

# Improving Math Learning Through Intelligent Tutoring and Basic Skills Training

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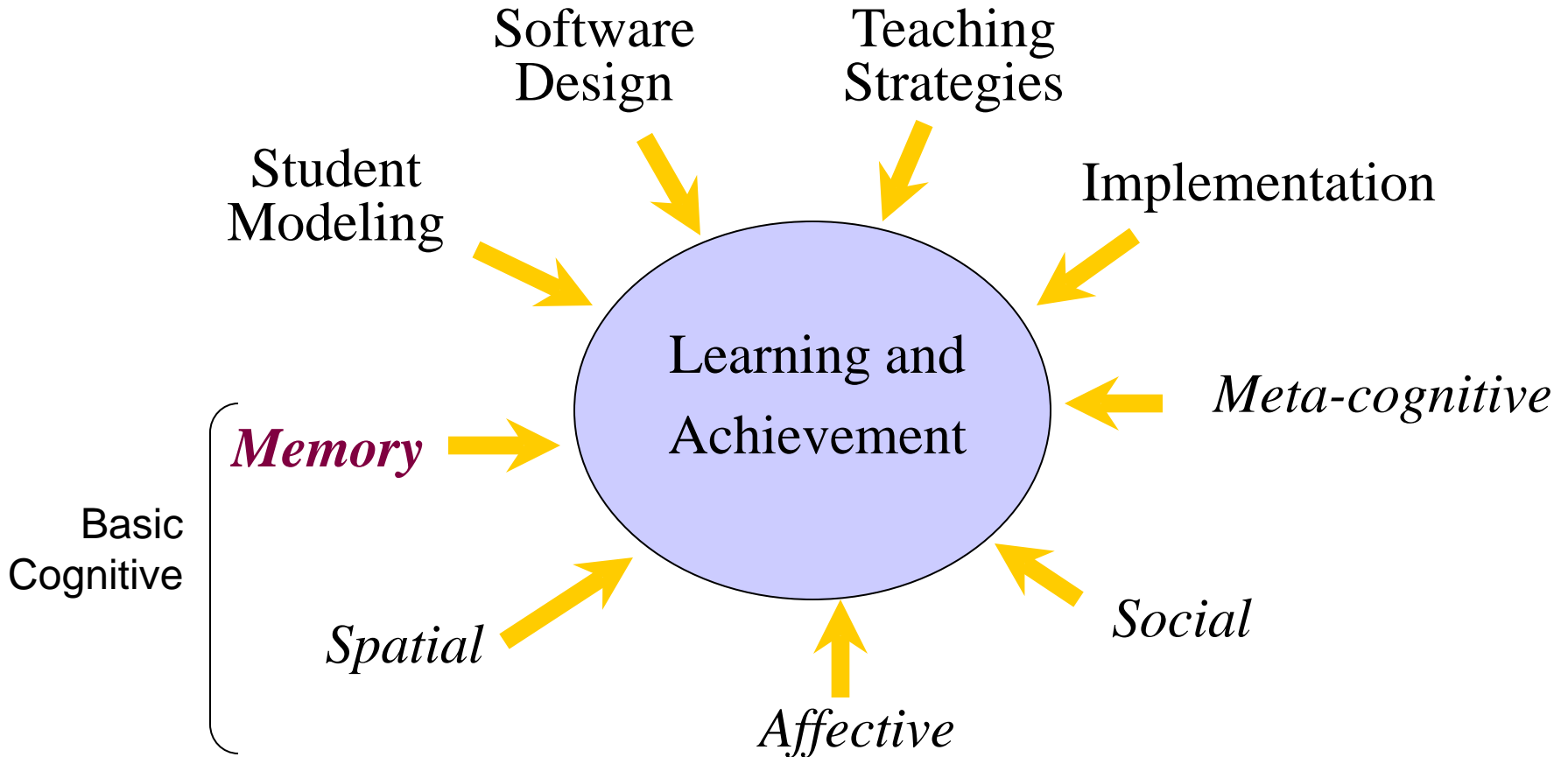
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# So many factors affect learning with ITS



*Italics: Student's baggage to the learning situation*



# Motivation



- Problem solving takes place in a cognitive system constrained by a limited capacity of *working memory*

## Working Memory Capacity When Solving a Math Problem



Basic Math

Strategy

- Doing Math is like speaking a language.
  - If you are *fluent*, you will concentrate better on the message.
- Math *Fluency*
  - Accuracy and Speed at Easy Math, e.g. addition, division
  - Math Fluency helps predict performance at state-wide tests
  - Training Math Fluency improves performance at tests

Royer&Tronsky (1998) ←

Royer et al. (1999) ←



# Hypotheses



- Do students *learn* more with a Math ITS when training basic math facts retrieval (MFR) from memory?
- Targeted hypotheses:
  - Does Math Fluency Training help *students w/ IEPs* learn more?
    - >> Students w/ Learning disabilities are seconds slower  
Royer&Tronsky (1998) ←
  - Does Math Fluency Training help *Females* learn more?
    - >> Females milliseconds slower and helped explain gender gap in SAT-M  
Royer (1999) ←
- Back to studying multiplication tables!

# Training Speed as a Game against yourself

*Math Success Software, LATAS Lab, Psychology Dept UMASS. James Royer.*

## Training with sound

## Assessment: speak answer

Incorrect Highlighted

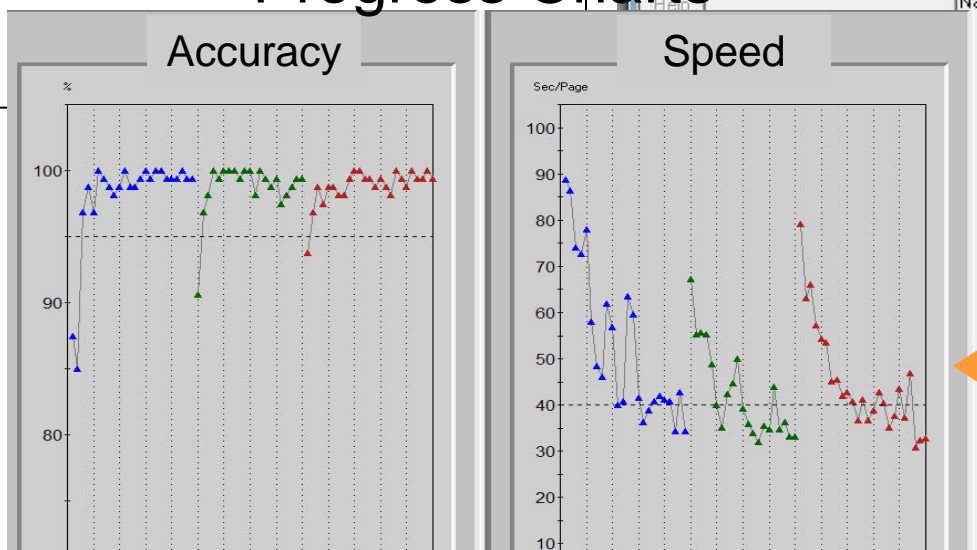
|                |                |                |                |
|----------------|----------------|----------------|----------------|
| $1 \times 3 =$ | $1 \times 0 =$ | $3 \times 4 =$ | $3 \times 7 =$ |
| $4 \times 0 =$ | $5 \times 6 =$ | $3 \times 1 =$ | $5 \times 4 =$ |
| $8 \times 6 =$ | $9 \times 0 =$ | $2 \times 6 =$ | $0 \times 8 =$ |
| $4 \times 4 =$ |                |                |                |

Simple Multiplication

Item: 1/3    Practice - SPACEBAR Active    Status: Ready...

$2 \times 3$

## Progress Charts



Say answer out loud  
Hit bar.  
Hear answer back.  
R-L click to code R/W

See a new dot  
for each round

# As a supplement to Wayang Outpost

*Multimedia Adaptive Tutoring System for Standardized-Tests Math Problems*

The screenshot displays a virtual classroom environment. On the left, a vertical toolbar contains icons for a 'psst!' notification, a refresh button, a hand cursor, a calculator, a film strip, and an 'EX:' icon. A vertical 'DRAW' button with a pencil icon is also present. The main area shows a math problem: 'When a certain rectangle is divided in half, two squares are formed. If each of the squares has perimeter 48, what is the perimeter of the original rectangle?' Below the problem are five multiple-choice options: (A) 96, (B) 72, (C) 36, (D) 24, and (E) 12. On the right, a character is seated at a desk with a computer monitor. The desk has a label 'problem\_013' and two buttons: 'Go Away!' and 'Mute'. At the bottom of the screen, there are four navigation buttons: 'Formulas', 'new problem', 'help', and 'village'.

psst!

When a certain rectangle is divided in half, two squares are formed. If each of the squares has perimeter 48, what is the perimeter of the original rectangle?

(A) 96  
(B) 72  
(C) 36  
(D) 24  
(E) 12

problem\_013

Go Away! Mute

Formulas new problem help village

# As a supplement to Wayang Outpost

## Multimedia Adaptive Tutoring System for Standardized-Tests Math Problems

Wayang Outpost

http://cadmium.cs.umass.edu/wayang2/flash/wayang\_main.html

Welcome to WomensMedia MCAS Questi...y Education Financial an...ost Analysis UMass PRO/UAW

psst!

HELP

DRAW

EX:

When a certain rectangle is divided in half, two squares are formed. If each of the squares has perimeter 48, what is the perimeter of the original rectangle?

(A) 96  
(B) 72  
(C) 36  
(D) 24  
(E) 12

24

12 12

12 12

24

Perimeter Rectangle = (2 \* height) + (2 \* width)  
Perimeter Rectangle = (2 \* 12) + (2 \* 24)  
Perimeter Rectangle = 24 + 48  
Perimeter Rectangle = 72

Choose (B)

problem\_013

Go Away! Mute

Formulas new problem help village

# Experiment Design

- 225 middle school students in a public high school
  - Six 7th grades, and six 8th grades
  - 12 different classes of ~19 students.
- Four groups, 3 classes each, assigned to either:

|        |     | Math Fluency Training |                         |
|--------|-----|-----------------------|-------------------------|
|        |     | Yes                   | No                      |
| Wayang | Yes | Wayang-MFR<br>7 8 8   | Wayang-NoMFR<br>7 8 8   |
|        | No  | NoWayang-MFR<br>7 7 8 | noWayang-NoMFR<br>7 7 8 |

- Two 7th and one 8th grade, or two 8th and one 7th.

# Procedure

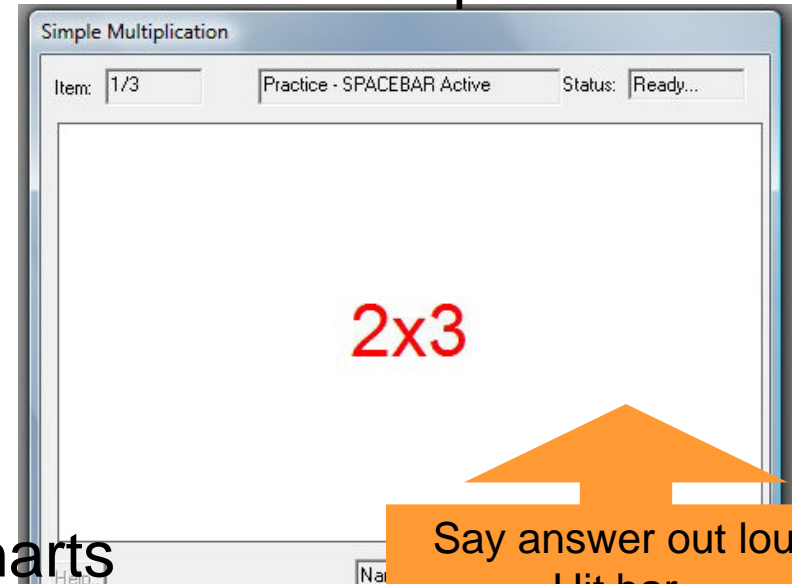
- Four days of study, one hour periods, within a 7-8 days.
- Math test on 1st and last day, tests A and B counterbalanced
- Math Facts Retrieval (MFR) posttest the last day
- MFR Groups trained first 3 days.
- Wayang Groups worked on tutor mostly on days 2-3.
- NoWayang groups had either class instruction, or other web sites

|                  | Day 1  | Day 2 | Day 3 | Day 4                           |
|------------------|--|-------|-------|---------------------------------|
| Wayang MFR       | Math Facts Retrieval Training                  |       |       | MFR Posttest, and Math-Posttest |
| Wayang No MFR    | Wayang Math ITS                                |       |       | Detailed Math                   |
| No Wayang MFR    | Other math web sites (NLVM, Wayang adventures) |       |       | Fluency and Math-Posttest       |
| No Wayang No MFR | Math Class or no time in between               |       |       | Wayang Posttest, MFR Posttest   |

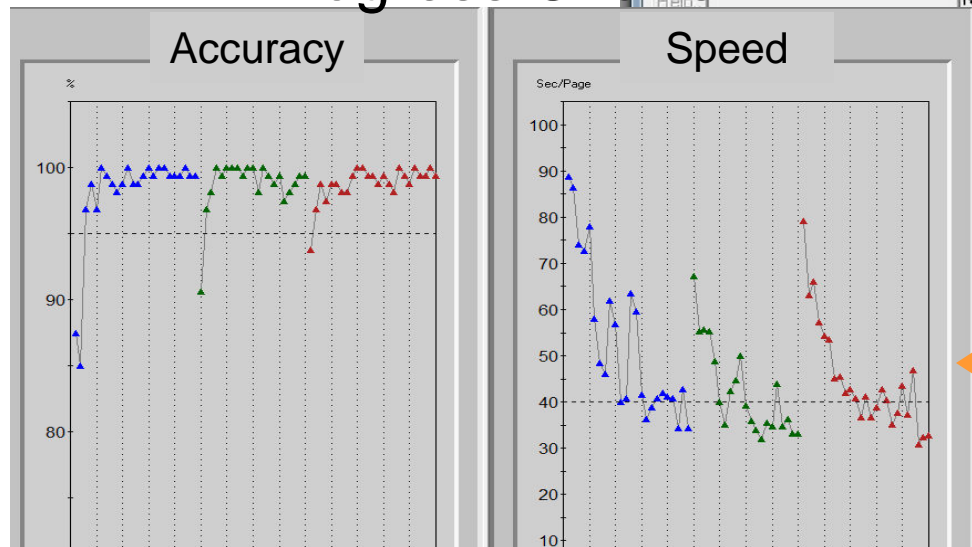
# MFR Posttest with Math Fluency Software

Assessment: speak answer

No Training Phase



Progress Charts



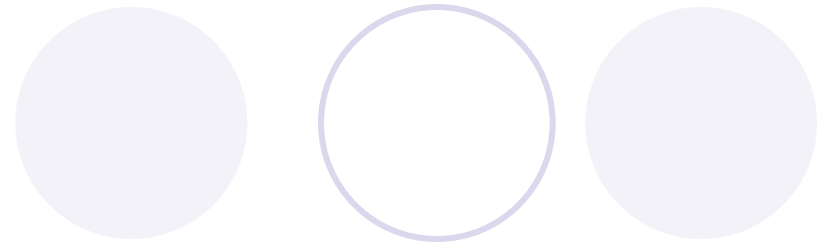
Say answer out loud  
Hit bar.  
Hear correct answer back.  
**R-L click to code R/W**

We did care  
about speed



# Expected Results

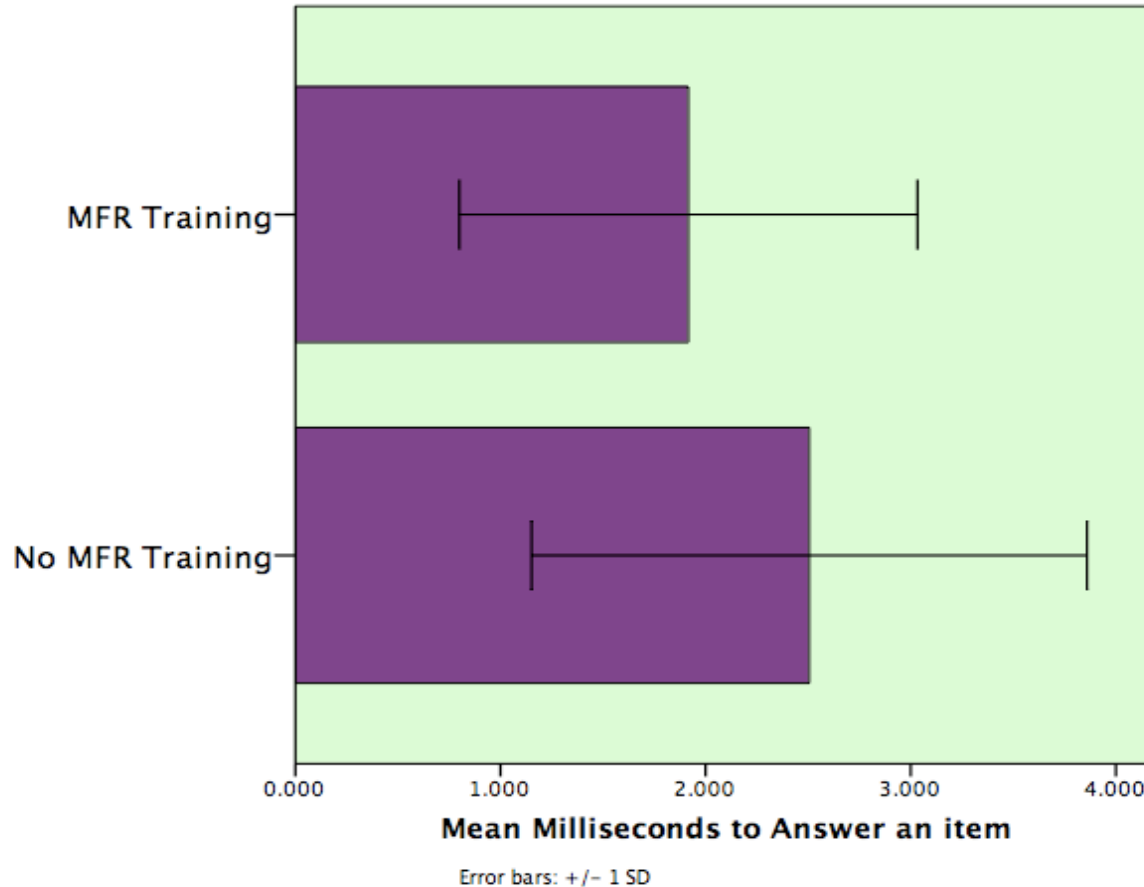
Realistically....



- Some improvement on stand. math test due to Wayang
  - Even though it was our first experience with middle school students
- Hesitant about students improving fluency
  - Previous MFR Training success was achieved after longer exposure
- Taking away time from Wayang for fluency training
  - ...might not be beneficial for performance at standardized posttest
- However, low achievement students really need MFR
  - Could be a hit for IEP students
  - Probably not better for females than males

# Math Fluency Training Worked

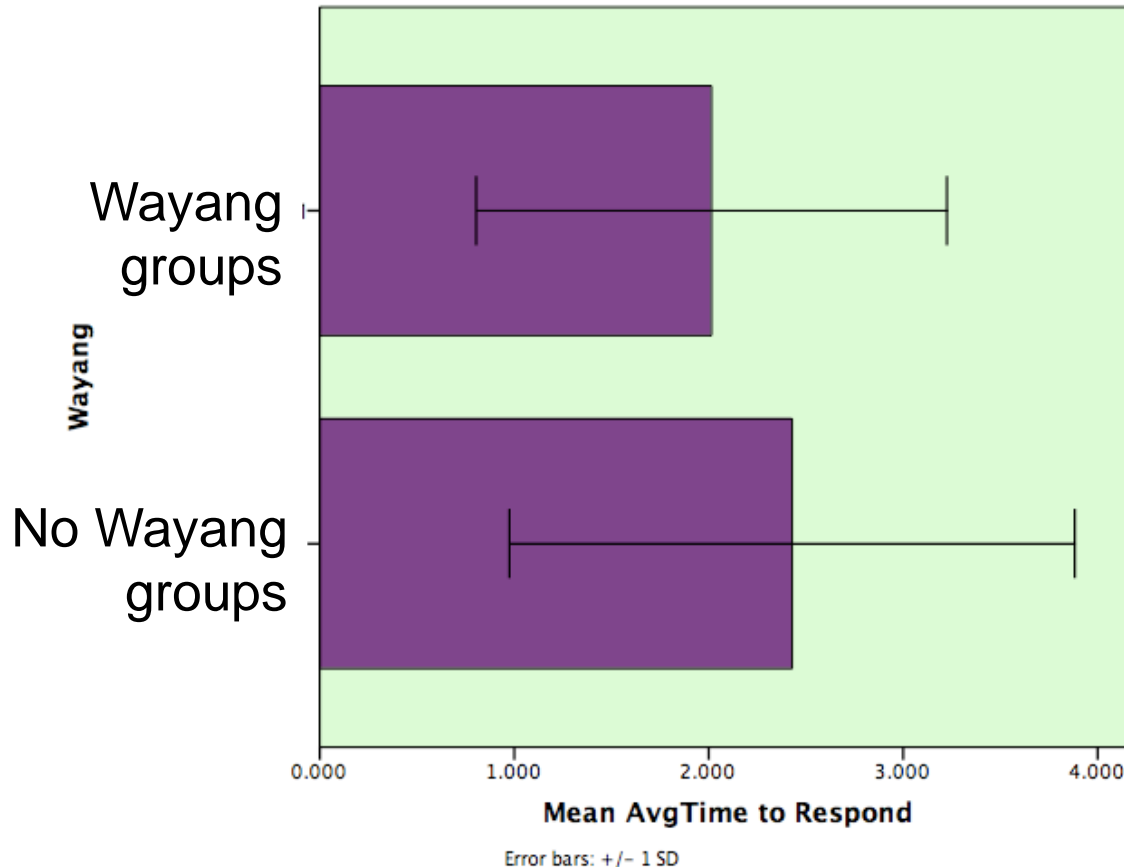
True Means for Post-tutor Speed at Fluency (MFR) Posttest



ANCOVA for Math Fluency Posttest, Math Fluency Pretest as covariate:  
**MFR Training Main Effect:**  $F(197, 1)=13.9, p<.001$   
**Wayang Main Effect:**  $F(197,1)=8.6, p<.023$

# Wayang helped improve Fluency

True Means for Post-tutor Speed at Fluency (MFR) Posttest



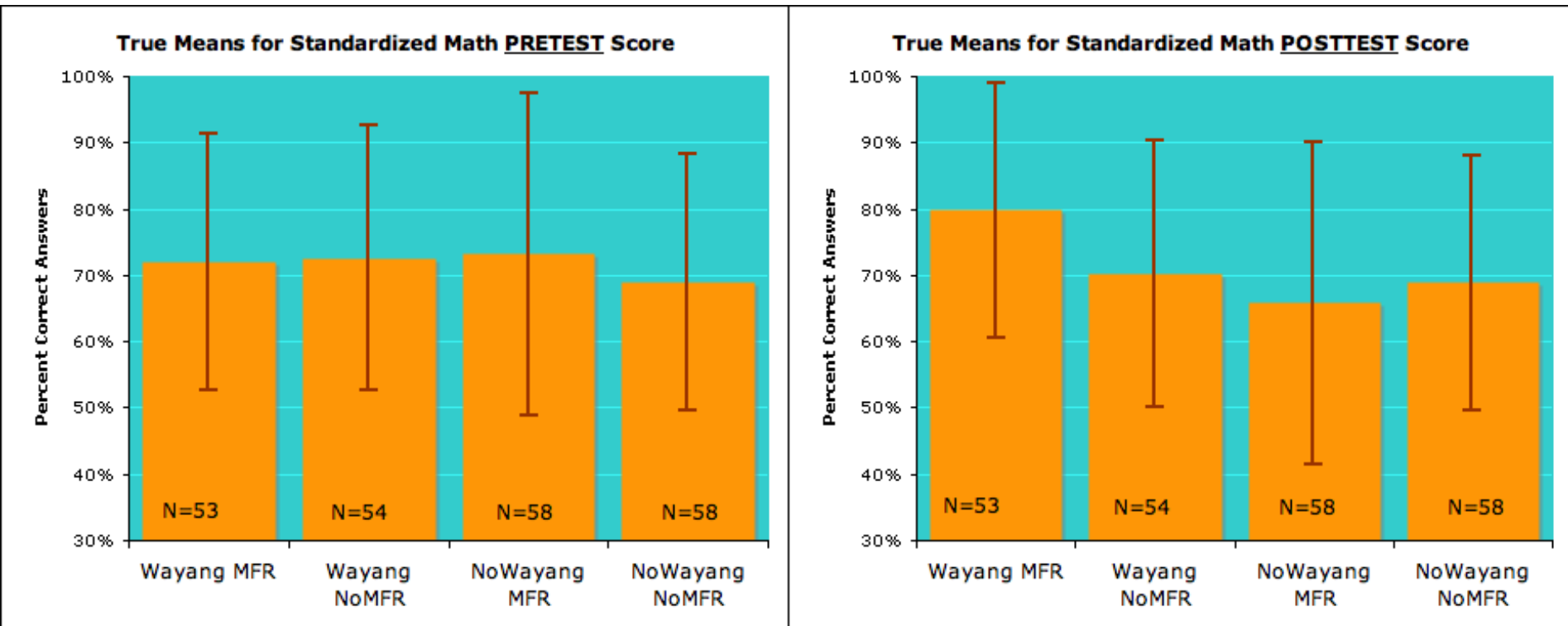
ANCOVA for Math Fluency Posttest, Math Fluency Pretest as covariate:

MFR Training Main Effect:  $F(197, 1)=13.9, p<.001$

**Wayang** Main Effect:  $F(197,1)=8.6, p<.023$

# Results on Standard Math Test

True Means and SD for the standardized math pretest and posttest



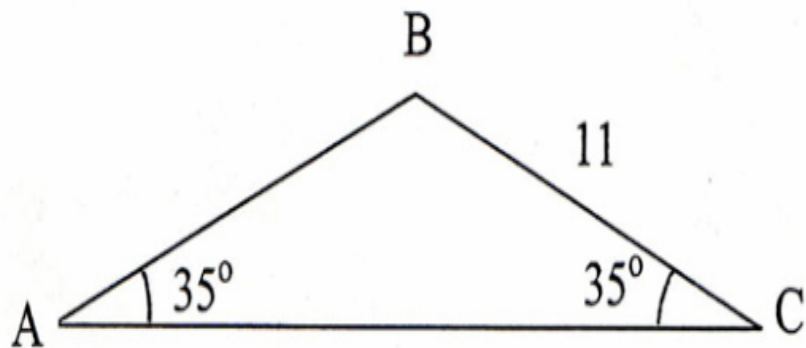
ANCOVA for Posttest with Pretest as Covariate, MFR, Wayang fixed factors:  
Wayang  $F(222,1)=3.8, p=.05$ ; Wayang x MFR ( $F(222,1)=7.9, p=.005$ )

Post-hoc Contrasts: *Wayang-MFR > all others*

# Differential Impact on Easy/Hard Items?

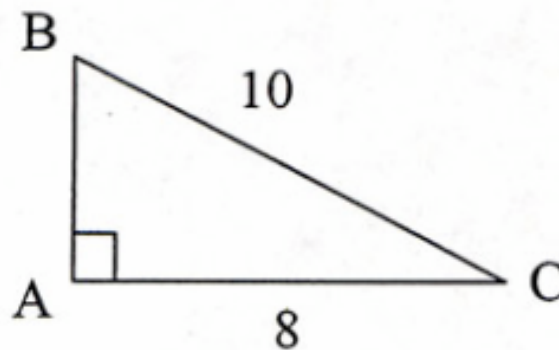
Easy/Hard is determined by item accuracy at pretest time

## Easier Test Items



What is the length of  $AB$ ?

## Harder Test Items

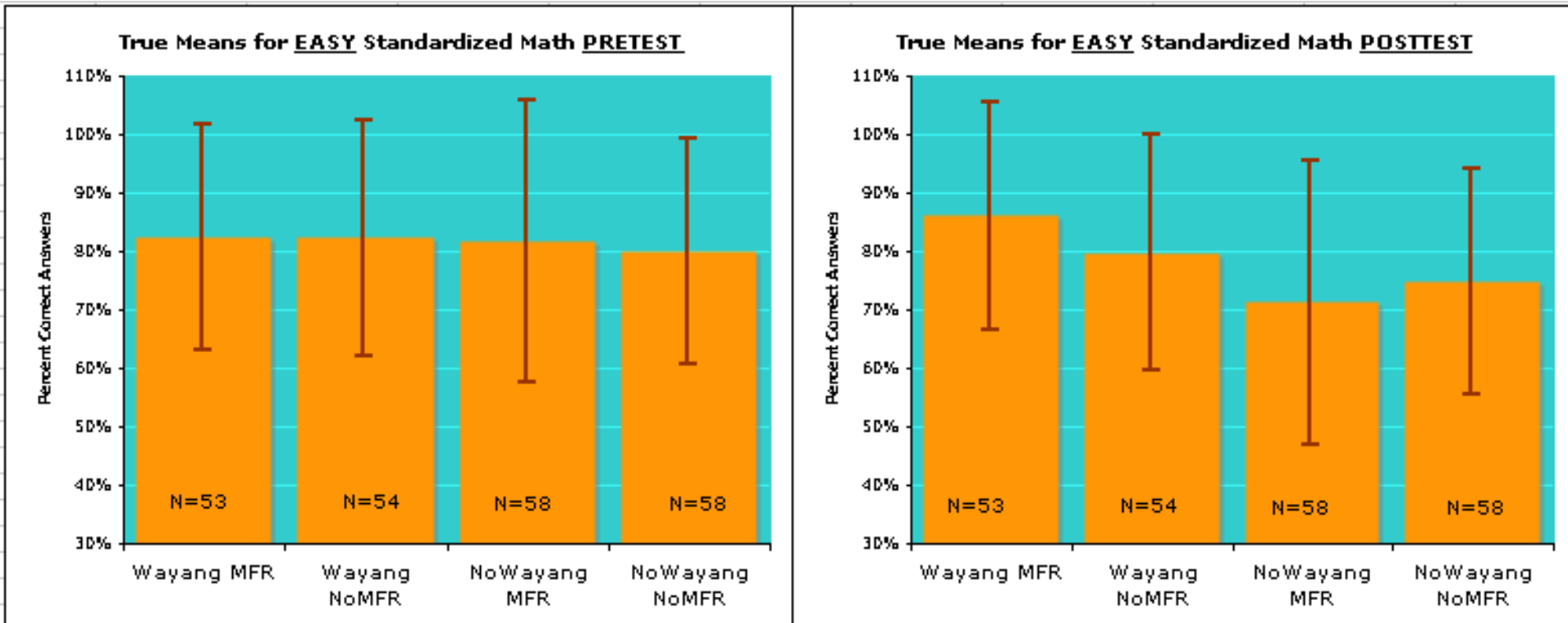


If  $BC$  is 10 and  $AC$  is 8, what is the measure of  $AB$ ?

Divided the tests in half: easy items and hard items

# Results on Standard Math Test (Easy Items)

True Means and SD for EASY items of the standardized pretest and posttest



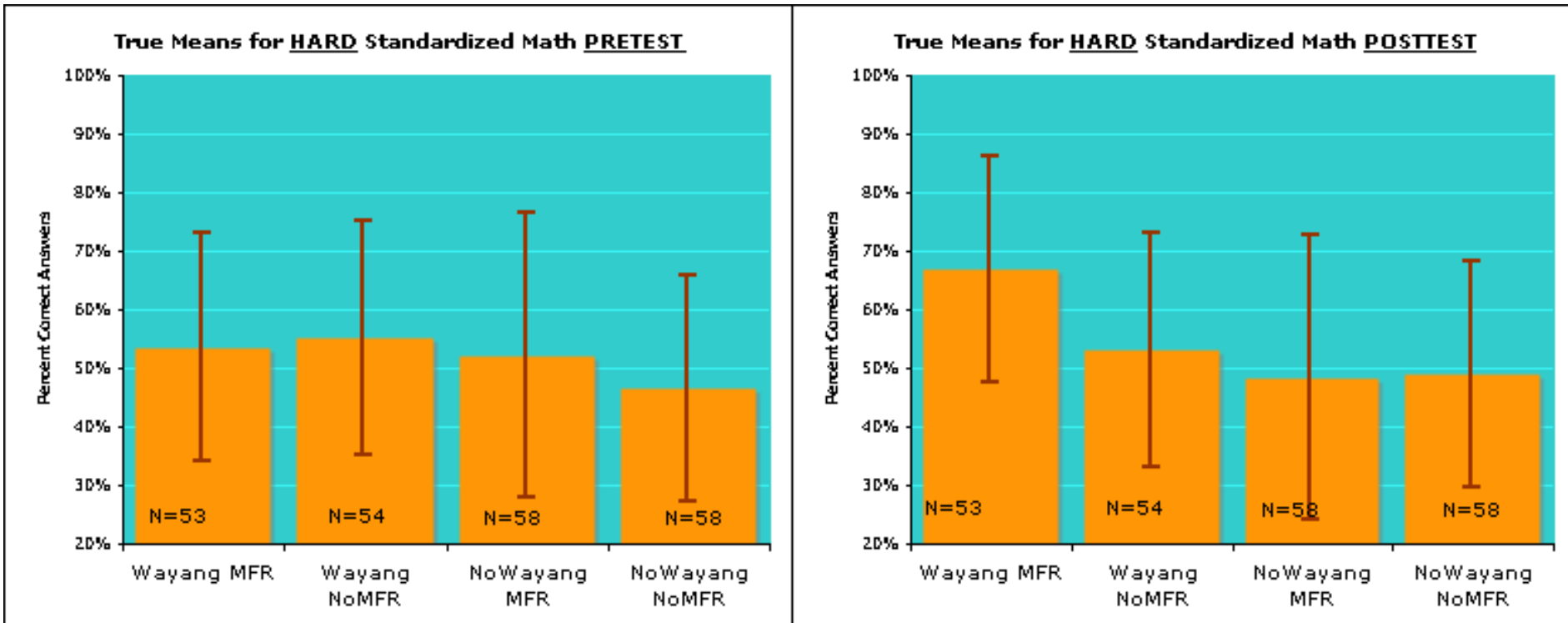
ANCOVA for Easy Posttest with Easy Pretest as covariate; MFR, Wayang fixed factors:  
Wayang  $F(2,22,1)=10.6$ ,  $p=.001$ ; Wayang $\times$ MFR  $F(2,22,1)=5.1$ ,  $p=.025$

Post-hoc Contrasts: *Wayang* > *no-Wayang*? Yes.

*Wayang-MFR* > *Wayang-NoMFR*? No.

# Results on Standard Math Test (Hard Items)

True Means and SD for HARD items of the standardized pretest and posttest



ANCOVA for Easy Posttest with Easy Pretest as covariate; MFR,Wayang fixed factors:

Wayang  $F(2,22,1)=6.8$ ,  $p=.01$ ; WayangxMFR  $F(2,22,1)=6.8$ ,  $p=.009$

**Post-Hoc Contrasts:** *Wayang > no-Wayang? Yes.*

*Wayang-MFR > Wayang-NoMFR? Yes.*



# Differential Effects?

For specific groups of students

- On Learning Disability Students?
  - Effects on IEP/Low Achievement students were not significant
- On Female students?
  - Gender effects were not significant
- Benefit of Fluency Training on math tests is for everyone
  - Or maybe need more exposure time to see differential effects
- Math Fluency improved for everyone
  - Or maybe need more exposure time to see differential effects



# Conclusions



- Immediate Conclusions:

- Math ITS that also train Math Fluency can teach better

- \* Freeing up memory resources

- \* Especially in hard math problems

- A math ITS can help improve Math Fluency

- \* The benefit goes both ways

- Far reaching implications:

- “Too easy” problems are not necessarily inappropriate

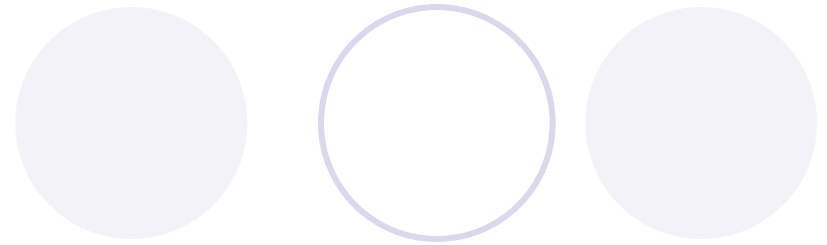
- \* As long as the goal changes to train speed.

- Addressing Basic Skills and Other Student Baggage

- \* Brought to the learning situation can lead to higher learning



# Future Work



- Lengthening the time of the Intervention
- Creating a Math Fluency module within the Wayang ITS
- Extending the idea of “Math Fluency”
  - Square root Fluency?
  - Equation solving Fluency?

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