CSI Regina: Teaching Mathematical Word Problems One Strategy at a Time ~or~

Cognitive Strategy Instruction (CSI), Schema-Based Instruction (SBI), Strategic Content Learning (SCL) for Students with Learning and Developmental Disabilities

Outcomes from a Multi-Site Action Research Project

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UNIVERSITY OF REGINA

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for supporting this research

Agenda

- Brief overview of Cognitive Strategy Instruction (CSI), Schema-Based Instruction (SBI) & Strategic Content Learning (SCL)
- SBI in an elementary classroom
- SCL in a high school classroom
- References

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Cognitive Strategy Instruction is…

- Cognitive Strategies: *directed goals* (intended to perform a definite function) and *consciously* controllable process (statable) that facilitate performance (do things better, easier, and quicker).
- *Guides* that serve to support or facilitate the learner as they develop internal procedures that enable them to perform the higher level operations.

Cognitive Strategy Instruction is…

- Types of strategies: visualization, verbalization, making associations, chunking, questioning, scanning, underlining, accessing cues, mnemonics
- Good strategy user – one who possesses a variety of strategies and uses these procedures to meet cognitive challenges

Cognitive Strategy Instruction in math word problems involves…

- Teaching students to *represent problems* by drawing a picture, constructing a chart or a table, imagining the salient features of a problem.
- Founded on a broad base of research that has validated its effectiveness *(evidence based practice)*
- With practice, students learn to figure out which approaches work and which do not work for solving problems in the same category.

CSI in solving math word problems involves…

- Students with learning disabilities generally have greater difficulty in:
  - representing mathematical problems
  - deriving goals for solving such problems
  - choosing among appropriate strategies for problem solving
  - engaging in self-monitoring processes,
  - Cognitive Strategy Instruction can assist with these areas.
- Cognitive Strategy Instruction can assist in student's learning and improve self-esteem

General Steps in Teaching CSI

Teach needed prerequisite skills*, activate prior knowledge

Describe the strategy to students (usually with the help of a prompt or cue)

Teach the cognitive strategy using small steps

Teacher models the strategy with think alouds

Students verbally rehearse the strategy, memorize (may have checklists)

Support the strategy. Students do guided practice with corrective feedback as necessary

Students have independent practice of strategy

Promote generalization and self-monitoring; gain mastery

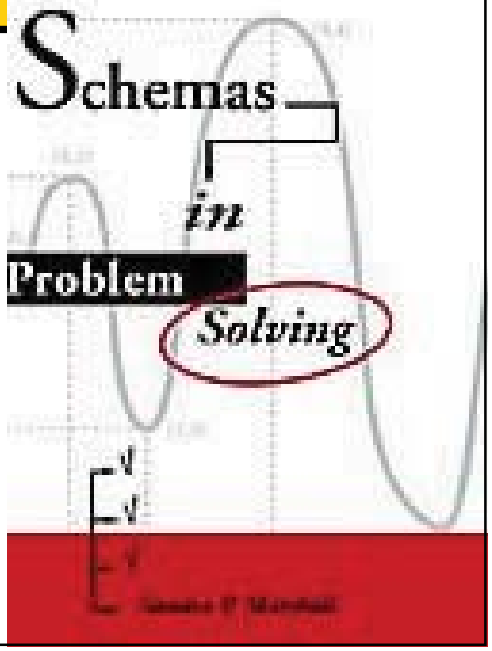
From: http://www.k8accesscenter.org/sharing/documents/HardyCognitive%20Strategy%20Instruction.ppt

from CSI to SBI

(from Cognitive Strategy Instruction to Schema-Based Instruction)

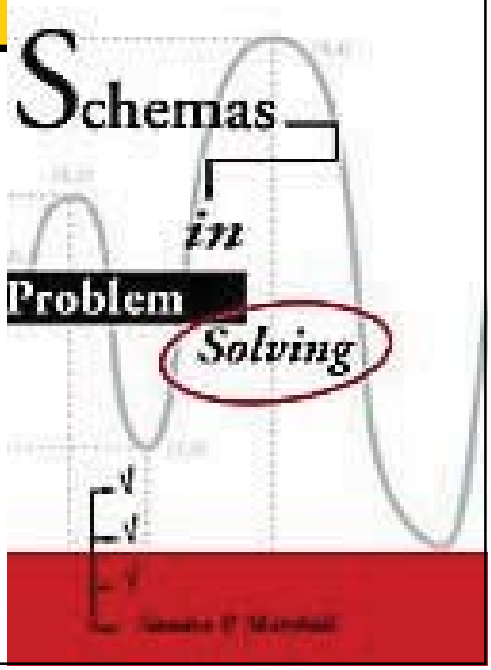
SBI (Schema-based Instruction)

- Sandra Marshall is the kind of *"guru"* in this area
- Conducted *very large survey* of the kinds of word problems there are in textbooks, etc.



SBI

- Developed *schemas* for them
- *Same schemas* can be used in elementary, middle years and secondary students!
- Most work in this area uses Sandra' findings



From CSI to SBI

"Ineffective instructional strategies may explain the poor problem-solving performance of students with learning disabilities.

One commonly used instructional approach is the "key word" strategy. For example, students learn that *altogether* indicates the use of the *addition operation,* whereas *left* indicates *subtraction*. Similarly, the word *times* calls for *multiplication,* and *among* indicates the need to *divide*.

However, the outcome is that students react to the cue word *at a surface level of analysis* and *fails to perform a deep-structure analysis* of the interrelationships among the word and the context"

From: Ping Xin, Y., Jitendra, A., Deatline-Buchma, A. (2005). Effects of mathematical word problem-solving instruction on middle school students with learning problems. ***The Journal of Special Education, 39*** (3), 181-193.

Example of SBI vs. CSI in Middle Years

From: Ping Xin, Y., Jitendra, A., Deatline-Buchma, A. (2005). Effects of mathematical word problem-solving instruction on middle school students with learning problems. ***The Journal of Special Education, 39*** (3), 181-193.

From CSI to SBI

"Overall, both groups were taught to follow the four-step general problem-solving procedure of reading to understand, representing the problem, and planning, solving, and checking.

However, the fundamental differences between the two conditions involved the second and third steps, with regard to how to plan and solve the problem. Specifically, the *SBI group was taught to identify the problem structure and use a schema diagram to represent and solve the problem,* whereas the CSI group learned to draw semiconcrete pictures to represent information in the problem and facilitate problem solving."

From: Ping Xin, Y., Jitendra, A., Deatline-Buchma, A. (2005). .Effects of mathematical word problem-solving instruction on middle school students with learning problems ***The Journal of Special Education, 39*** (3), 181-193.

Outcomes: CSI vs. SBI

TABLE 3. Percentage of Correct On-Target and Transfer Problems by the SBI and GSI Groups

	M		*SD*		*n*		
Test	SBI	GSI	SBI	GSI	SBI	GSI	ES[a]
Pretest	25.19	29.85	22.52	21.36	11	11	–0.21
Posttest	79.41	47.55	13.92	22.70	11	11	+1.69
Maintenance	87.29	45.45	14.51	17.97	9	11	+2.53
Follow-up	91.68	46.06	13.79	19.04	9	10	+2.72
Gen. pretest	25.45	35.00	29.11	22.69	11	11	–0.37
Gen. posttest	62.43	45.50	21.52	15.89	11	10	+0.89

Note. SBI = schema-based instruction; GSI = general strategy instruction; ES = effect size; Gen. = generalization.
[a]Effect size was calculated as the two conditions' mean difference divided by the pooled standard deviation (Hedges & Olkin, 1985). A positive ES indicates a favorable effect for the SBI condition; a negative ES indicates a favorable effect for the GSI condition.

From: Ping Xin, Y., Jitendra, A., Deatline-Buchma, A. (2005). .Effects of mathematical word problem-solving instruction on middle school students with learning problems ***The Journal of Special Education, 39*** (3), 181-193.

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Setting

- Grade 4 classroom
- 15 students
- 8 female and 7 male students
- 1 student diagnosed with FASD
- From January 2007 to May 2007
- Students were proficient at addition and subtraction

Type of Problems

1. Change Problems: contain a beginning set, ending set and change set. A passage of time is inferred and where we learn what the object is and the amount.
2. Group Problems: contain at least two smaller sets and a larger set. There is a part-whole relationship, the amount of the object does not change and there can be more than one object but there is an association between the objects.
3. Compare Problems: contain two compared sets and a difference set. The same unit of measure is used, the same objects and there is a difference in value between the two sets.

Approach

- Each problem type was taught as a one week unit
- *Students created the problems that we used using their names and real situations*
- A 9 question pre-test was given that included 3 of each problem type prior to starting these units
- A 3 question post-test was given at the conclusion of each one week unit on the problem type we had just studied
- A 9 question post-test was given at the conclusion of the 3 units and a review unit.
- 7 students completed a 3 question pre-test and post-test using the think aloud strategy
- All students participated in an interview after the final post-test.

Steps to Solving the Problems

1. Problem Identification: introduce the problem with all of the variables known and teach the parts of the problem and common characteristics
2. Problem Representation: introduce the schematic representation and how to map the information from the problem onto the representation. This is the step where the visual cue card is introduced to the students.
3. Problem Solution: once the information is mapped what steps to we take to solve the problem. We found 'T' for the Total and then we decide what operation to apply to solve the problem.

Change Problems

Step 1: Identification

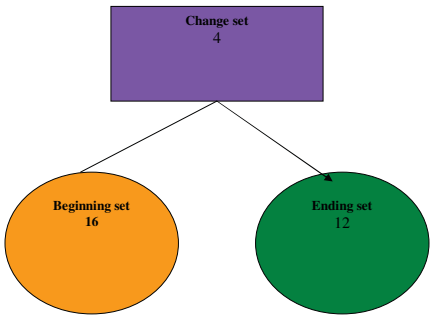
- Introduce the change problem using an example story situation with all quantities known
- Identify the sets in the problem: beginning, ending and change
- Discuss as a class how we could identify the sets – chose colour coding
- Explore a few more examples
- Students wrote their own story situations

- **Example: Mrs. HD had 16 paper fish in her fish bowl (beginning set). She lost 4 of them when she was in the gym (change set). Now Mrs. HD has 12 paper fish (ending set).**

Change Problems

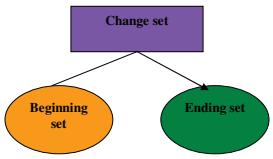
Step 2: Representation

- Introduce schemata diagram to the students
- Discuss how to map information from the problem to the diagram
- Students practice mapping information from problems onto schemata diagrams using their problems
- Visual Cue Card is given to students



Change Problem Visual Cue Card

Change Problem



1. Change problems are about one thing.
2. From past to present

Change Problem
T = Total

Finding the Total:

If the problem ends with **more** than it started with, then the **ending set** is the **total.**

If the problem ends up with **less** than it started with, then the **beginning set** is the **total.**

ADD or SUBTRACT?

When the **total is *unknown*, ADD** to find the total.

When the **total is *known*, SUBTRACT** to find the other amount.

From *Schemas in Problem Solving* (p.135) by S.P. Marshall, 1995, New York: Cambridge University Press. Representation adapted by permission.

Change Problems
Step 3: Solution

- Identify the set that is the total, represent it with a T
- The total is the set with the greatest amount.
- In a change problem the beginning or ending set can be the total.
- Once the total is found then we can determine the operation needed
- When the total is unknown, ADD to find the total
- When the total is known, SUBTRACT to find the other amount
- Students completed 18 practice problems in the duration of this unit

Group Problems

Step 1: Identification

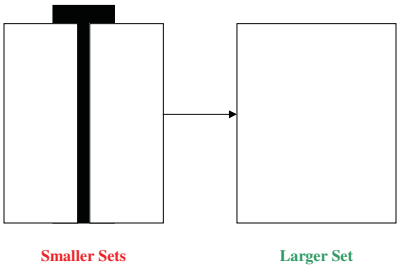
- Introduce the group problem using an example story situation with all quantities known
- Identify the sets in the problem: at least 2 smaller sets and one larger set
- Discuss as a class how we could identify the sets – chose colour coding
- Explore a few more examples
- Students wrote their own story situations

- **Example: Tina had 9 tubes of lip smackers in her purse (larger set). 6 tubes were glittery (smaller set) and the remaining 3 were fruit flavored (smaller set).**

Group Problems

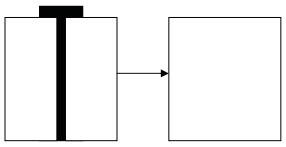
Step 2: Representation

- Introduce schemata diagram to the students
- Discuss how to map information from the problem to the diagram
- Students practice mapping information from problems onto schemata diagrams using their problems
- Visual Cue Card is given to students



Group Problem Visual Cue Card

Group Problem



Smaller Sets Larger Set

1. The object amount does not change
2. Time does not matter
3. Not all the same object

Group Problem
T = Total

Finding the Total:

The **larger** group set is always the **total**.

ADD or SUBTRACT?

When the **total is *unknown***, **ADD** to find the total.

When the **total is *known*, SUBTRACT** to find the other amount.

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Group Problems

Step 3: Solution

- Identify the set that is the total, represent it with a T
- The total is the set with the greatest amount.
- In a group problem the larger set is always the total.
- Once the total is found then we can determine the operation needed
- When the total is unknown, ADD to find the total
- When the total is known, SUBTRACT to find the other amount

- Students completed 24 practice problems in the duration of this unit

Compare Problems

Step 1: Identification

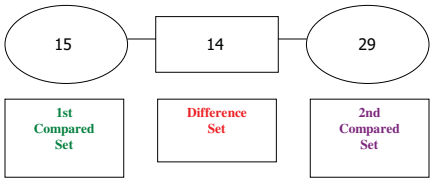
- Introduce the change problem using an example story situation with all quantities known
- Identify the sets in the problem: 1st and 2nd compared sets and difference set.
- Discuss as a class how we could identify the sets – chose colour coding
- Explore a few more examples
- Students wrote their own story situations

- **Example: Dale has 15 computer games (1st compared set) and Perry has 29 (2nd compared set). Perry has 14 more computer games than Dale (difference set).**

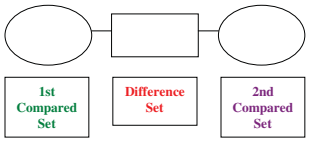
Compare Problems

Step 2: Representation

- Introduce schemata diagram to the students
- Discuss how to map information from the problem to the diagram
- Students practice mapping information from problems onto schemata diagrams using their problems
- Visual Cue Card is given to students



Compare Problem Visual Cue Card

Compare Problem	Change Problem T = Total
 1. Compare problems are about one thing 2. Time does not matter	*Finding the Total:* The **larger** set (1st or 2nd compared set) in the compare story problem is the total. *ADD or SUBTRACT?* When the **total is *unknown*, ADD** to find the total. When the **total is *known*, SUBTRACT** to find the other amount.

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Compare Problems

Step 3: Solution

- Identify the set that is the total, represent it with a T
- The total is the set with the greatest amount.
- In a compare problem the 1st or 2nd compared set can be the total.
- Once the total is found then we can determine the operation needed
- When the total is unknown, ADD to find the total
- When the total is known, SUBTRACT to find the other amount

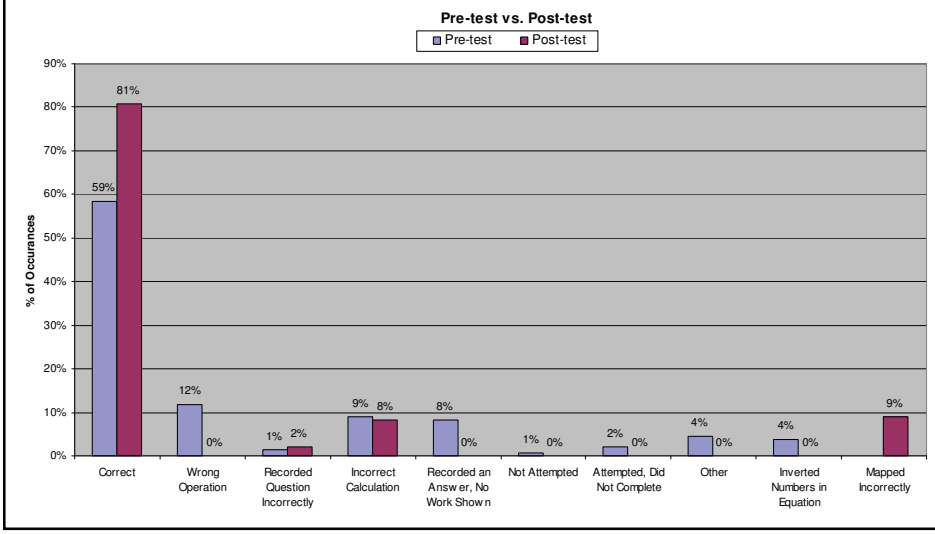
- Students completed 18 practice problems in the duration of this unit

Reviewing Change, Group and Compare Problems

- Reviewed the different problems and their characteristics
- Acted the problems out
- Sorting activities
- 15 practice problems were completed.

Pre-data and Post-data

Grade 4



Reflections

- Allowing the students an opportunity to create the problems encouraged them to take more chances
- Teach from problem solving
- Encouraging students to take control of their learning and to think about the process

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Strategic Content Learning is…

"A unique characteristic of SCL is that, in contrast to other strategy training models, *task specific strategies appropriate for individual students are not determined in advance.* Instead, students and instructors *establish an understanding of the task, define task goals*, and then, using task goals as a foundation for decision making, select, adapt, or invent task-specific strategies. Factors that go into decision making about strategies also include the specific difficulties students have with the task"

From: http://www.ecps.educ.ubc.ca/faculty/Butler/Confer/AERA%201996%20Instructional%20Analysis.pdf

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Who – All Students Diagnosed with Specific Learning Disabilities

Student Name (Pseudonym)	Age	IQ (full scale)	Area of Difficulty (Diagnosis)
Hustin 	14	Average 	- math facts - math reasoning - fine motor - spelling - written language
Jack	15	Average	- fine motor - spelling
Jay	14	Average	- math facts - math reasoning

Who – All Students Diagnosed with Specific Learning Disabilities

Student Name (Pseudonym)	Age	IQ (full scale)	Area of Difficulty
Marry	14	Low Average	- math facts - math reasoning
Matt 	14	Low Average 	- fine motor - math reasoning - spelling - reading comprehension
Tony	14	Average	- reading comprehension - math reasoning - written expression

Why – Survey Comments

- Question - How do you feel about word problems?
  - Hustin has a little bit of trouble with word problems
  - Jack finds word problems "Ok"
  - Jay says "sometimes they are easy and sometimes they aren't"
  - Marry "dislikes" word problems and finds them difficult
  - Matt Finds word problems "stupid" and "dumb"
  - Tony loves word problems and finds them "not hard at all"
- Question – What is your way to attack word problems?
  - Hustin says he "gets all the facts" and then he "does it in steps"
  - Jack says he "wings it"
  - Jay says he "writes down important facts, and does the question"
  - Marry stated her strategy as "question, facts, solve, sentence"
  - Matt says he "just solves them"
  - Tony says he "circles key words in the problem"

How Research was Conducted

- Initial interview
- Large pre-test
- Vocabulary of word problems (flash cards) – Cognitive Strategy Instruction
- As a class – decided how to set up word problems – represent steps (problem, facts, calculate, check, sentence) – Strategic Content Learning
- As a class – decide how to grade word problems (guided teaching – Strategic Content Learning) – represent 1, record problem 1, facts 1, correct equation 1, correct answer 1, each alternative answer 1 each, check 1, sentence 1 (minimum of 7 marks each)
- Think aloud strategy – learn and get used to it as a teaching strategy – All 3 - Cognitive Strategy Instruction, Schema Based Instruction, Strategic Content Learning
- Taught different types of questions in isolation (before each there was a pre-test and after each a post-test on the specific type of word problem)
- Taught Consecutive number problems (concrete to abstract) – All 3 Strategies
- Perimeter questions (concrete to abstract)
- Coin word problems (concrete to abstract)
- Setting up equations to solve (concrete to abstract)
- Large post-test
- Post-interview (more detailed)

Think Aloud Strategy

- Example: Find the ages of four friends if their ages are consecutive numbers. All you know about them is that when you add up their ages it is equal to 90.
- Problem: What are the four friend's ages?
- Facts: ages are consecutive #'s, and they add up to 90

X = the youngest, or 1st friend's age
X + 1 = the 2nd friend's age
X + 2 = the 3rd friend's age
X + 3 = the 4th friend's age

- Calculate: X + X + 1 + X + 2 + X + 3 = 90

4X + 6 = 90
4X = 84
X = 21

- Other Friends: X + 1 = 22, X + 2 = 23, X + 3 = 24
- Check: 4(21) + 6 = 90

84 + 6 = 90
90 = 90

- Sentence: The ages of the friends are 21, 22, 23, and 24.

Consecutive Number Problems

Ex: Kelly picked 3 numbers. She hinted that the 3 numbers were consecutive and their sum was 78. Find the numbers.

- Taught with concrete representational, abstract model – all three "Cognitive Strategy Instruction, Schema Based Instruction, and Strategic Content Learning" agree this is a good teaching strategy
  - Concrete – Pennies on desk
    - Notice how many coins you have to add to get to the next consecutive number
    - Work in pairs (figure out consecutive numbers giving the partner 2 clues – what the number of coins add up to and the # of consecutive numbers) *keep #'s small
  - Representational – Pennies still on desk
    - decided the smallest # could be represented as "x".
    - Looking at the pennies we decided the second # could be "x + 1", then "x + 2".
  - Abstract – Pennies gone
    - Worked on practice questions from both the text book and extra made-up problems (incorporated their names into the problems for interest)
- Started the technique of "Directed Questions" to assist with doing the word problems – Strategic Content Learning strategy
- *** Used this throughout the unit – and CONTINUE TO USE ***

Perimeter Problems

Ex: Find the length and width of Scott's office if the perimeter is 18 m, and the length is 3 m longer than the width.

- Taught with concrete representational, abstract model
  - Concrete – Use meter sticks and rulers
    - Defined the word "Perimeter" as the distance around something
    - Measured the perimeter of classroom objects with meter sticks and rulers
    - Worked in pairs (figure out the side lengths of a triangle in the room giving the partner 2 clues – what the perimeter added up to and two of the side lengths)
  - Representational – Still have meter sticks and rulers
    - Given the problem that a rectangle in the room had a perimeter of 30 cm, and the length was 5 cm longer than the width
    - Decided that one side of an object could be represented as "x"
    - As long as we have a relation to the other sides, we could represent all sides of the shape with relation to "x" (x = width, x + 5 = length)
  - Abstract – Measuring tools gone
    - Worked on practice questions from both the text book and extra made-up problems (incorporated their names into the problems for interest)

Coin Word Problems

Ex: Lara has $0.85 in nickels and dimes. She has 2 more nickels than dimes. How many nickels and dimes does she have?

- Taught with concrete representational, abstract model
  - Concrete – Dimes and nickels on desk
    - Looking at coins determined the difference between number of coins and value of coins
    - Figured out a formula for "value" of coins
  - Representational – Dimes and nickels on desk
    - Work in pairs (figure out how many of each coin their partner had giving the partner 3 clues – what type of coins were used, the total value of the coins, and how many more dimes/nickels they had compared to the other coin)
    - Decided the type of coin we had less of could be represented as "x".
    - Decided the other coin could be represented as "x + ___"
  - Abstract – Coins gone
    - Worked on practice questions from both the text book and extra made-up problems (incorporated their names into the problems for interest)

Setting up Equations to Solve

Ex: Jeff picked 2 numbers for his classmates to figure out. He hinted that one number was 5 more than the other number, and that 3 times the first plus twice the second was 30. Find the numbers.

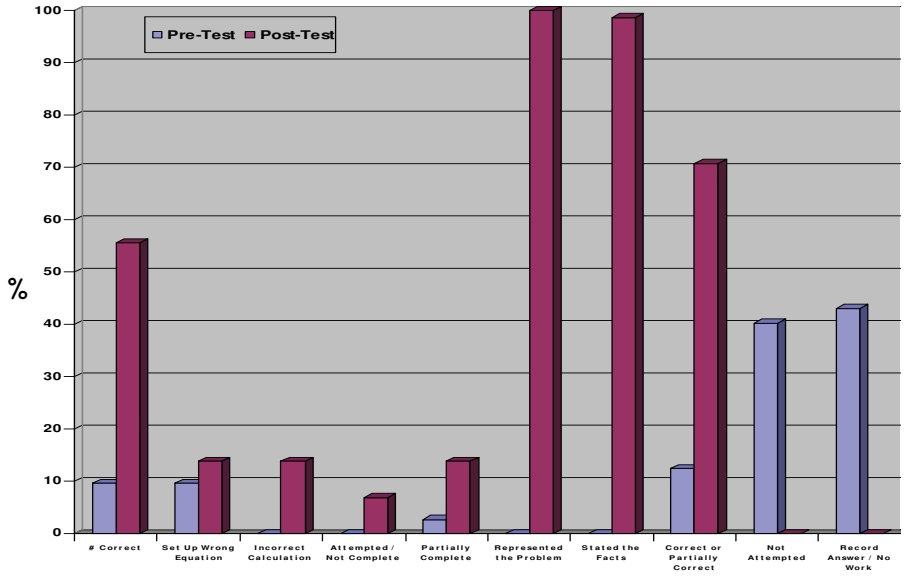
- Taught with concrete representational, abstract model
  - Concrete – Pencils, pens and flash cards on desk
    - Vocabulary of common word-problems (flash cards)
    - Took 4 pencils and 3 pens on desk and told them that the total cost was $9.75, and that the pen was 3 times as expensive as the pencil.
    - Worked at writing "math sentences" ("cost of 4 pencils + cost of 3 pens = $9.75")
  - Representational – Pencils, pens and flash cards on desk
    - As a class came up with representing the cost of a pencil as "x", and the pen as "3x"
    - Change the "math sentence" into a formula to solve
      (4(x) + 3(3x) = 9.75)
  - Abstract – Only flash cards on desk
    - Worked on practice questions from both the text book and extra made-up problems (incorporated their names into the problems for interest)

Pre-Data and Post-Data

Factors Analyzed as an Overall Class

- **Number Correct** – strictly correct or incorrect (want to increase)
- **Set up wrong equation** – tried an equation or formula, but it was not correct (Ex: perimeter = length + width) (want to increase)
- **Incorrect calculation** – had the question set up properly, but made a mistake when doing the calculation (Ex: perimeter = 2(L) + 2(W) but multiplied incorrectly) (want to increase – because at least they are on the right track)
- **Attempted not complete** – the student tried a few strategies to answer the question, but did not record an answer (want to increase because at least they tried)
- **Partially complete** – answered part of the question correctly, but not entirely finished or correct (Ex: the question asks for four consecutive numbers and he/she got some numbers correct but not all, or only answered for the first consecutive number but not the rest) (want to increase)
- **Represented the problem** – the student divided the problem into small steps and used some type of symbol to show the parts of the word problem (Ex: when the student was going to calculate the answer, he/she drew a calculator) (want to increase)
- **Stated the facts** – the student wrote down the important facts from the problem (want to increase)
- **Correct or partially correct** – added together the overall number of correct or partially correct answers (want to increase because the student is showing a better understanding of the word problem)
- **Not attempted** – left the question blank (want to decrease)
- **Record answer, no work** – guessing answer or not showing any work, but writes down an answer (want to decrease)

Pre-Data and Post-Data



Reflections

- Pro's
  - Saw a difference in the student's attitudes towards word problems (classroom culture)
  - Students enjoyed being part of deciding how to set up word problems and how to mark them (owned it)
  - Directed questions increased students' self-confidence because he/she came up to the conclusion (I did not "tell" how to do it)
  - Teaching/modeling using "Think alouds"
  - Concrete (manipulative), representational, concrete worked well for these students
  - Students enjoyed seeing their names in the assignment questions
  - Teaching types of problems in isolation so the students focus on one type at a time
- Con's
  - Took longer to teach the Problem Solving Unit than usual
  - Difficult to re-teach when students miss class

Reflections – Post Interview

- How did you feel about getting math word problems correct?
  - "I felt really good" "Halleluiah. Another question done"
- What have you improved on?
  - 5 out of 6 said how to set it up (5 steps)
  - Matt said, "Liking them" (remember he was the one that said they were "stupid & dumb" when we started ☺)
  - Hustin said "working on consecutive number questions"
- What will you continue to do?
  - All students said they would continue to use the 5-step method
- How did you like the concrete strategies (hands on)?
  - 5 out of 6 students said it was helpful
  - Jack said he "wasn't really sure" if he liked it
- How did you like representing the parts of a problem with symbols?
  - 5 out of 6 students said it was helpful, Jack commented that "I felt like it took a lot of time, but oh, yes, it did [help]"
  - Matt would "just rather do the question"
- What would you recommend to someone struggling with word problems?
  - 4 out of the 6 students said they would recommend the 5-steps
  - 2 out of the 6 students said they would recommend the hands-on strategies

Agenda

- Brief overview of Cognitive Strategy Instruction & Schema-Based Instruction
- SBI in an elementary classroom (Kelly)
- SBI/SCL in a high school classroom (Lara)
- References

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