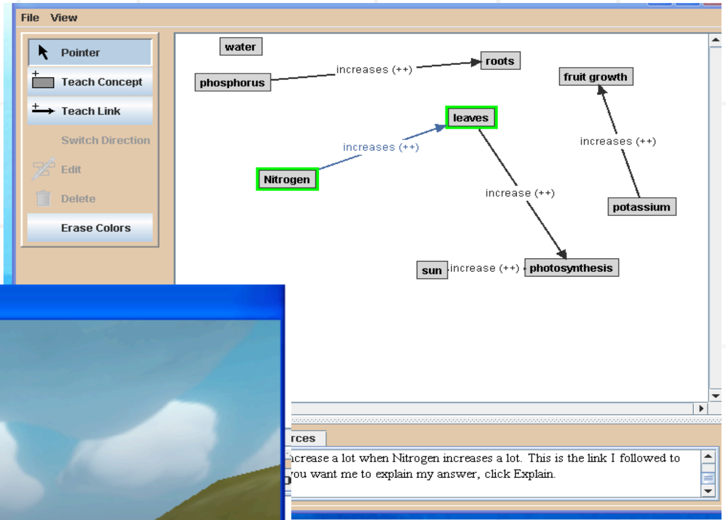
- Student teaches agent.
  - Student uses agent's visual representations to teach.
- Agent performs based on teaching.
  - Generic AI algorithms draw inferences based on student teaching.
- Student revises agent to do better.
  - Based on agent performance student updates knowledge.

Extensions to TA paradigm

- Students know they are not real people.
  - We are more interested in enabling social learning interactions than simulating “reality.”
  - The well-known teaching schema works well.
- Plus, once the basic engine is developed, it can be extended in numerous ways.

Videogames
(Kristen Blair)

- Students teach agent to perform in game.
- Besides motivation, it permits harnessing a range of learning mechanisms.

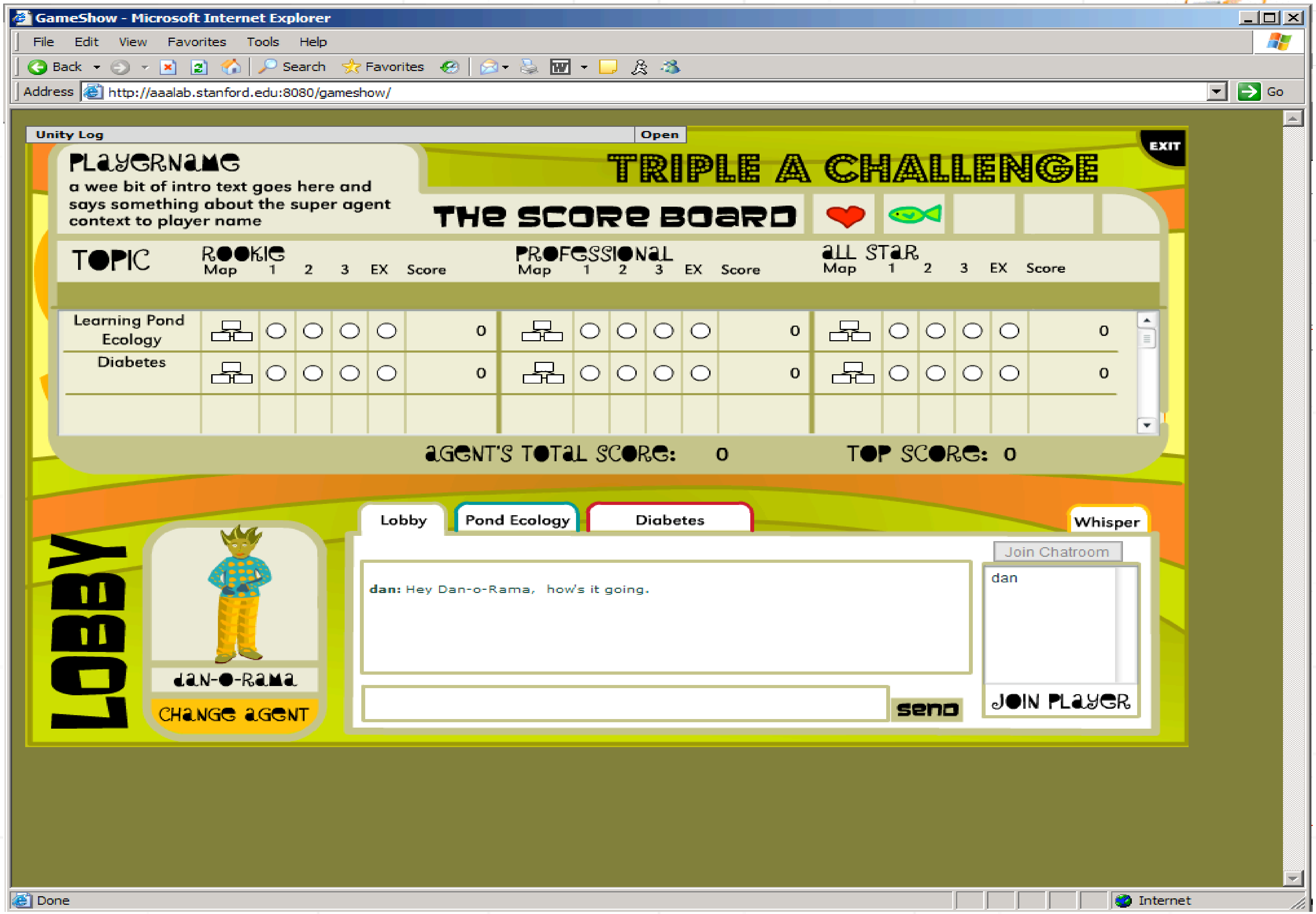


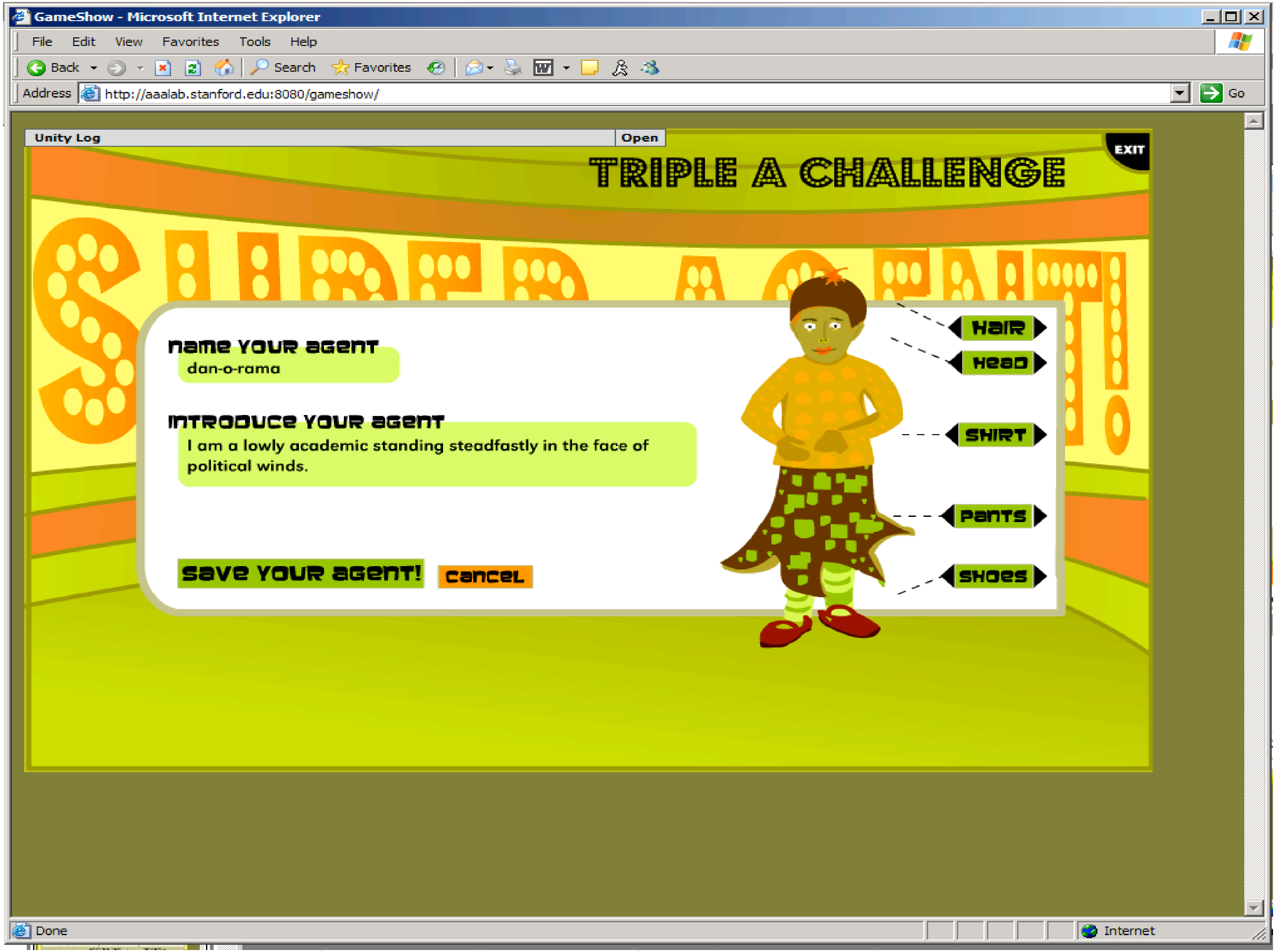
On-Line Homework Game Show

(Paula Wellings)

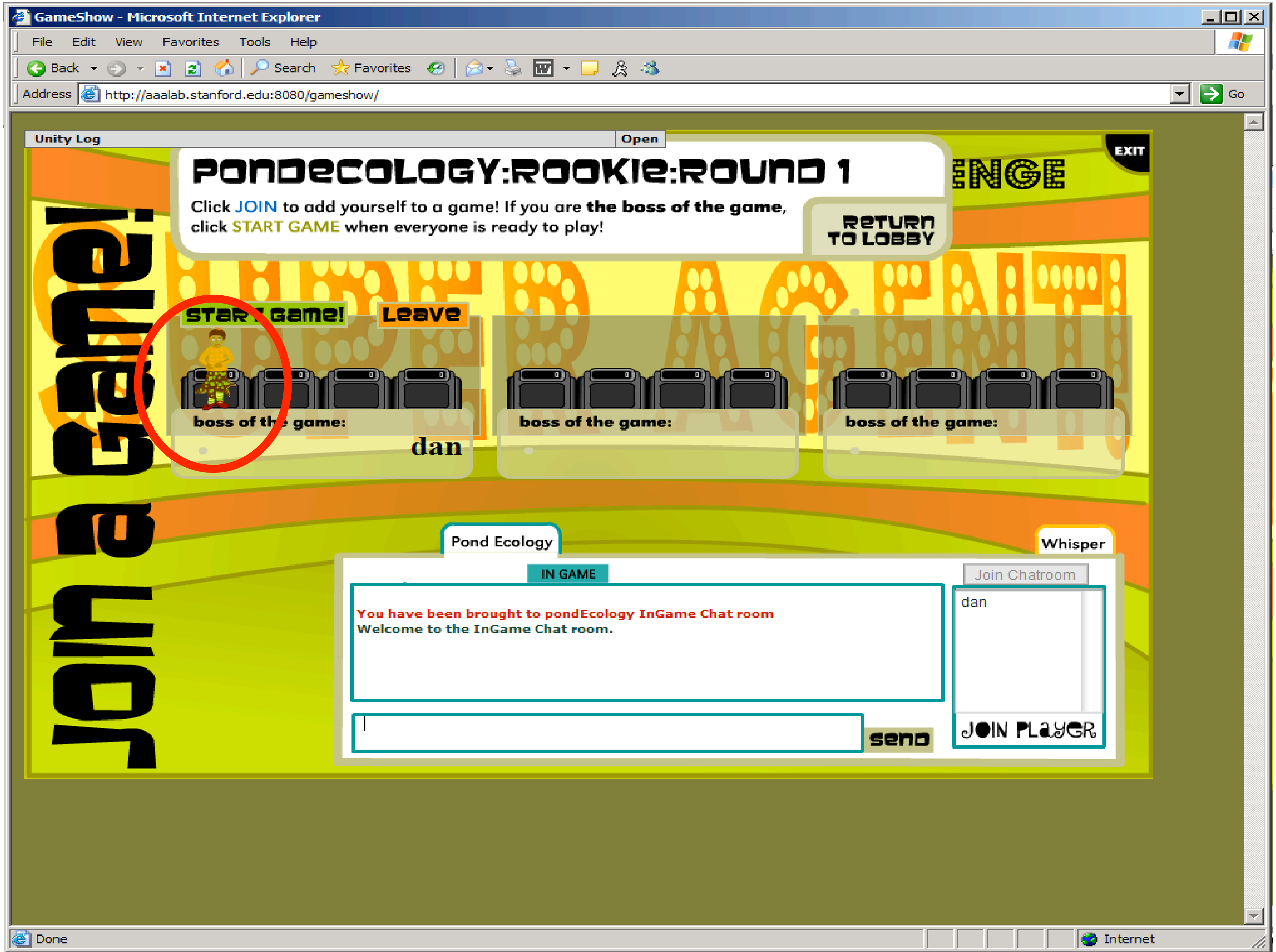
- Students can log on, chat, and do homework with whomever is on-line.
- Teach agent, who performs in a gameshow.

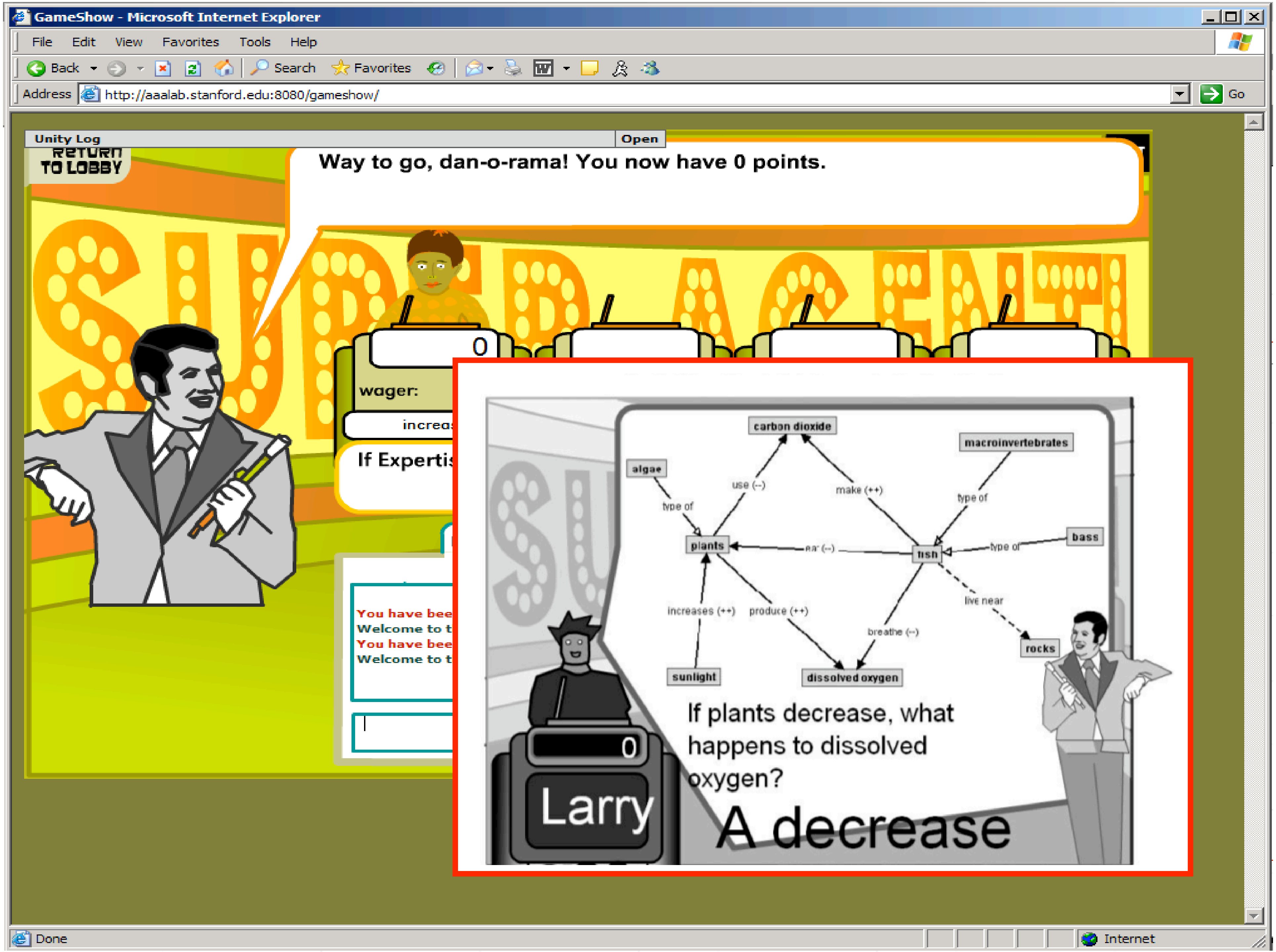
On-Line Homework Game Show





GameShow - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites
Address http://aaalab.stanford.edu:8080/gameshow/
Go
Unity Log
Open
EXIT
TRIPLE A CHALLENGE
name your agent
dan-o-rama
introduce your agent
I am a lowly academic standing steadfastly in the face of political winds.
save your agent!
cancel
Hair
Head
Shirt
Pants
Shoes
Done
Internet


GameShow - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites
Address http://aaalab.stanford.edu:8080/gameshow/
Go
Unity Log
Open
EXIT
PONDECOLOGY:ROOKIE:ROUND 1
Click JOIN to add yourself to a game! If you are the boss of the game, click START GAME when everyone is ready to play!
RETURN TO LOBBY
Join a Game!
START GAME!
Leave
boss of the game:
dan
boss of the game:
boss of the game:
Pond Ecology
Whisper
IN GAME
Join Chatroom
You have been brought to pondEcology InGame Chat room
Welcome to the InGame Chat room.
dan
send
JOIN PLAYER
Done
Internet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Address http://aaalab.stanford.edu:8080/gameshow/
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RETURN TO LOBBY
Way to go, dan-o-rama! You now have 0 points.
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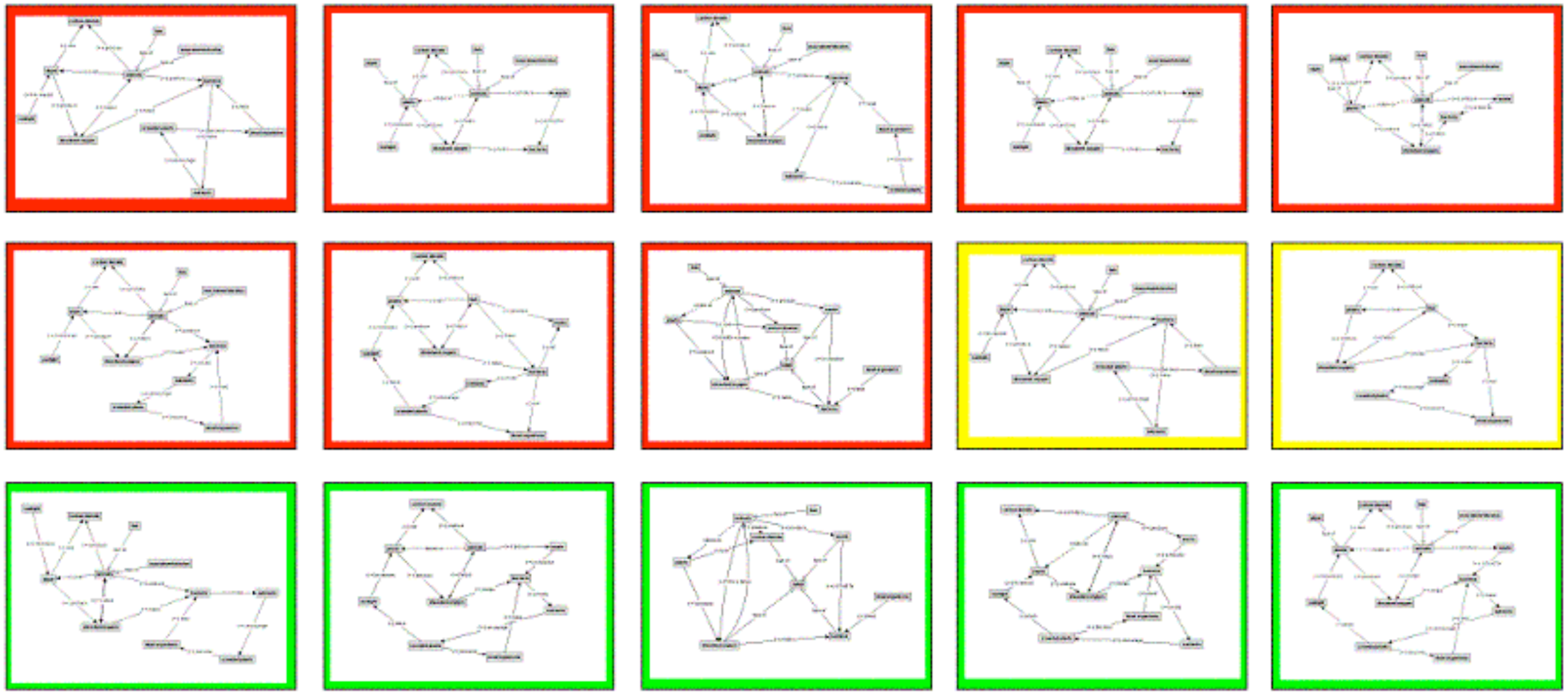
Welcome to t
You have bee
Welcome to t
carbon dioxide
algae
macroinvertebrates
use (--)
make (++)
type of
type of
plants
fish
bass
type of
live near
increases (++)
produce (++)
breathe (--)
rocks
sunlight
dissolved oxygen
If plants decrease, what happens to dissolved oxygen?
0
Larry
A decrease
Done
Internet

Front of the Class System

(Joan Davis)

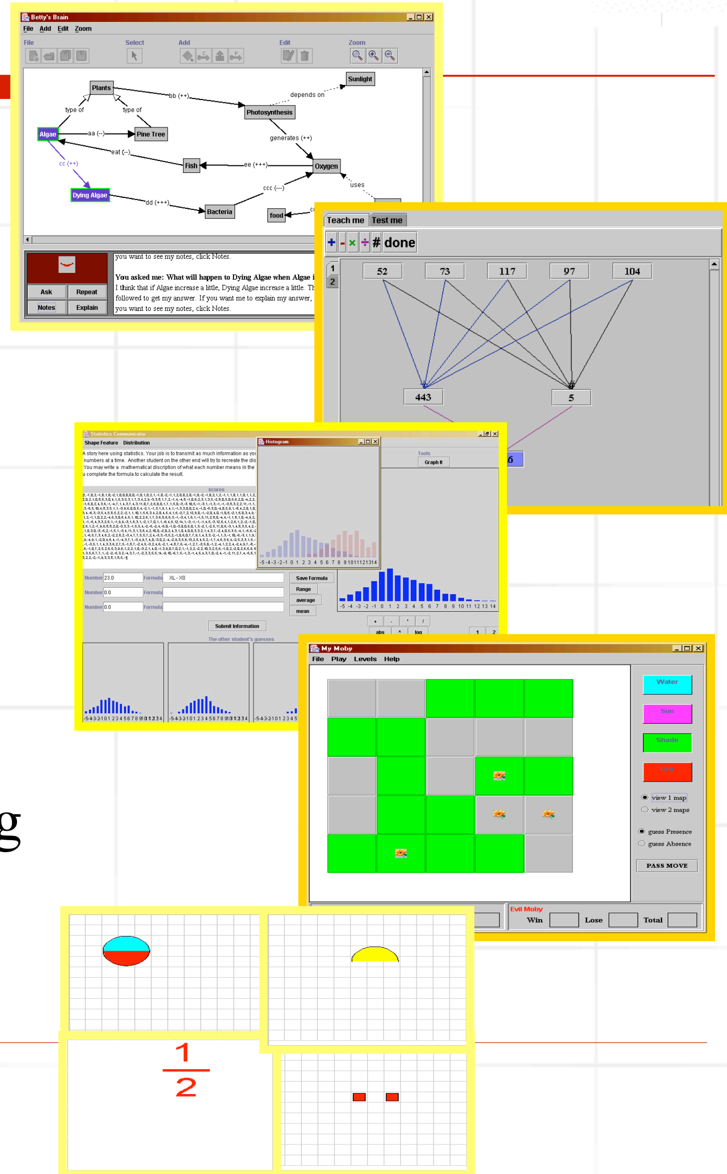
Test Results



1. If waste increases, what happens to plants?	17%
2. If waste increases, what happens to bacteria?	50%
3. If sunlight increases, what happens to bacteria?	33%
4. If nutrients increase, what happens to crowded plants?	67%
5. If crowded plants increase, what happens to sunlight?	33%
6. If sunlight decreases, what happens to plants?	83%

A Suite of Homely TA "Engines"

- **Betty**
  - Qualitative Reasoning
- **Orbo**
  - Reasoning by Assumption
- **Milo**
  - Reasoning by Model
- **Moby**
  - Hypothetico-Deductive Reasoning
- **J-Mole**
  - Reasoning by Discrepancy



Also, a suite of homely collaborators

- In order of homeliness:
  - Gautam Biswas
  - Jason Tan
  - John Bransford, Krittaya Leelawong, Joan Davis
  - Kristin Blair, Thomas Katzlberger, George Chang
  - Bilikiss Adebiyi, Yanna Wu, and Kadira Belynne
  - Paula Wellings, Girija Mittagunta, Anh Huynh, Nancy Vye

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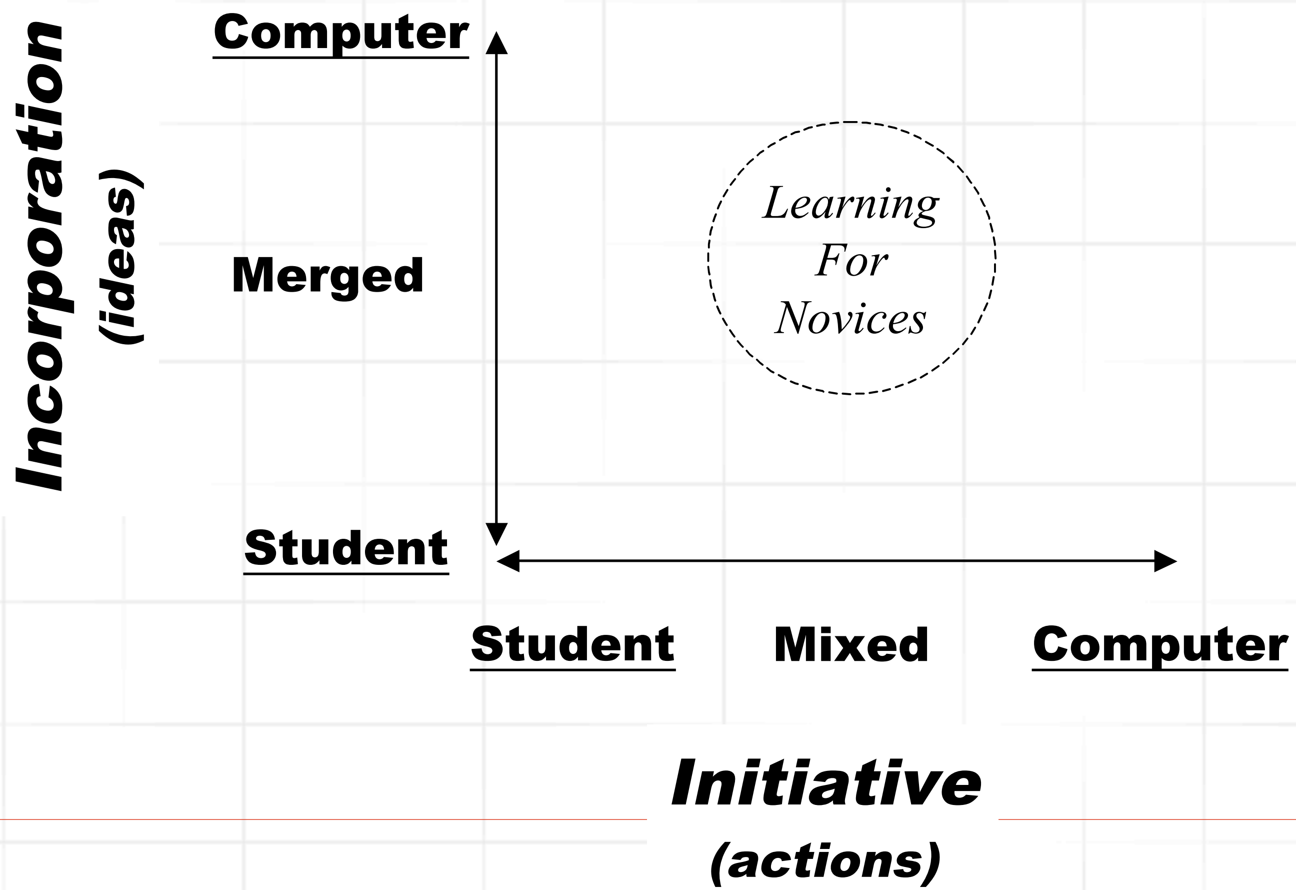
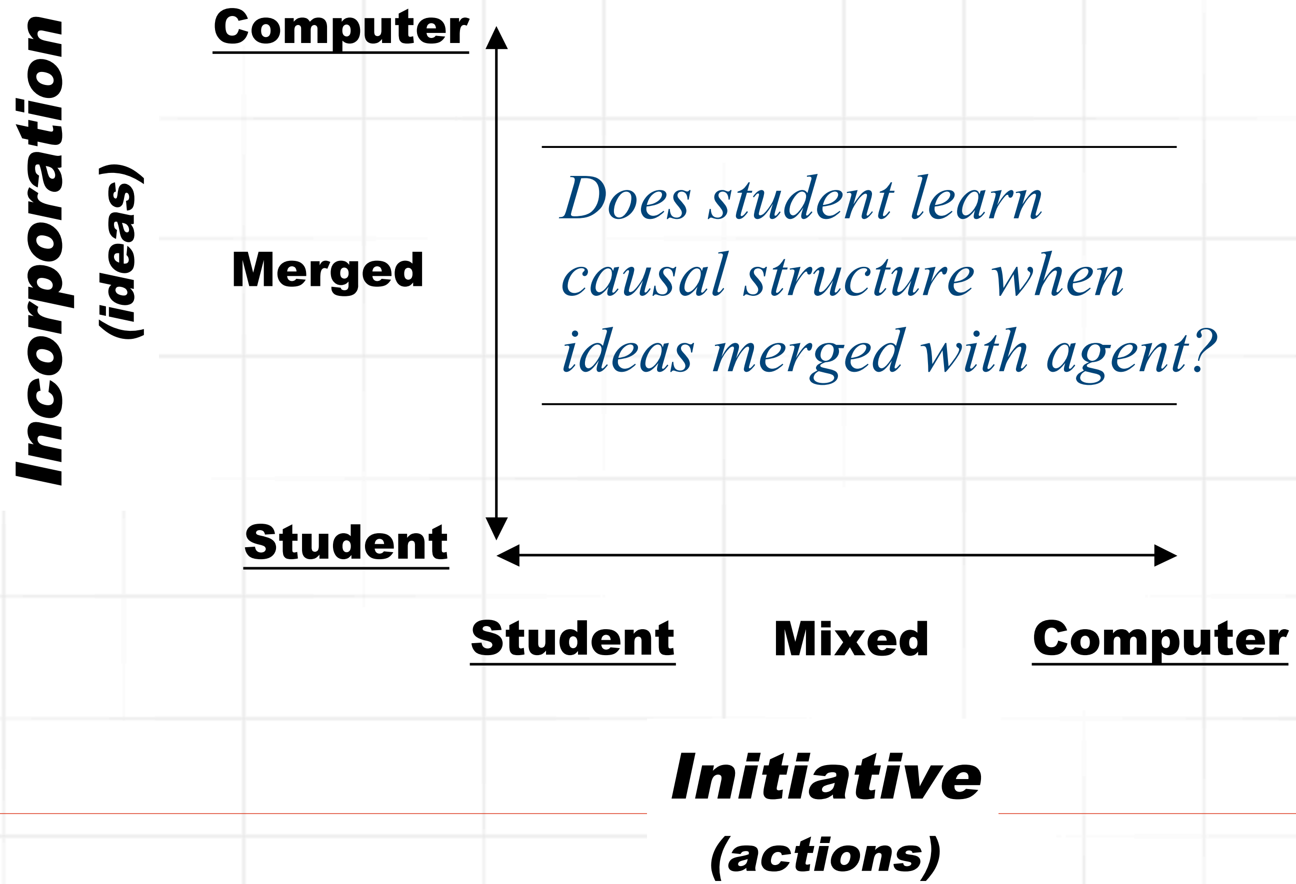
Look for relevant evidence using Teachable Agents



Incorporation (merging ideas)

- Agents, by design, merge ideas with students.
  - Students provide facts of the matter.
  - Agent provides representations and reasoning.
- Not a simulation of the domain, but rather a simulation of thoughts about a domain.
  - Make thinking visible so students can learn how to reason about the domain.

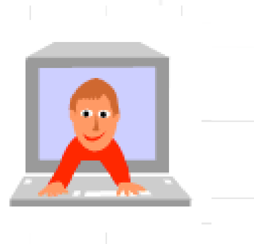
Testing incorporation dimension



Merging Ideas

- Undergraduates read exercise physiology text.
- 1/2 Taught Betty on cell metabolism.
- 1/2 Wrote Summary on cell metabolism.
- Would students adopt Betty's knowledge structure?

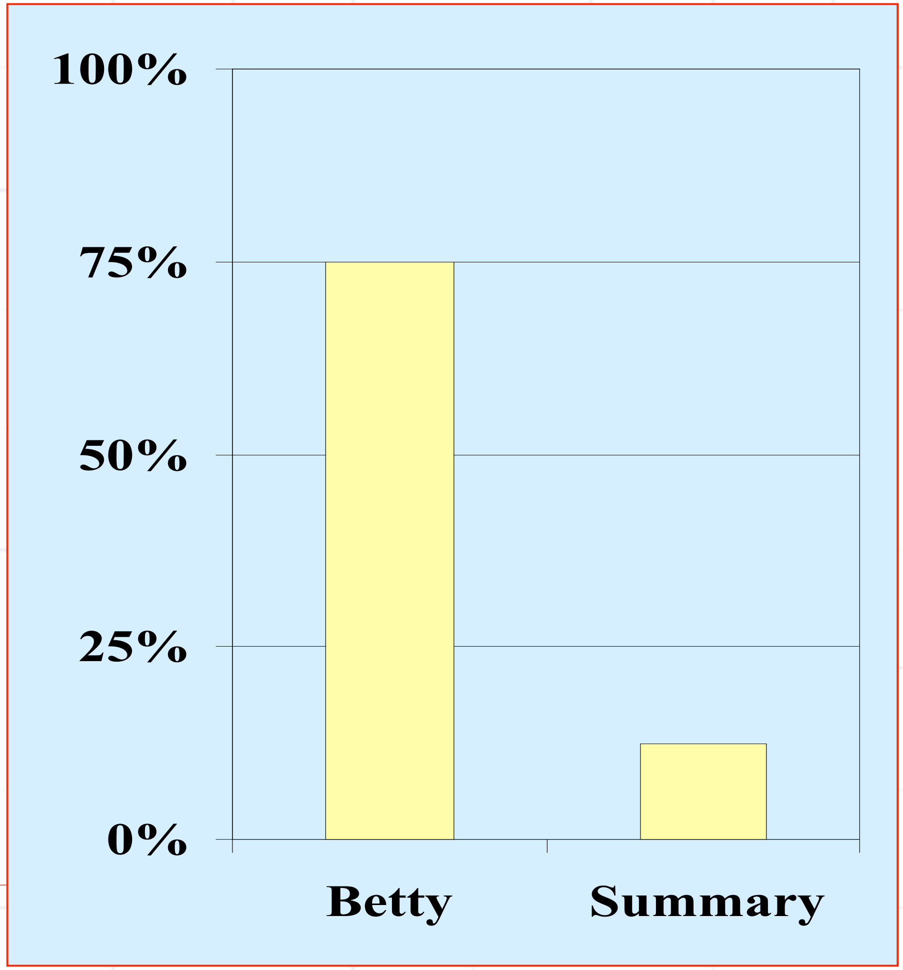
Direction of Causality



<u>During activity:</u>

Betty students discovered they had confused causation and correlation.

Mitochondria <-> ATP synthesis

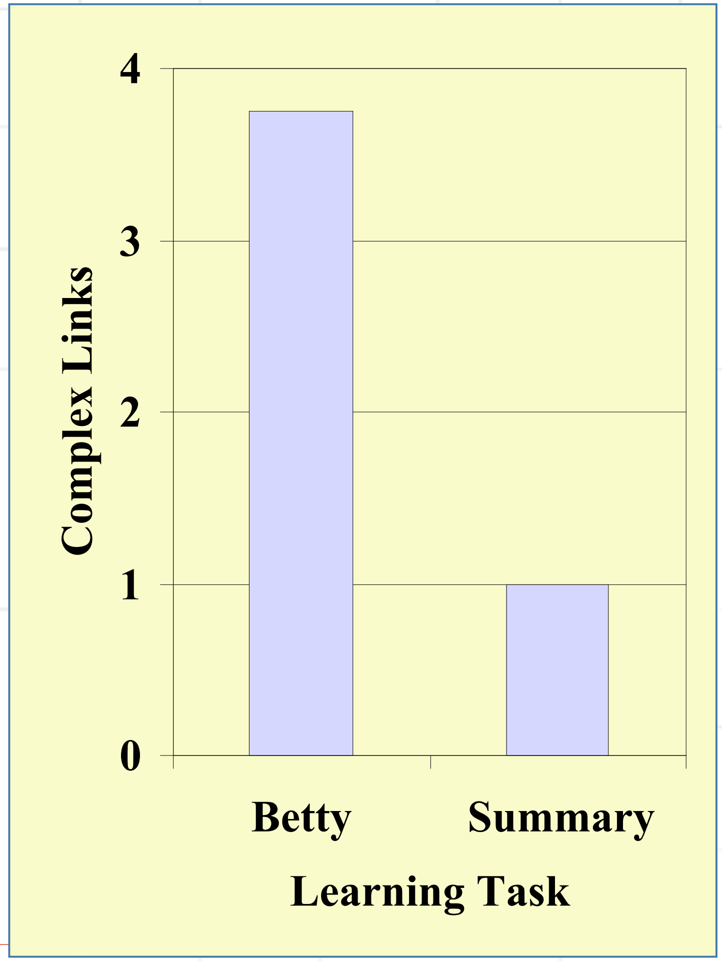


Multiple Causality

Given a metabolism word, list entities related to it.

Simple Link: **Mitochondria** increase ATP synthesis.

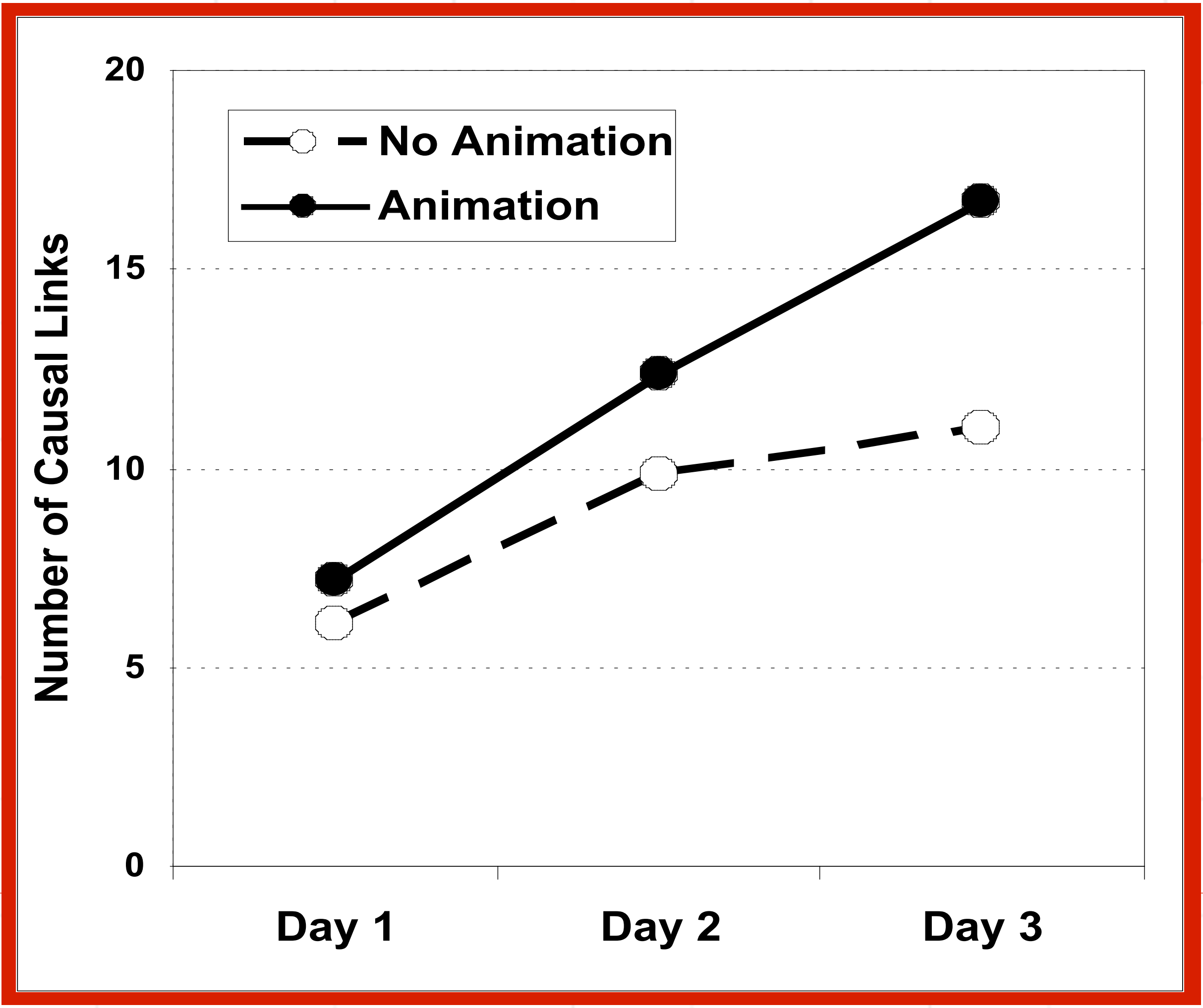
Complex Link: **Mitochondria** with glycogen or free fatty acids increase ATP synthesis.



Is there value in AI component?

- Merging includes representations and reasoning.
- Examined if AI reasoning is important for merging?
- 4th-grade students learned about pond ecology over three days. Had resources for learning (e.g., texts).
  - **Animation** condition:
    - Taught Betty and she could answer their questions.
  - **No Animation** condition:
    - Created concept map using Betty (reasoning turned off)

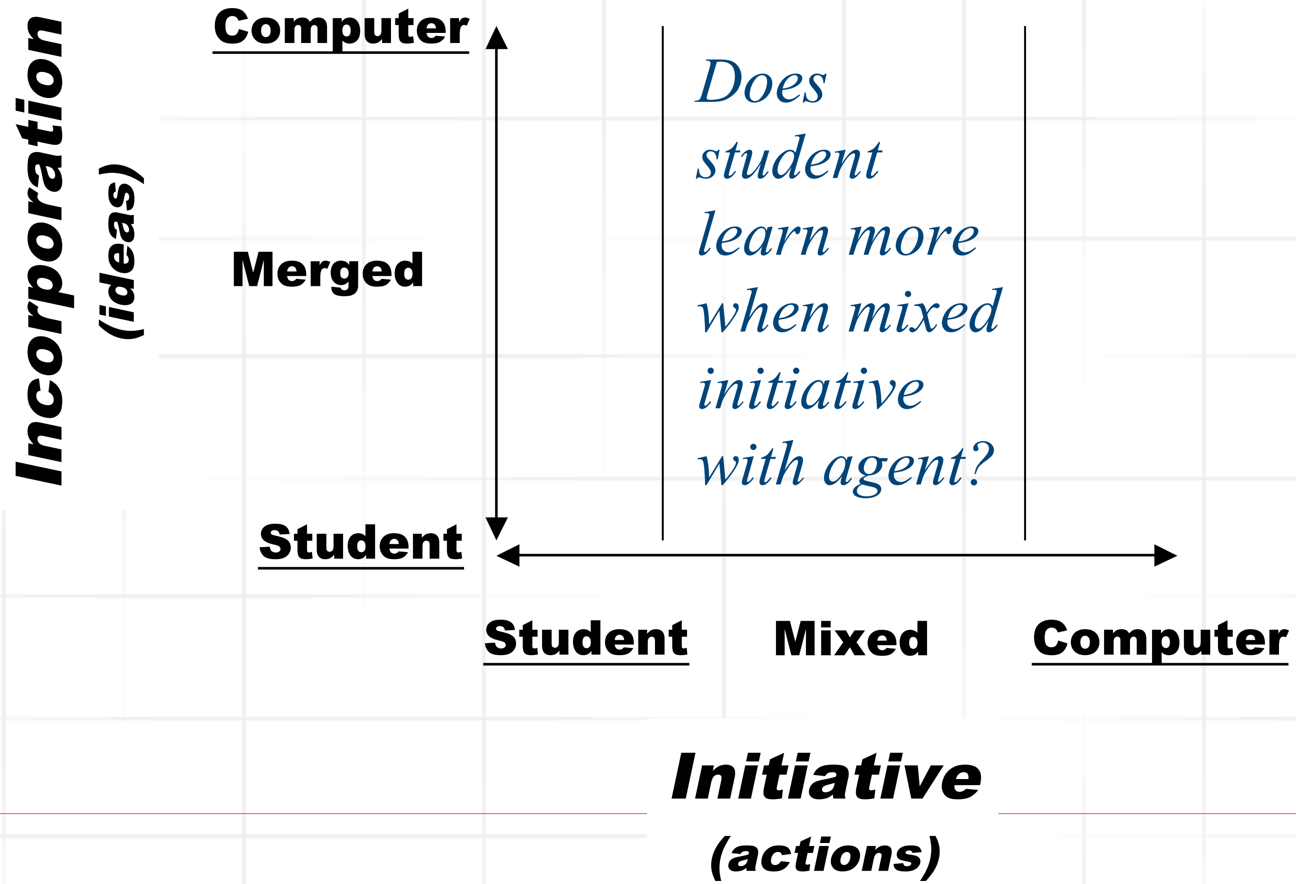
Adoption of Causal Structure



Incorporation

- Opportunities to commingle thoughts with agent helped students learn/adopt causal structure.

Testing Initiative Dimension



Expanding the notion of mixed-initiative

- Conversation is often taken as THE model of social interaction
  - Mixed-initiative involves taking turns.

- A broader view extends interaction over time.
  - Performance in a secondary context.
  - Teaching and then watching one's student perform.

- Examine value of mixed-initiative when agent initiative occurs in a secondary context.

Moby
(Anh Huynh)

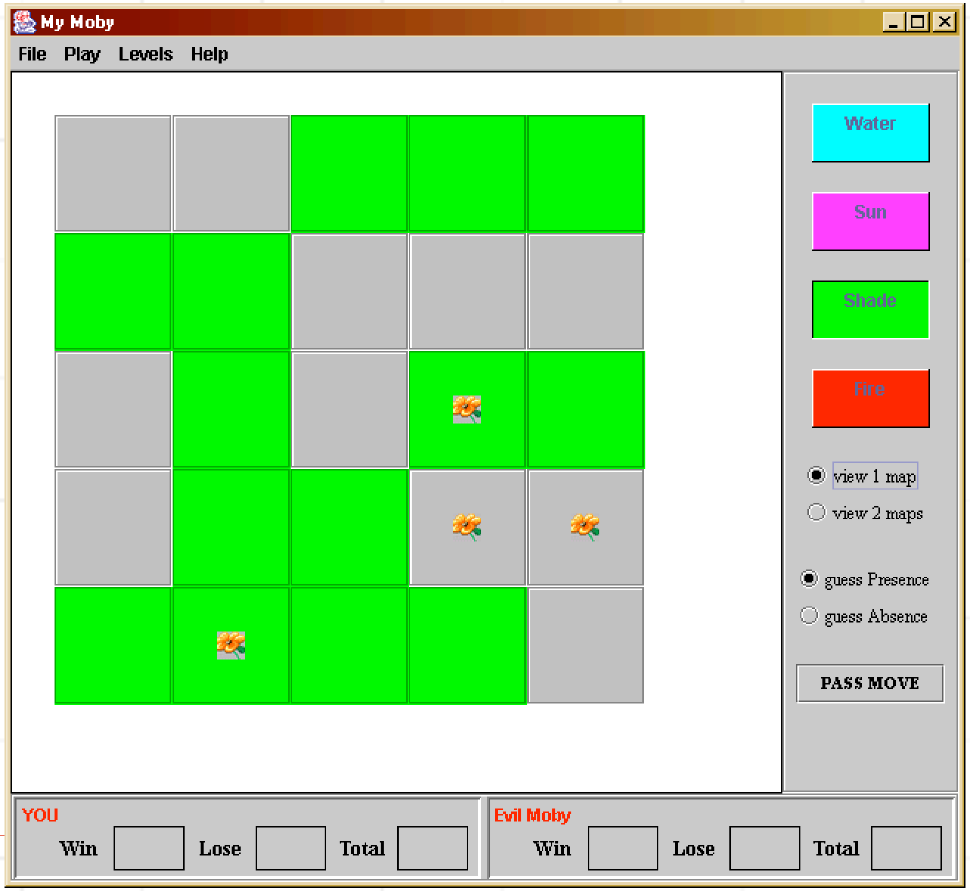
Teach science content using hypothetico-deductive reasoning.

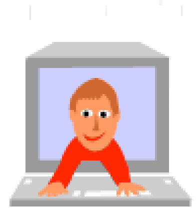
Three phases:

–Induction of Hypothesis

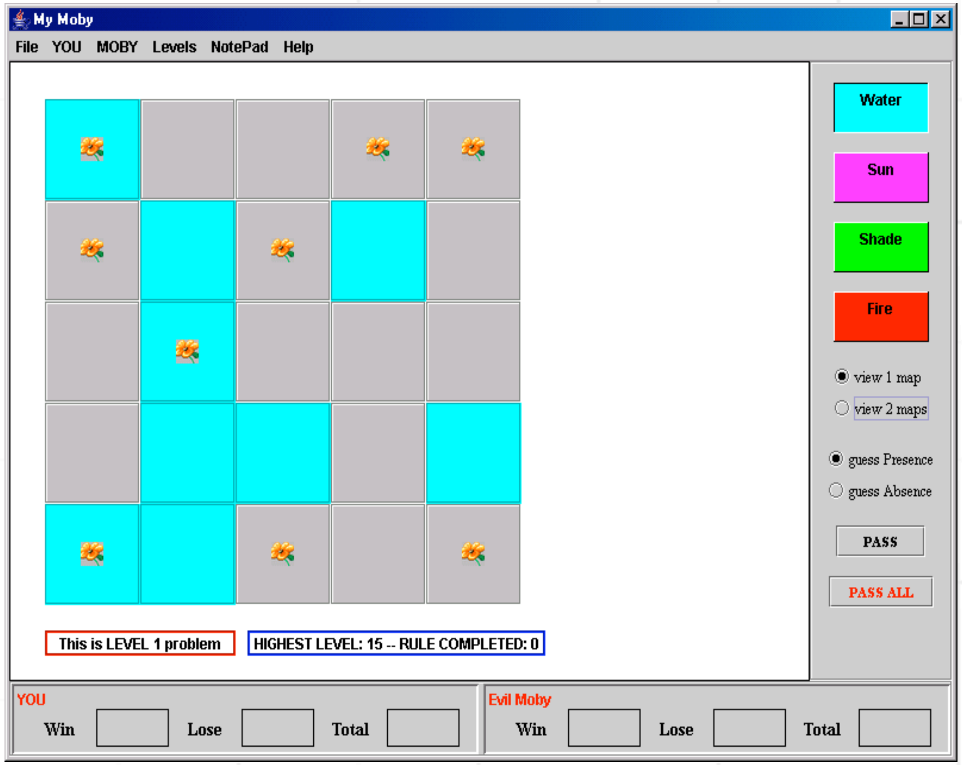
–Teaching of Hypothesis

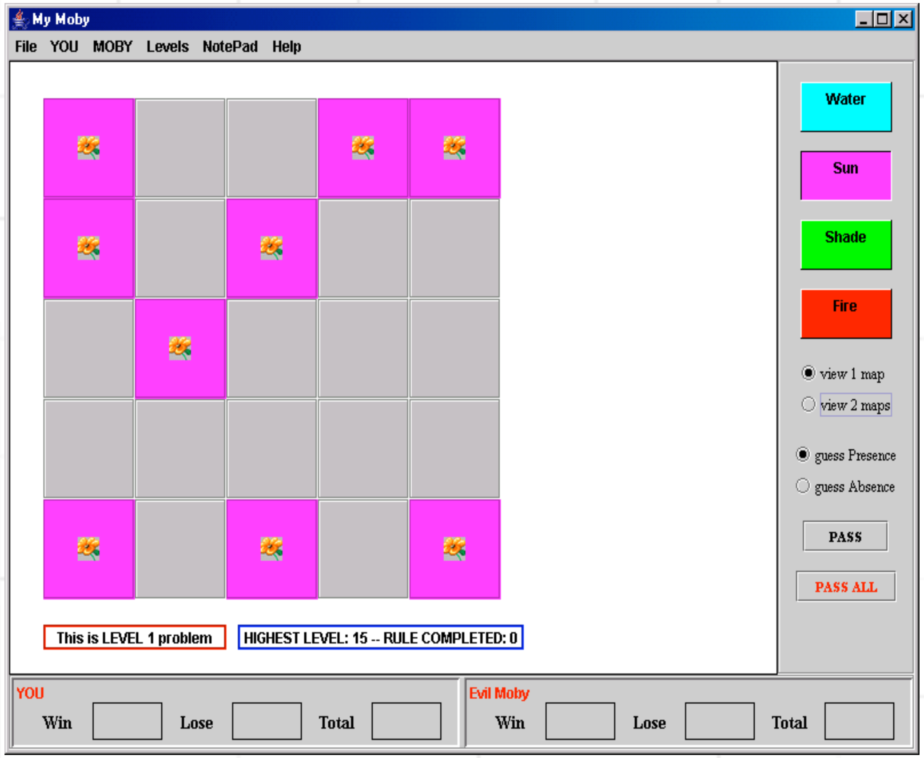
–Deductive Application

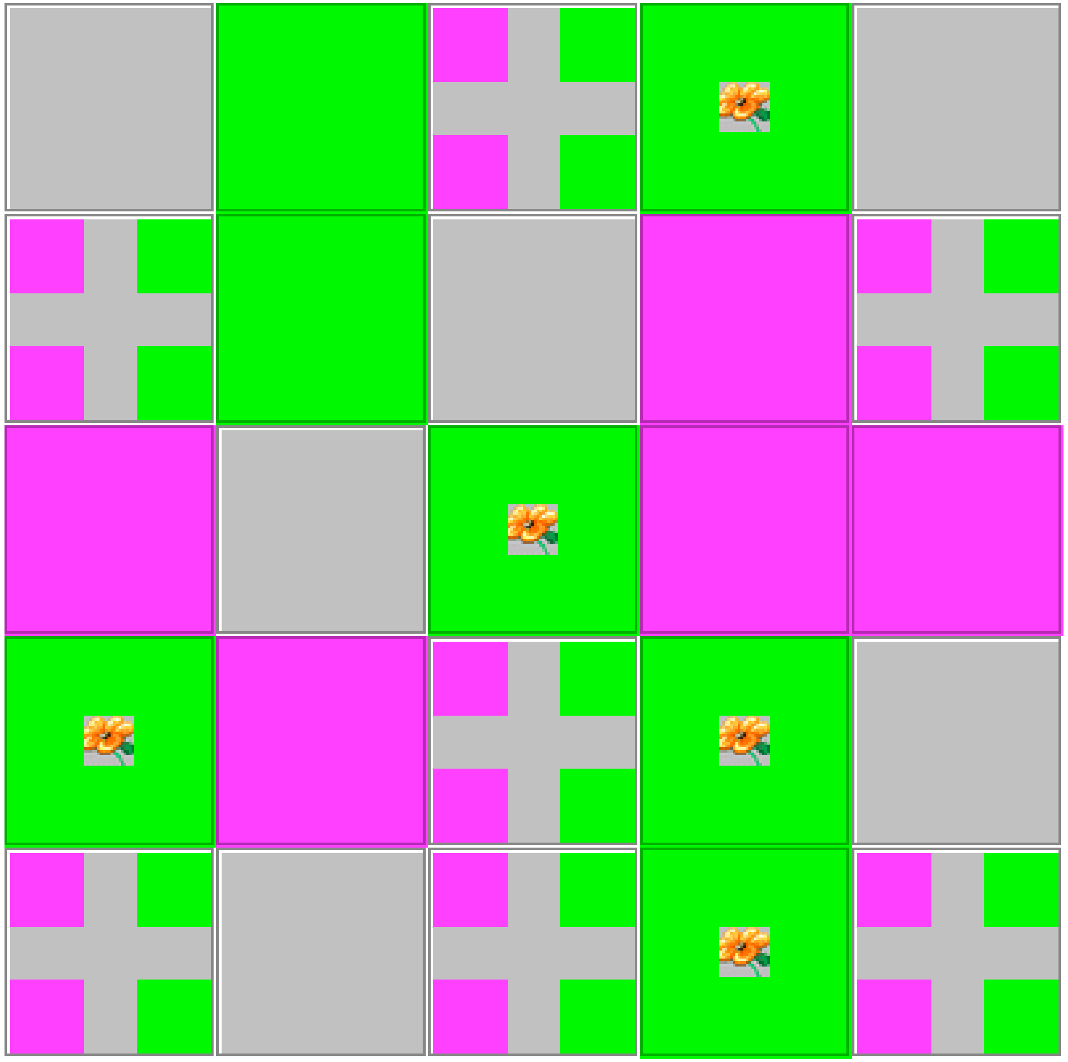




Inducing the Rule



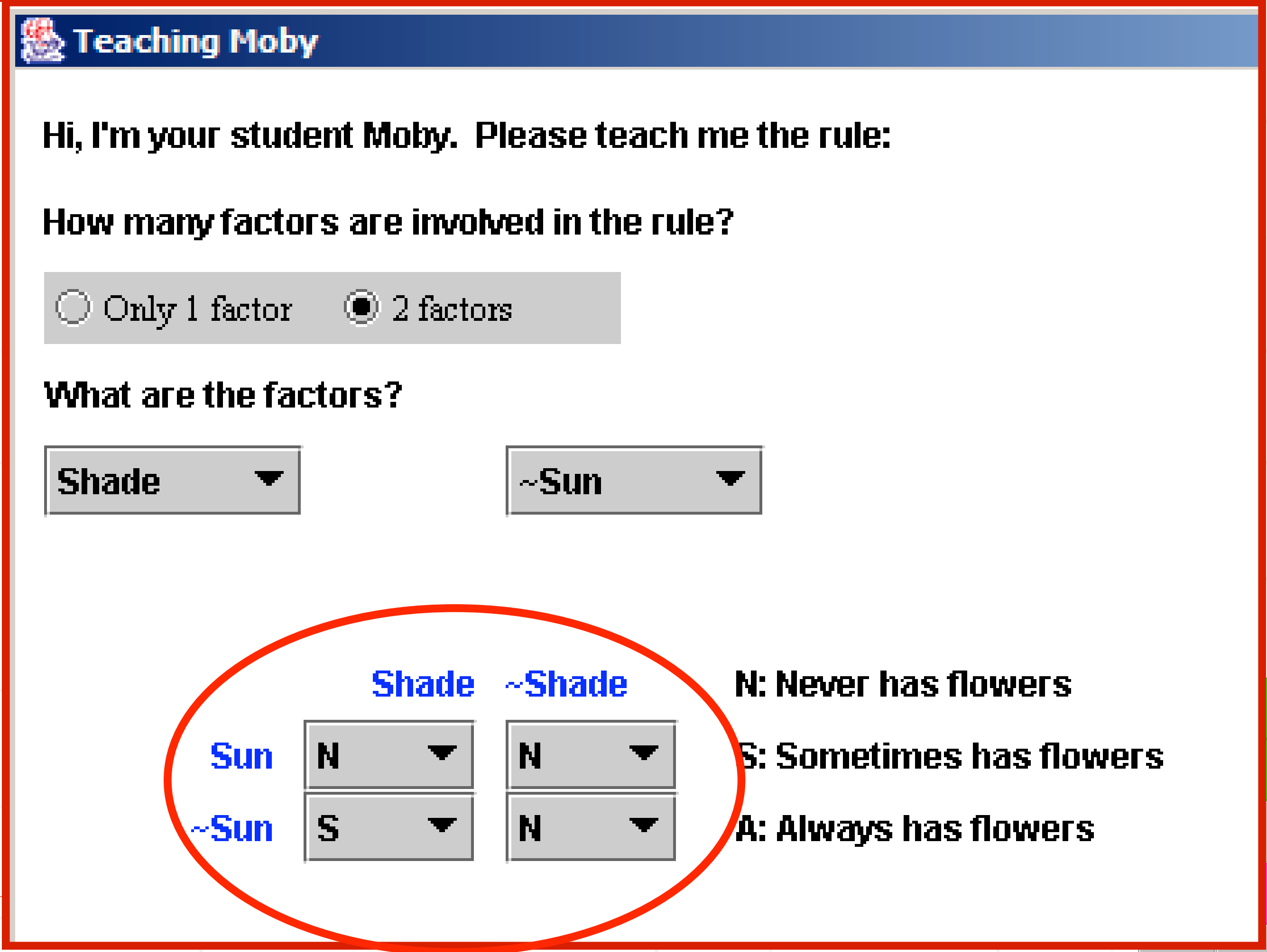


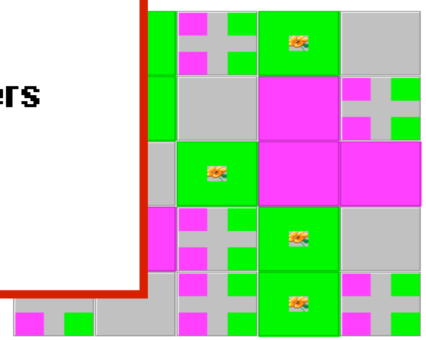


Green and Not Pink are Necessary for a Flower

(Shade and ~ Sun are Necessary for a Flower)

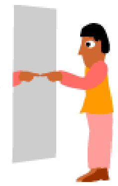
Teaching the Rule



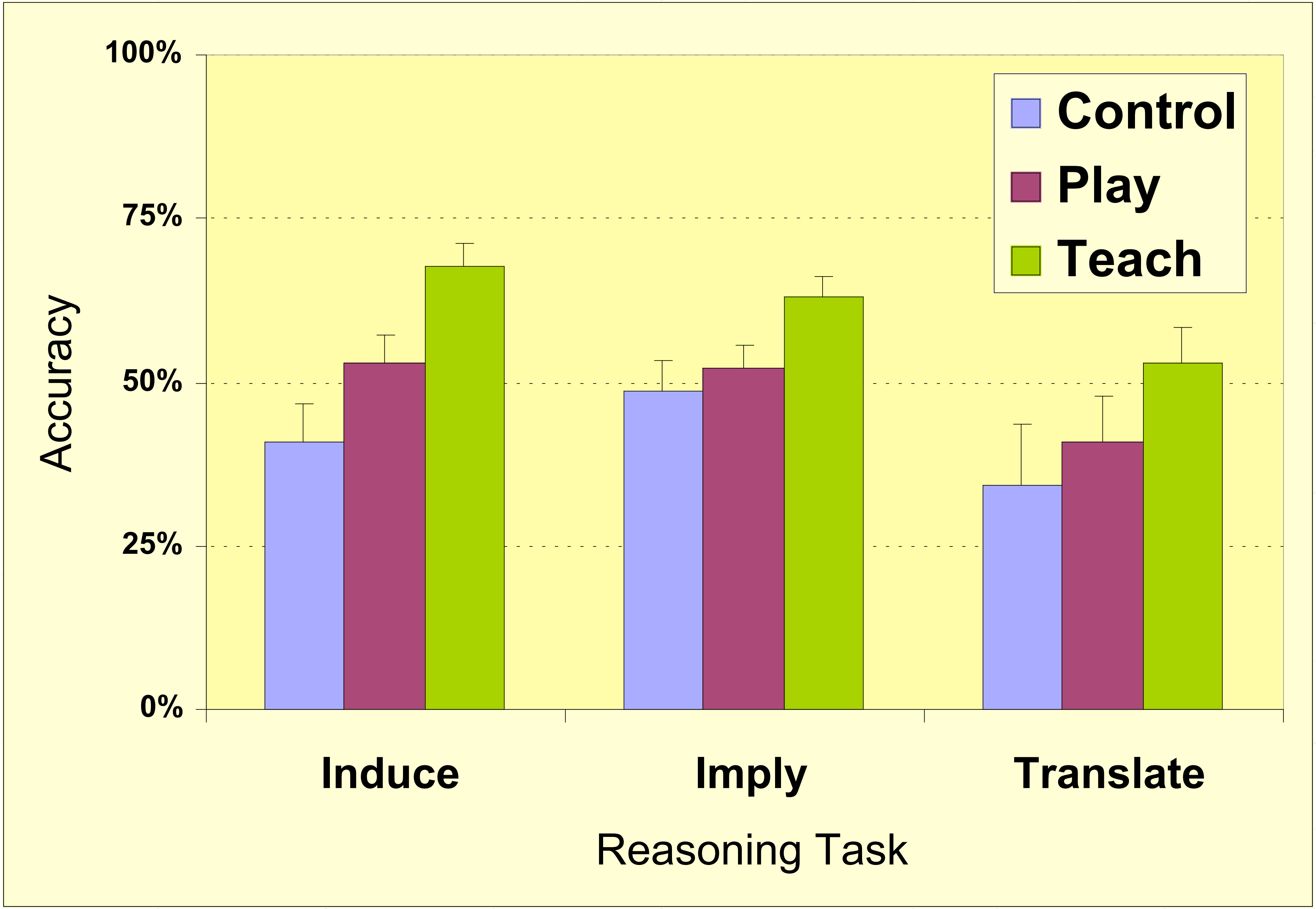


Deductive Use of Rule

Significance of Initiative in a 2nd Context



- Study with 100+ high school seniors
  - Control
    - Never used game
  - Play
    - Played game themselves without teaching feature
    - But did fill in rule matrix after each "win"
  - Teach
    - Used game, filled in rule matrix (teach), watched Moby play
- Play & Teach students reached same level; same time.
- Posttest of inductive-deductive reasoning

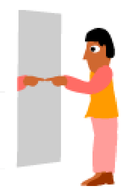


100%
75%
50%
25%
0%
Accuracy
Control
Play
Teach
Induce
Imply
Translate
Reasoning Task

Summary

- Mixed Initiative helped
  - Students learned more when they saw their agent play than when they played themselves (and filled out the same rules).
- Merged Incorporation helped students adopt structure of agent’s thought.

Interactivity and Learning

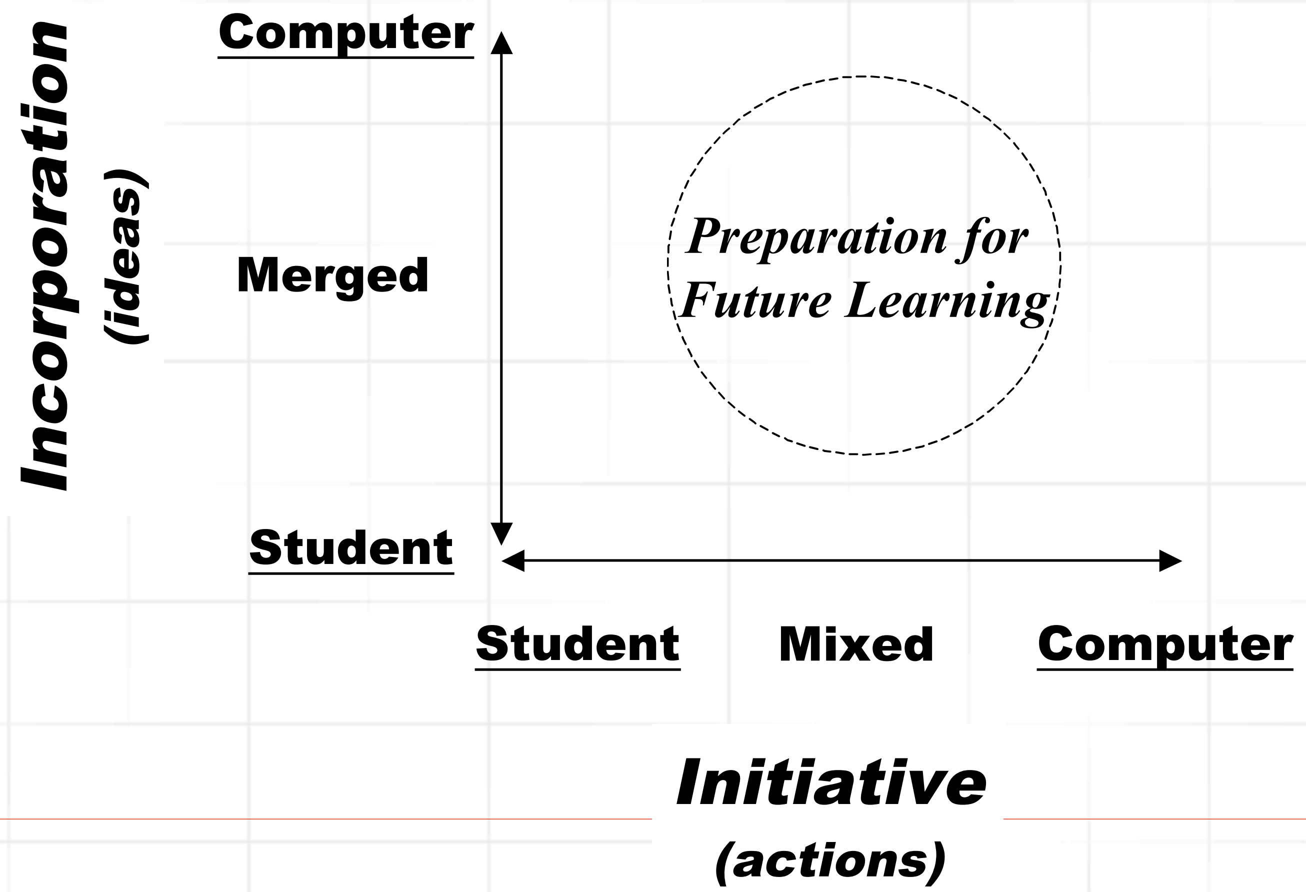


- What is valued learning?
- What is valued social interaction?
- Enhancing social interaction for learning
- Teachable Agents
- Relevant Evidence using the Agents
- → Sweet Spot of Social Interaction and Learning

Sweet Spot

- The studies showed the value of two aspects of social interaction for learning.
- They did not test "valued learning"… learning that prepares students to continue learning.
- Time to bring valued interactions and valued learning together.

Looking for the Sweet Spot



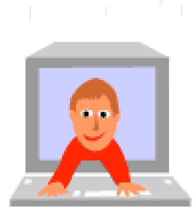
Bumping up the mixed-initiative

(Krittaya Leelawong, Gautam Biswas)

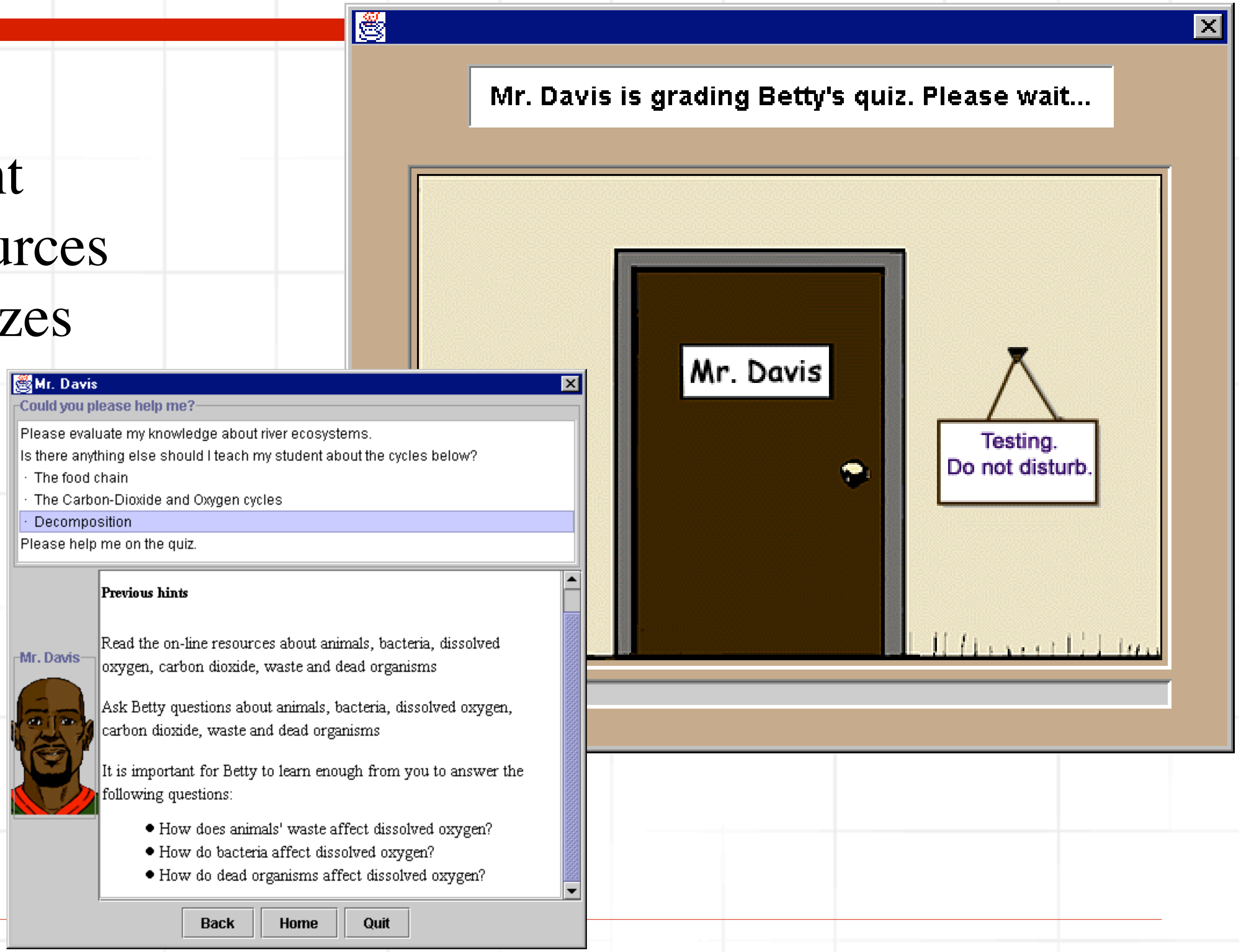
- Thus far, Betty had just-ok initiative.
  - Students often said they wished Betty would say more.

- Enhanced initiative in system:
  - Betty spontaneously takes initiative.
    - "Hey let me see if I understand this…"
  - Mentor agent provides tips if student initiates.
    - "Do you need help teaching Betty? You should read the section on bacteria."

Some Features of Enhanced System



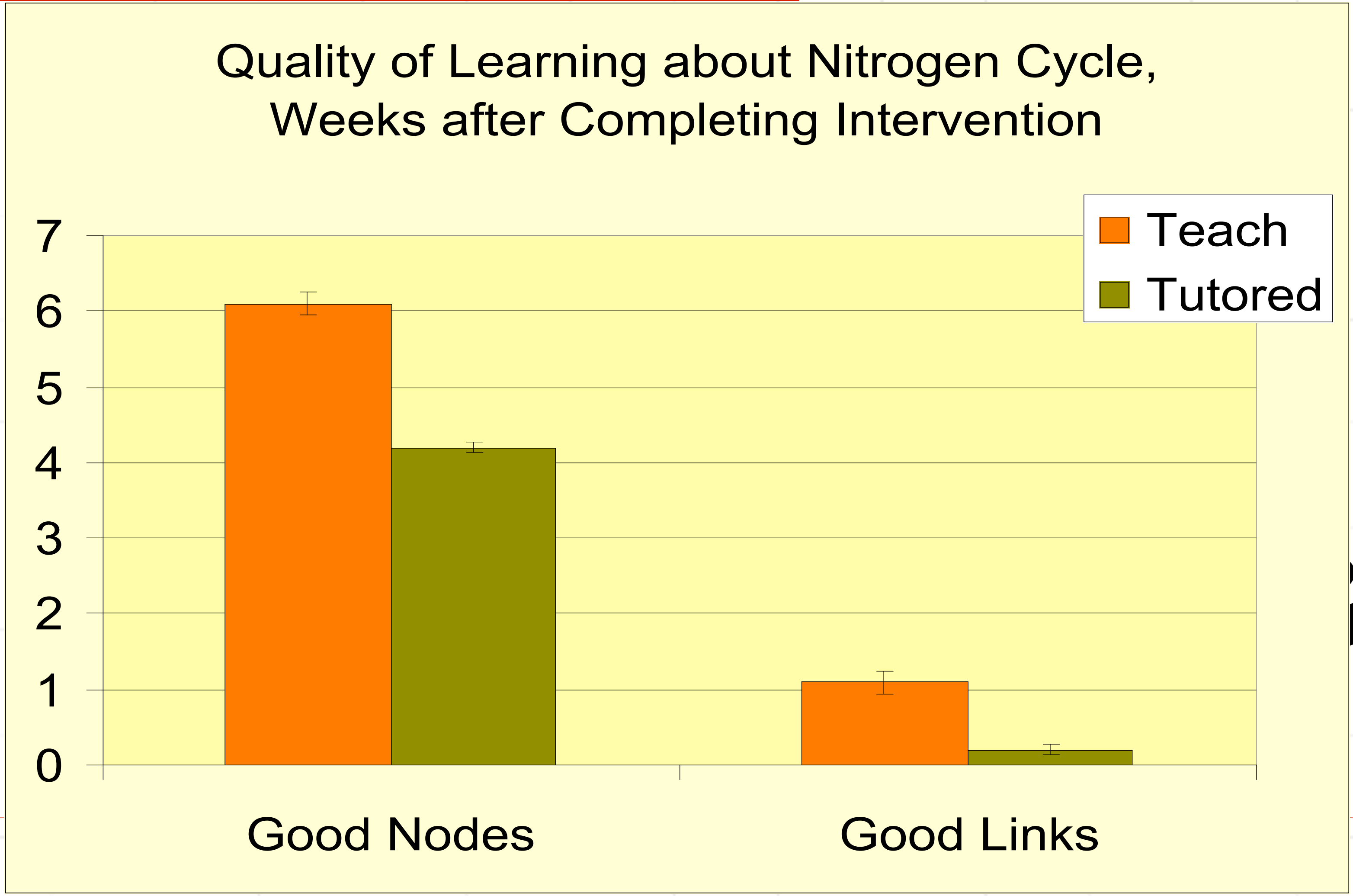
- -Chatty Betty
- -Mentor Agent
- -On-line resources
- -Practice quizzes



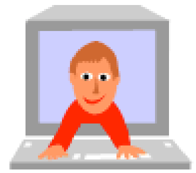
Preparation for Future Learning

- 5th-graders
  - Teach Betty about the Oxygen Cycle (innovative).
  - Tutored by Mentor how to create Oxygen Cycle (efficient).
- At first, Tutored group looks better, but over a few days the Teach students catch up.
  - Conditions look the same on an SPS test of Oxygen Cycle.
- Returned 7 weeks later for PFL test. Asked children to learn about Nitrogen Cycle from on-line resources and create a concept map.

Preparation for Future Learning

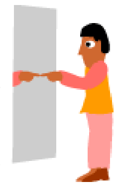


Significant but modest



- Modest effects
  - Nitrogen cycle hard and limited time to learn.
- Even so, results provide some promise that mixed-initiative and merging of ideas can prepare students to learn on their own.
  - Seemed to create a sweet spot of valued interactions and valued learning.
    - *Teach* students consulted learning resources for the nitrogen cycle much more than *Tutored* students (who had been told what to do and did not learn to do it themselves).

Interactivity and Learning



- What is valued learning?
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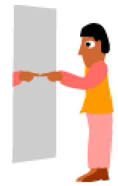
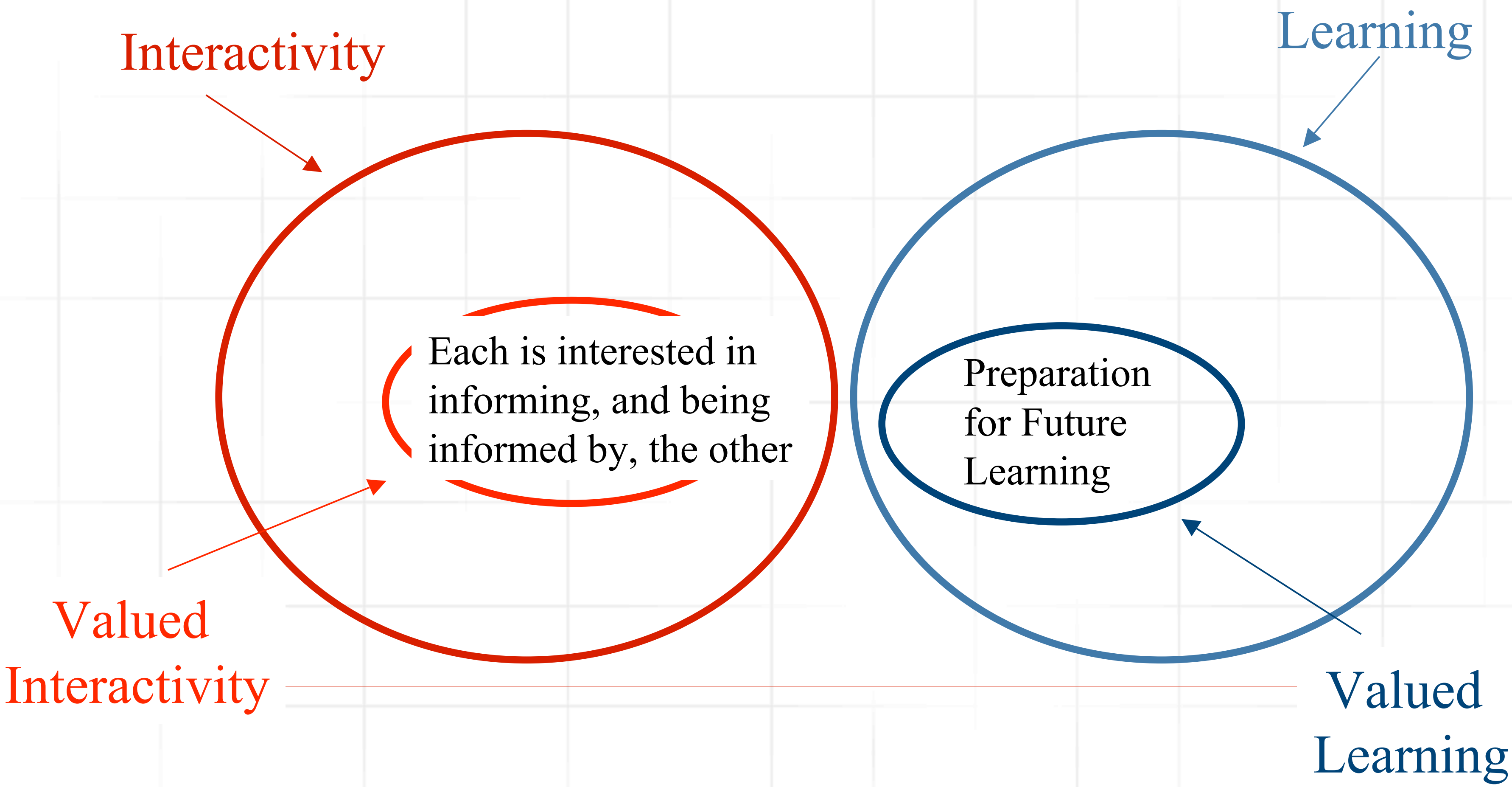
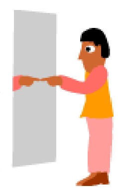
- Summary

Conclusion

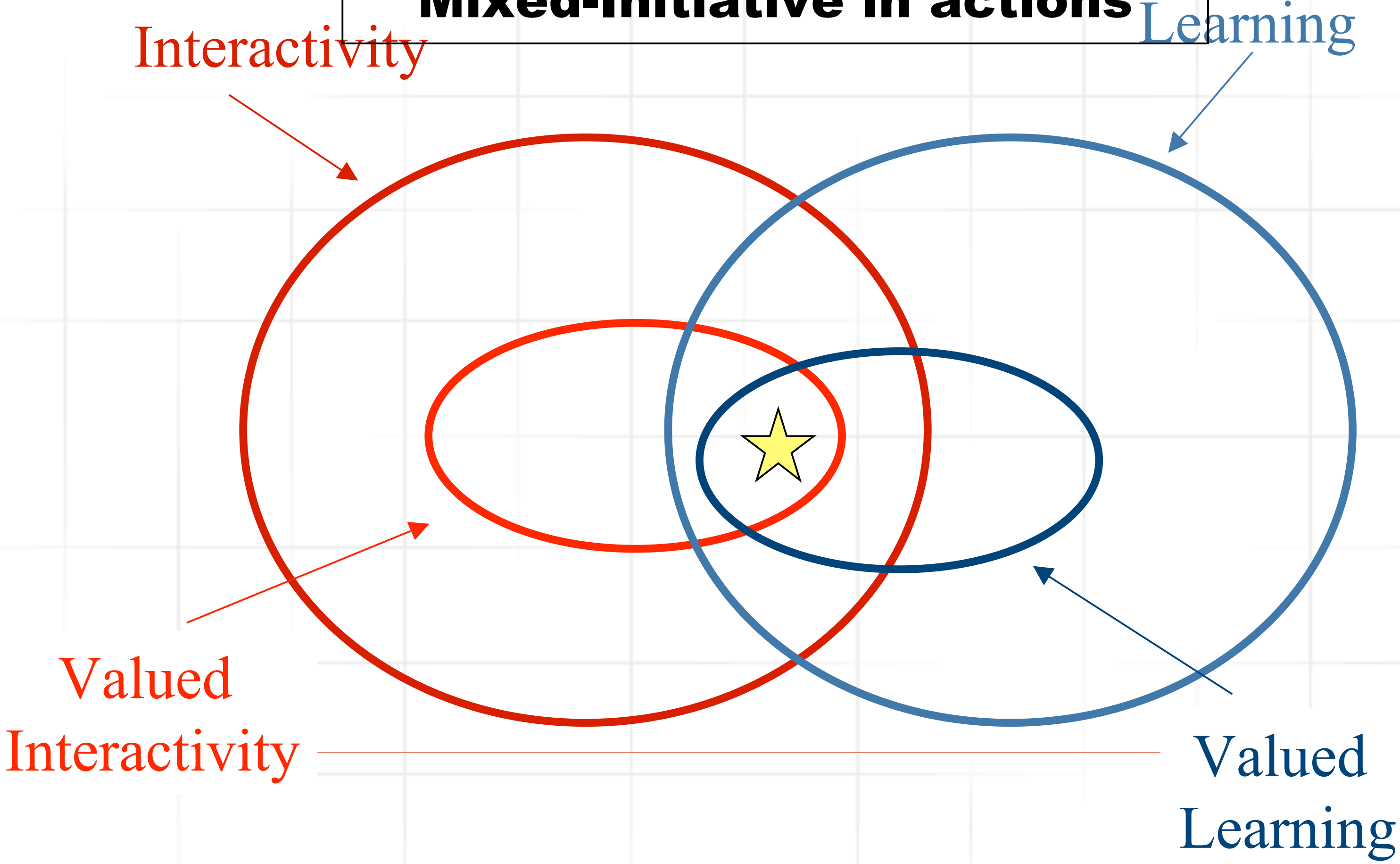



Interactivity
Learning
Each is interested in informing, and being informed by, the other
Preparation for Future Learning
Valued Interactivity
Valued Learning

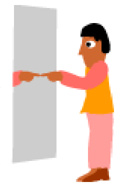
Tried to design valued social interactions that achieve desired learning.



Merged Incorporation of ideas
Mixed-Initiative in actions



Conclusion



- Designed valued interactions using Teachable Agents that emphasized merging ideas and mixing initiative.

- Found some promising evidence.
  - Students adopt knowledge and reasoning structure.
  - Students learn better when agent performs independently.
  - Students are prepared to learn when initiative is mixed compared to being told what to do.

- Need more evidence, and this will depend on a clearer definition of incorporation and initiative.

- For now, I hope the examples have been sufficient to stimulate some thoughts on this year's theme.
  - Thank you.

Daniel.schwartz@stanford.edu -or- <AAALab.Stanford.Edu>