



Who plays the math game best -
you or the agent you just taught?

Teachable Agent Games for Early Math

WGLN project (planning grant)

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Stanford

Lena Pareto
University West

Combined two ideas

Stanford

University West

Teachable agents:
Learn by teaching
a computer agent

Graphical Arithmetic Microworld
Learn arithmetic concepts by
playing games in graphical world

Similar aims:

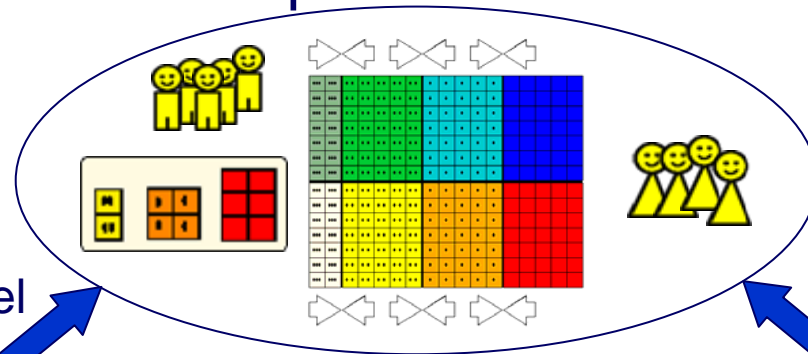
recall Gärdenfors lecture

- inner motivation
- understanding
- abstract representation
- meta cognition

Teachable agent enhanced Graphical Arithmetic Microworld

The Math Game - a microworld of arithmetic

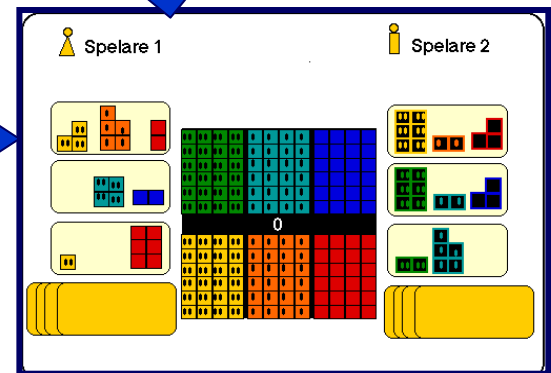
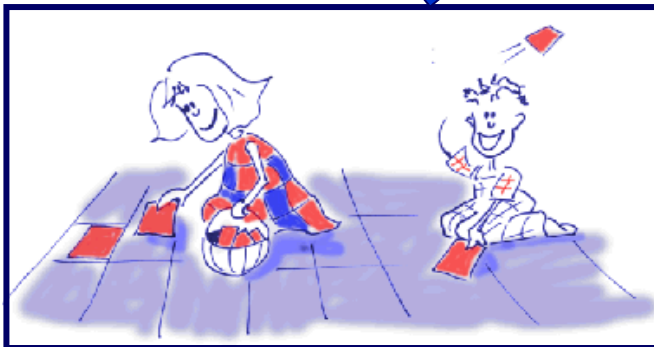
Graphical model



explains model
Stories

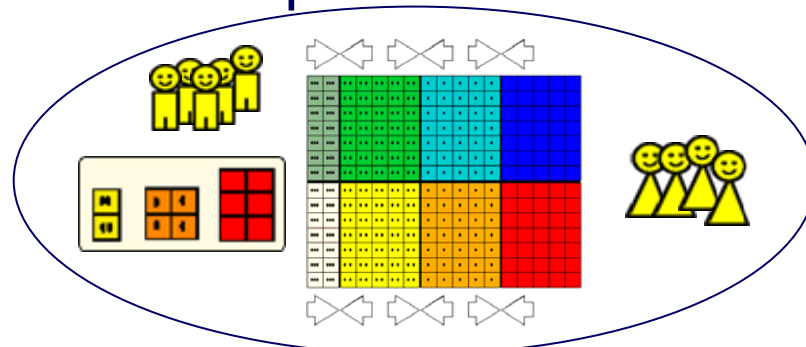
uses model
Games

introduces games

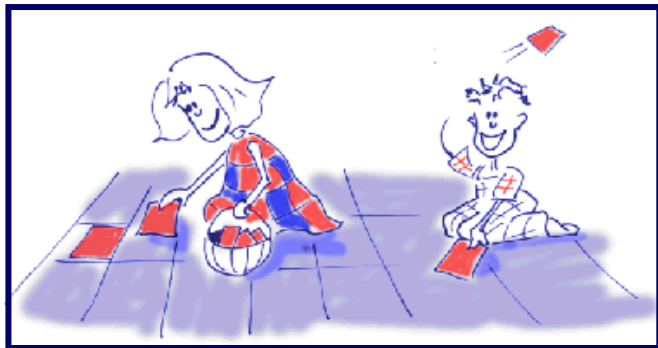


The Math Game - a microworld of arithmetic

Graphical model

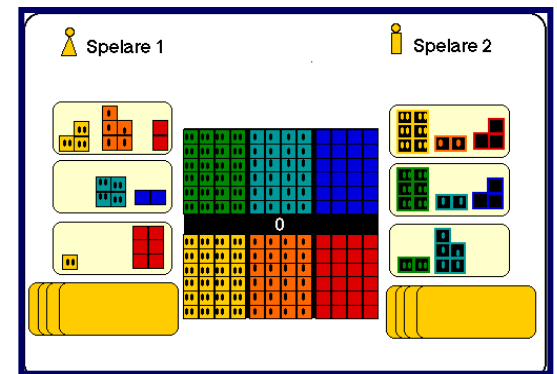


Stories



gives intuition of

Games

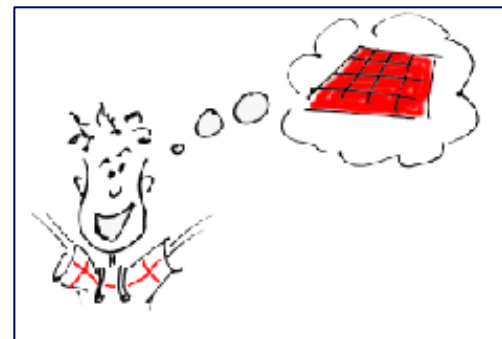
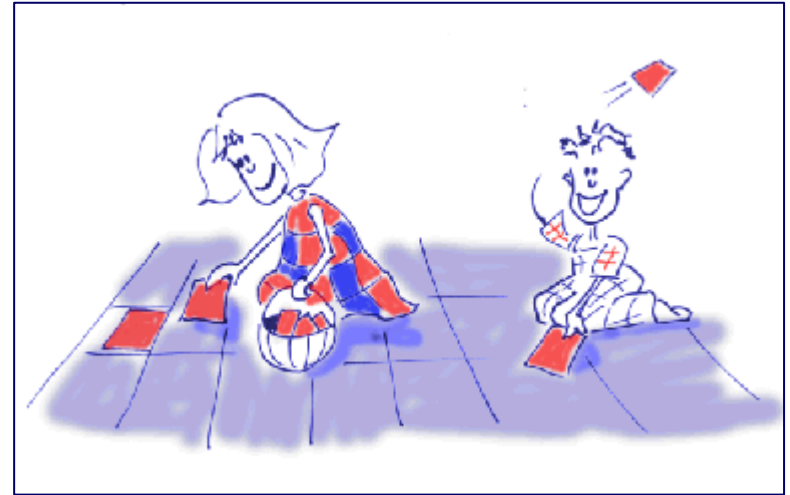


practices aspects of

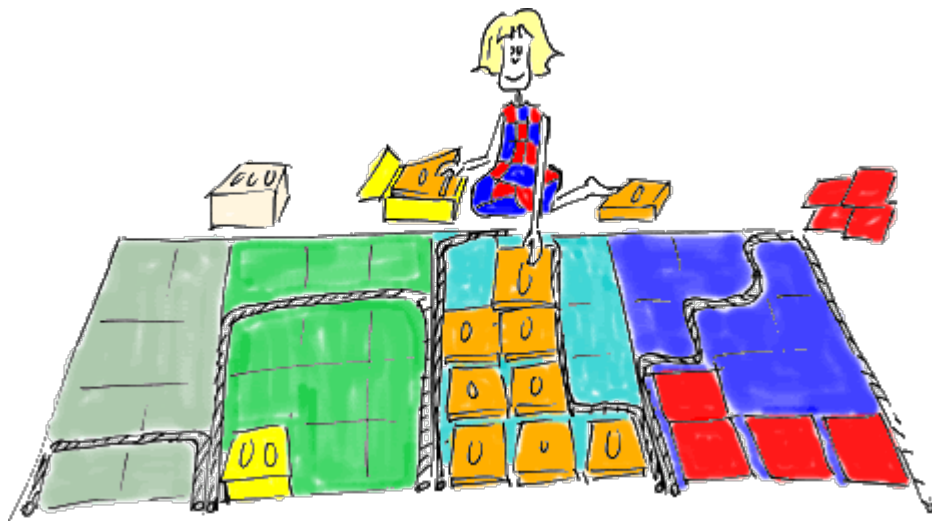
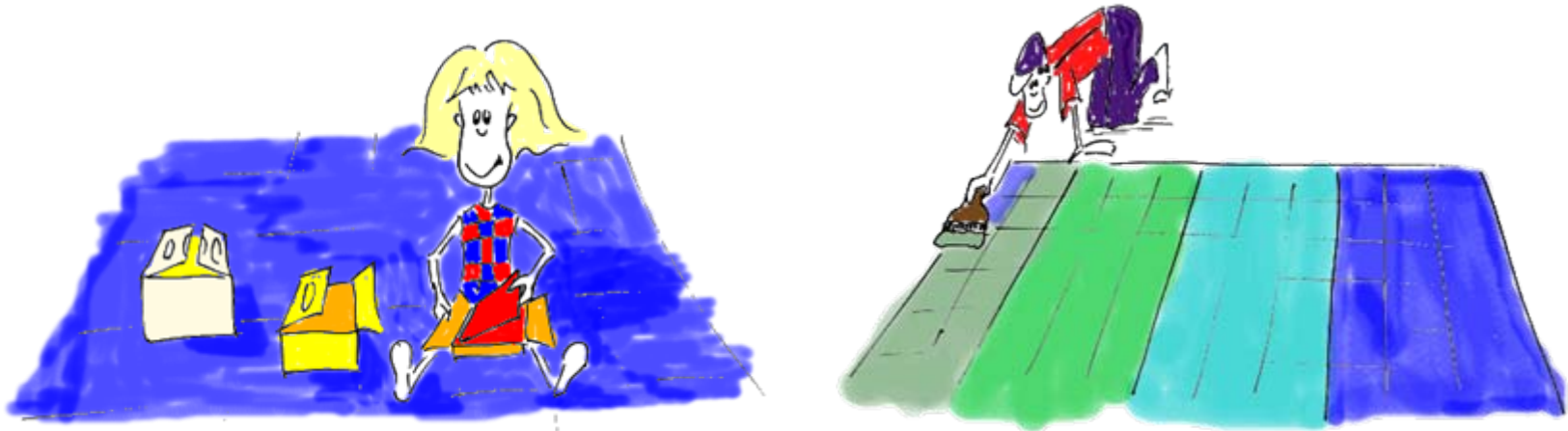
direct translation, rules and properties built in

arithmetic

The story - introducing negative numbers



The story - introducing decimal system



Graphical Arithmetic Microworld

Graphical numbers

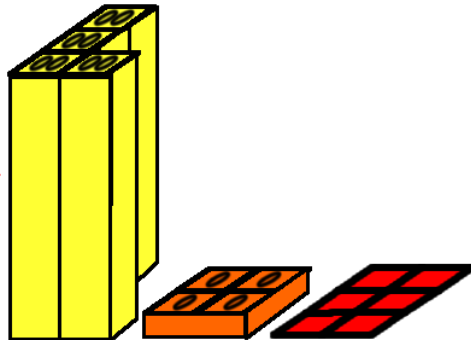
Symbolic

446

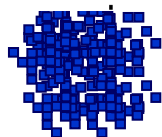
Graphical



Graphical:
quantitative
view

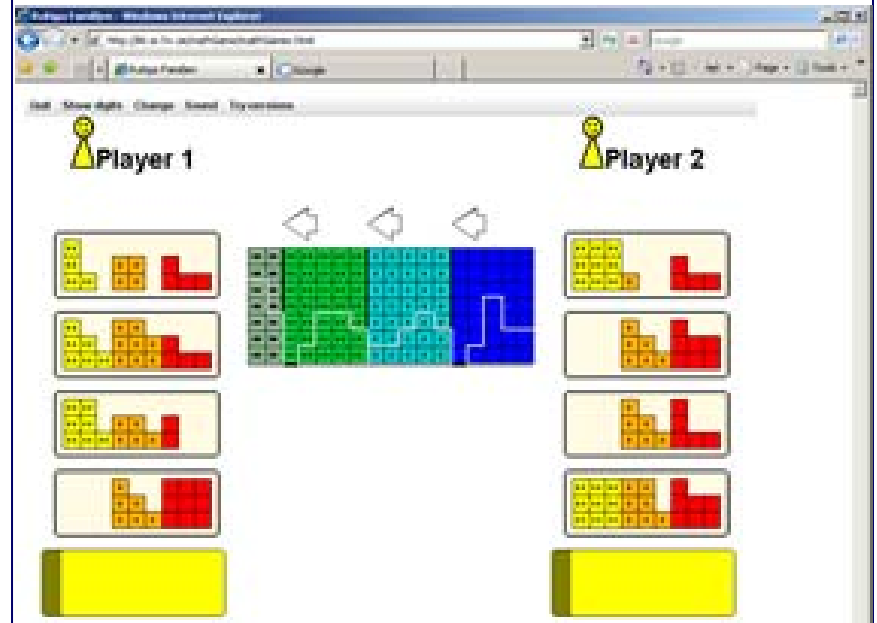


Quantity



Board- and card games

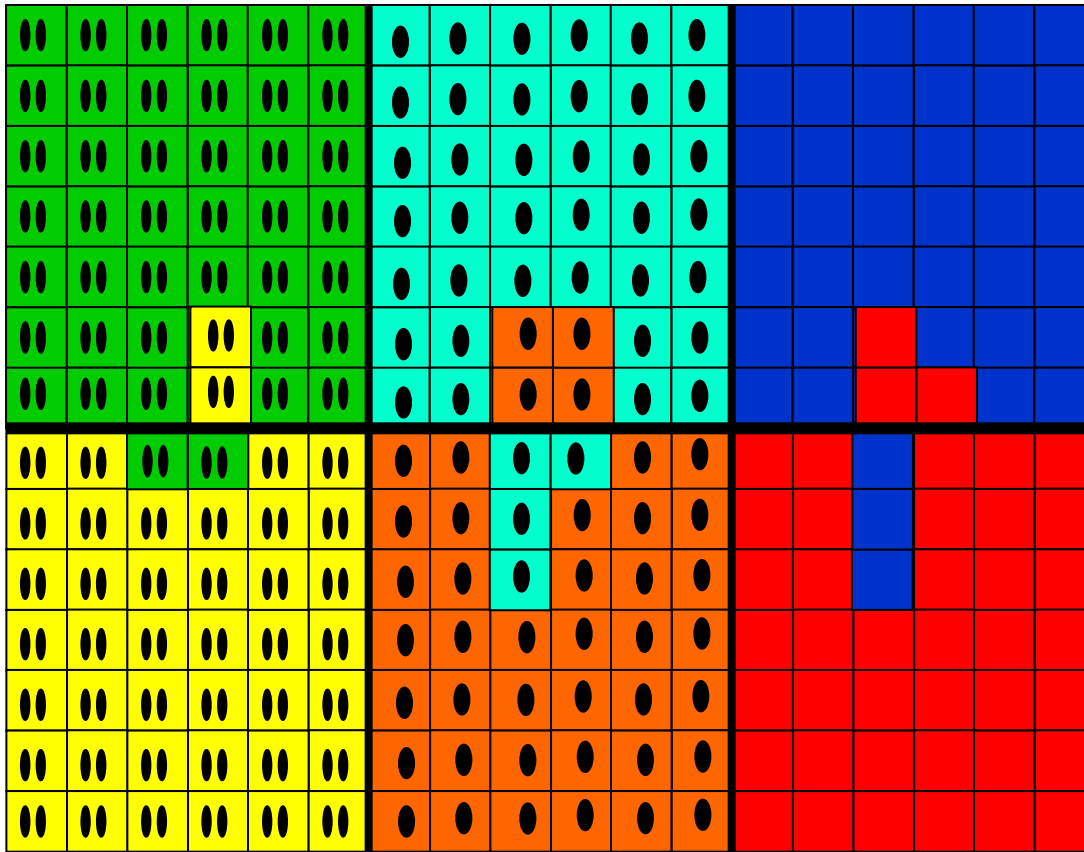
- No focus on computation
- No one-answer problems
- Two-player games
- Can be played competitively or collaboratively



Graphical model - decimal system



zero line →



positive numbers above the zero line

243

-243

negative numbers below the zero line

Graphical model - operations



- addition is to put squares onto the game board



- subtraction is to take squares from the game board



- multiplication is repeated addition



- division is repeated subtraction (without a rest)

Teachable Agent enhanced games

- Kids teach an agent to work with base 10
- Teach by guiding:

Kids	Agent
show & answer agent's questions	observes & asks questions → learns
correct or acknowledge agent's choice	chooses card, waits for kids response
observe agent's behavior	plays according to acquired knowledge



Applet Viewer: MathGames.class

Applet

Quit Show digits Change Sound Try versions

Agent says:

A star! That must be because...

- the result was 250?
- the 8 red and the 2 red were packed, leaving 0 red
- the 2 orange and the 2 orange were packed, leaving 5 orange

Okey

Teach-by-guiding model

■ Advantages

- Agent formulates explanations as multiple-choice questions
- Agent helps child to be aware of own behaviors
- Help child's progression
"playing well" → "recognize rules" → "understand rules".

■ Agent's questions 4 difficulty levels:

- 1) acknowledge good action;
- 2) explain a good action (after performed)
- 3) anticipate an action's consequence (before performed)
- 4) as 3), but a more detailed and elaborated explanation

Logging user behavior

- We have built an infrastructure logging the user behavior in the games, used to
 - update the agent knowledge, and which guide the agents behavior (dialog and playing abilities)
 - log the childs behavior in the games → analyses
- We keep track of
 - when a scoring card is chosen, and *if the child gave the proper reason* or not
 - when better cards are missed
 - when the child acknowledge or dismiss a scoring card and if the alternative is better or worse

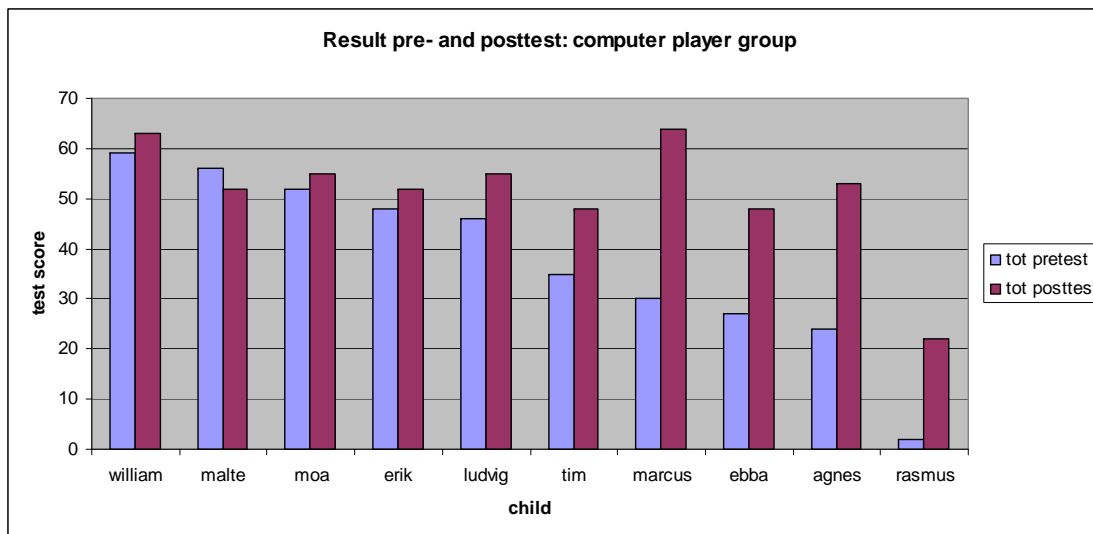
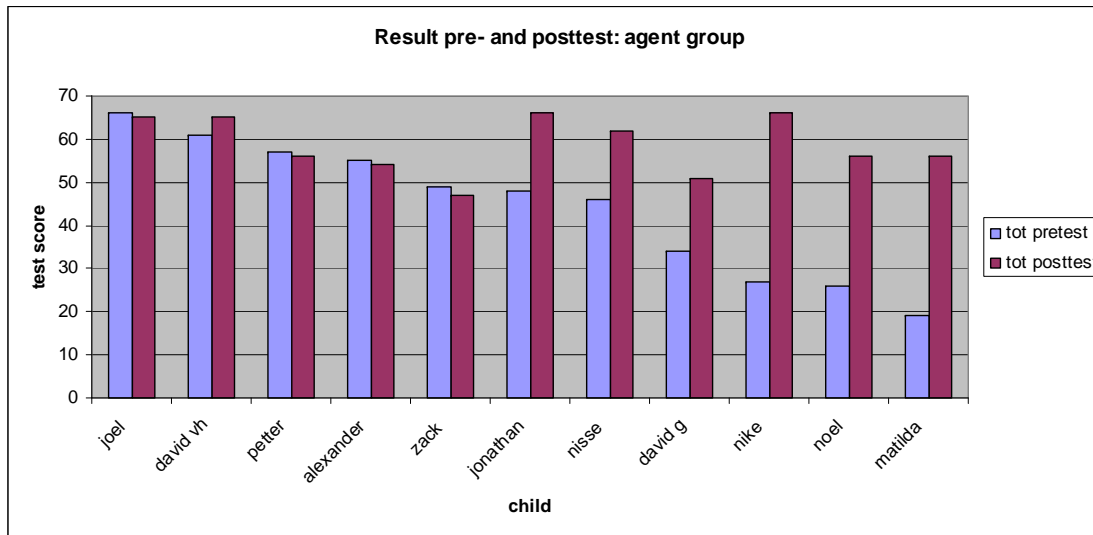
```
agent.watchAndLearn()
***Agent learn from addition***
MatchResult =
  unit 0 = rule<ADD,0,NO_EFFECT      ,==9>    [1,1,0,0,0,0,1]
  unit 1 = NO MATCH
  unit 2 = NO MATCH
----- Agent player Agent X -----
rule<ADD,0,NO_EFFECT      ,==9>    [2,2,0,0,0,0,2]
rule<ADD,1,NO_EFFECT      ,==9>    [0,0,0,0,0,0,0]
rule<ADD,1,ADDS_ONE_PLUS  ,==8>    [1,1,0,0,0,0,1]
rule<ADD,2,NO_EFFECT      ,==9>    [0,0,0,0,0,0,0]
rule<ADD,2,ADDS_ONE_PLUS  ,==8>    [0,0,0,0,0,0,0]
```

Pilot study

- In a small Swedish school, 4th grade class, 21 children
- One week, 6 sessions, 1-2 hours each
- 2 conditions: agent group & computer player group
- Kids were divided according to their ranking from the pre test
- The application logged the kids' sessions and how they played

Agent group	Computer player group
pre test, exercises on paper	pre test, exercises on paper
played 10-base games, addition	played 10-base games, addition
<i>taught their agents to play</i>	<i>played against computer, addition</i>
<i>taught agents, agents "competed"</i>	<i>played other games, subtraction</i>
post test, same type as pre test	post test, same type as pre test
group interviews	group interviews

Pre- and post test results



- 16 of 21 did better on post test (average 18,6 points better)

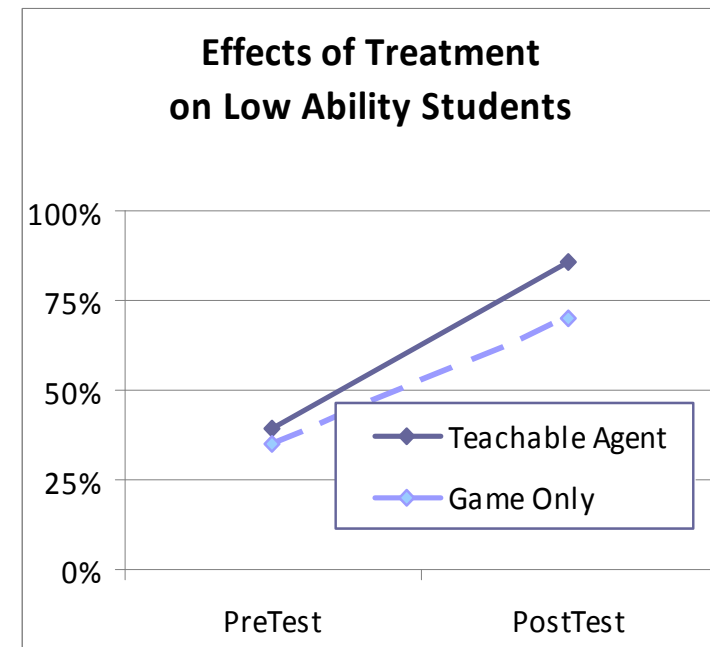
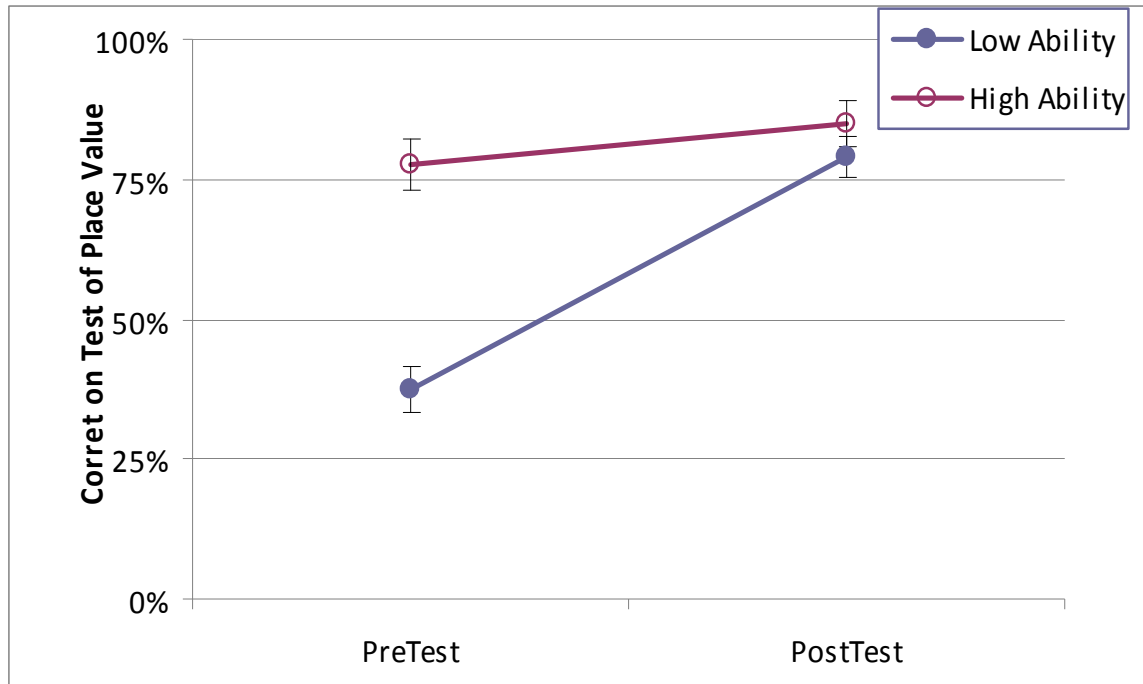
- 5 of 21 did slightly worse (average 1,8 points), but they were all among the top 7

- Low performing kids increased more

- Agent group improved slightly more.

- All girls improved, and 4 out of 5 improved a lot.

Pre- and post test results, cont'



Some preliminary conclusions

- The games are engaging, and the **Teachable Agent enhances the engagement and reflection further**
- **Low performing kids benefit more.**
- The **Graphical Arithmetic Microworld Games alone, and to a greater extent the Teachable Agent enhanced games, show potential to improve kids' arithmetic understanding.**



Possible continuations...

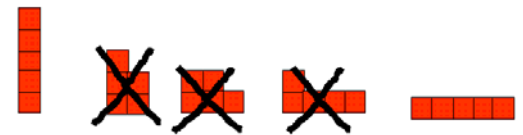
- More and longer studies
-

- Teachable Agent for all games

- More games

- More concepts

- prime numbers,
- area and circumference and their relationships
- binary numbers (box-size 2 instead of 10)
- (finite) decimal numbers



- Experimental studio, where problems can be stated and explored

- Game-design studio, where kids design their own games

- Play on-line

- ... ?

Looking for collaborators...

What is interesting? What should we focus on?
What do YOU want to do?



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Game: ikt.ei.hv.se/mathGame/eng/ (ikt.ei.hv.se/mathGame/sve/)