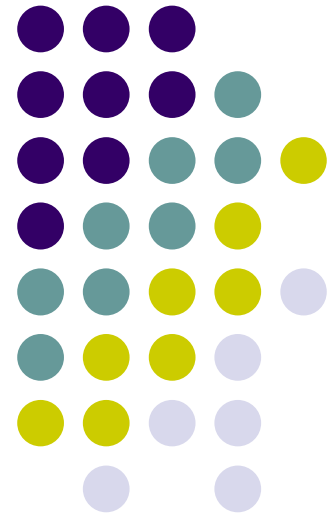
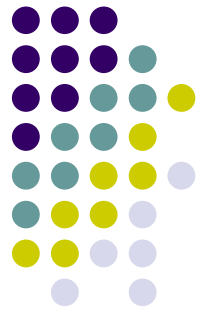


Transfer of Learning: Implications for Teaching Basic Science

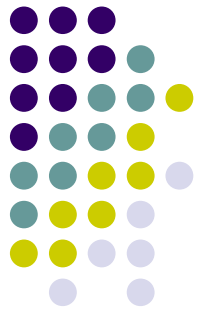
Geoff Norman, Ph.D
McMaster University



Transfer



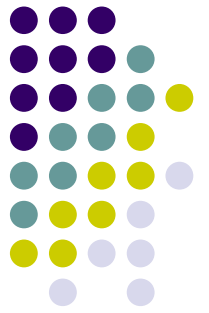
- What is it?
- Why do we need to worry about it?
- How does it work / not work?
- Why is it so hard?
- What can we, as teachers, do about it?



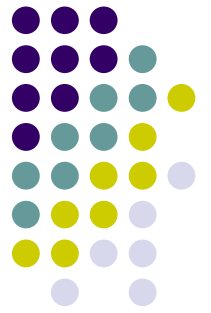
What it's not

- It's not transference (psychoanalysis)
- It's not knowledge translation (informatics)
- It's ***TRANSFER*** (cognitive psychology)

What is it?



Transfer = applying what was learned to new situations (Mayer, 2004)



Views of Transfer

General Transfer (1900-1915....)

Subjects like Latin, algebra teach general “habits of mind”

(disproved by Thorndike, 1913)

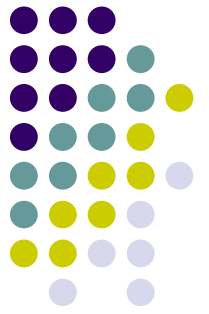
Specific transfer (Behaviorism, 1910--> Now)

Learned concepts can only be transferred if new behavior = old behavior

(disproved by Judd, 1908, Wertheimer, 1959, Pressley 1990)

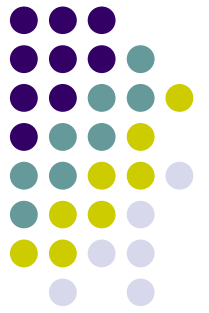
Intermediate / hybrid transfer

Learned concepts can be applied (with difficulty) to new, dissimilar problem situations



Why does it matter?

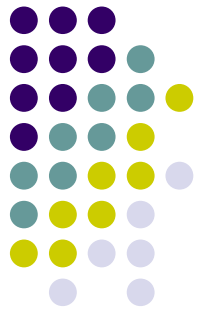
- Students spend 1.5-3 years learning basic science
- Teachers hope that these concepts can be used to solve clinical problems
- Can they?



STUDY 1

(Woods, Brooks, Norman, 2003)

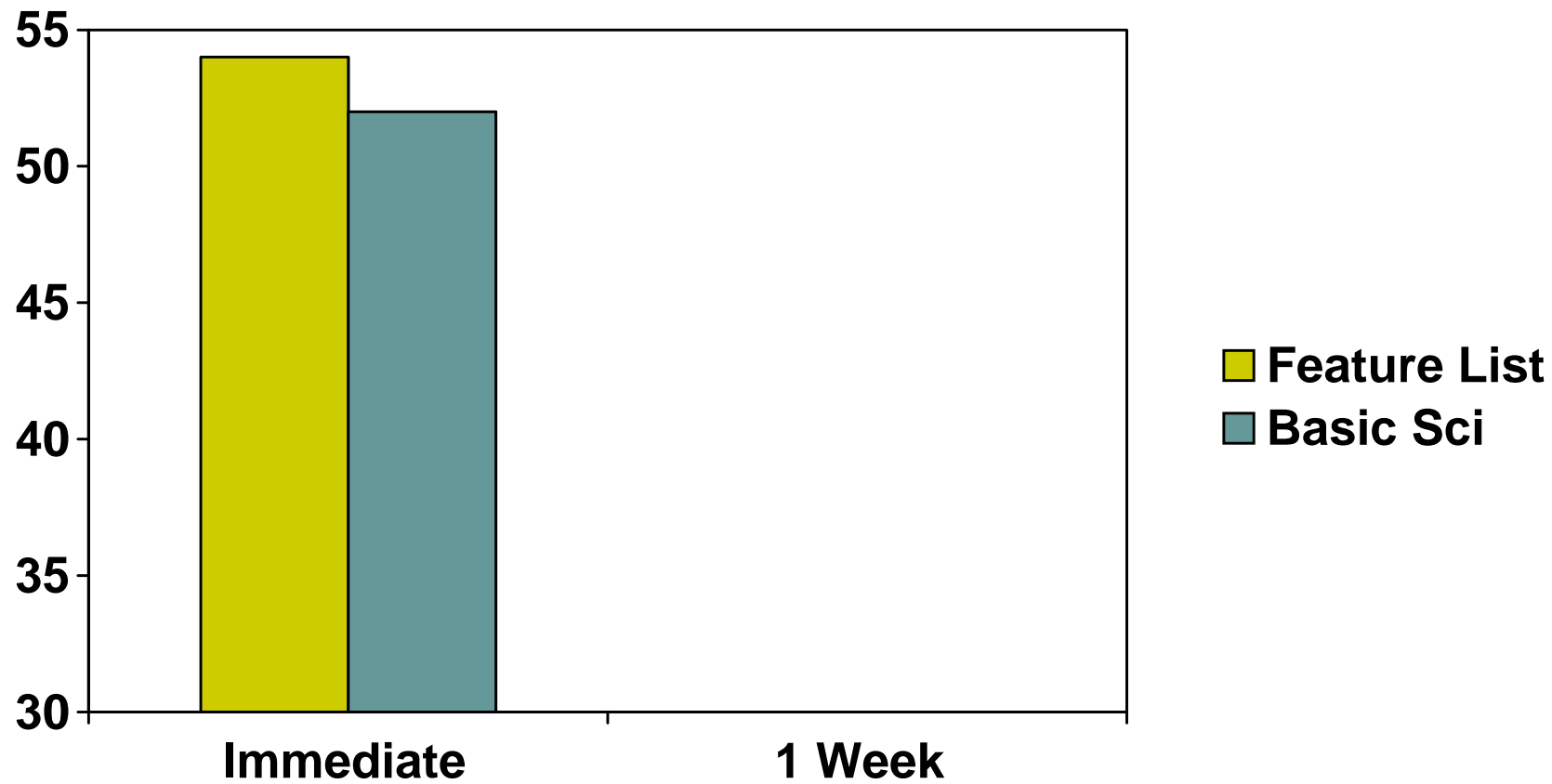
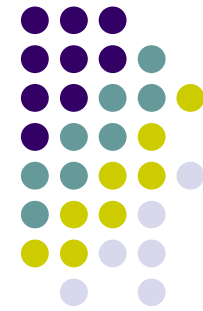
- 4 neurology / muscular diseases
- 36 medical students
- Basic Science or Symptom/Disease probability



Measurement

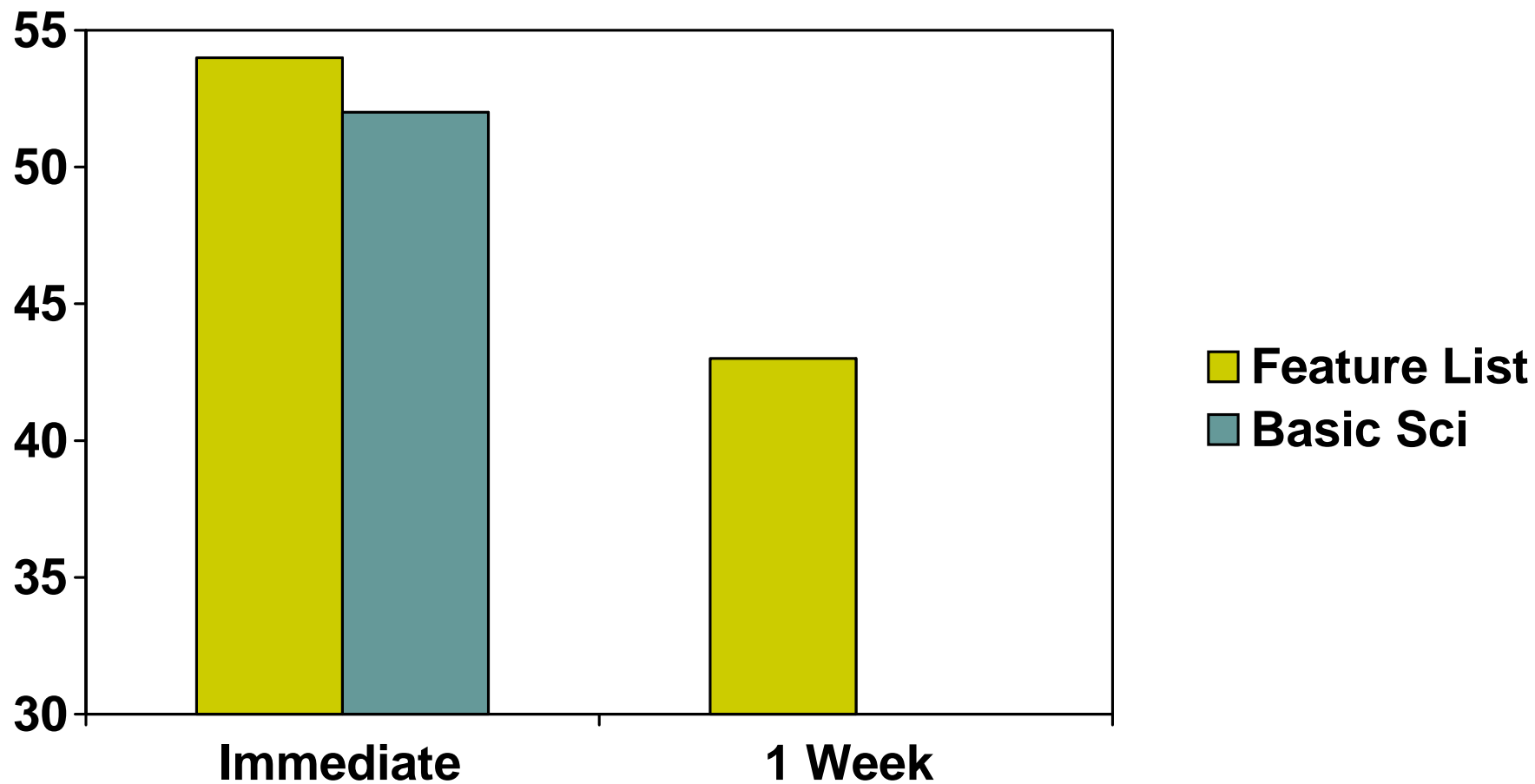
- Diagnostic Test
 - 15 cases, 4-6 features
- Administered at 0, 7 days

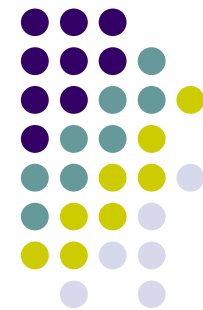
Score on Dx Test



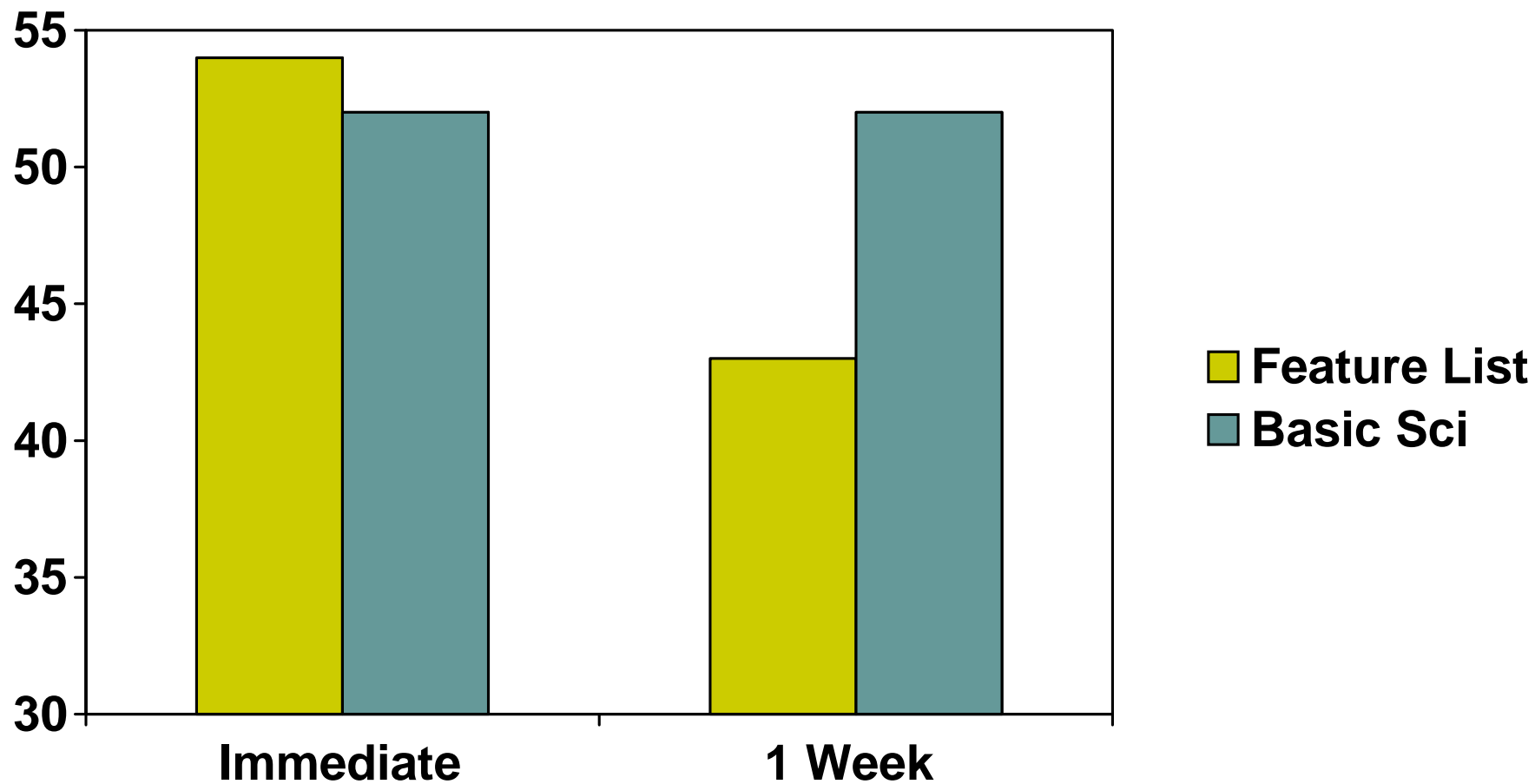


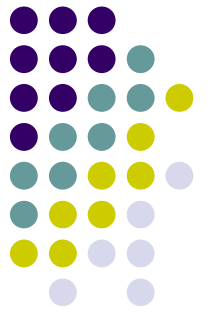
Score on Dx Test



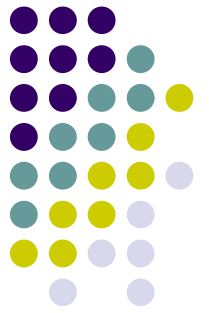


Score on Dx Test





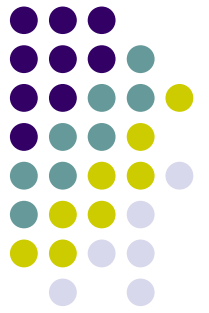
- All students in Basic Science condition had learned Basic Science to mastery
- But average score on diagnostic cases 50%



Pilot study 2

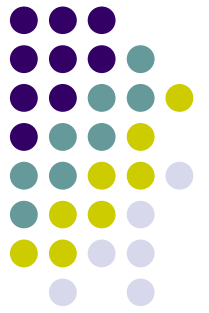
- 8 high performing undergrad (Health Sciences) students.
- 3 principles (Laplace, Poiseuille, Starling)
- 12 test cases

- Score
 - 0= wrong answer,
 - 1= right answer, wrong explanation
 - 2 = right answer, right but poor explanation
 - 3= right answer, good explanation



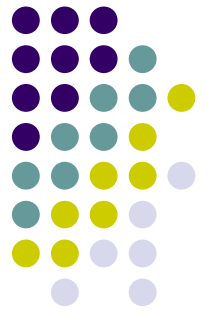
Laplace's Law

In a cylindrical vessel, the wall tension is proportional to the radius and pressure exerted by the vessel contents. This can be expressed as $T = PR$ where T is wall tension, P is pressure exerted by the contents, and R is the radius of the vessel.

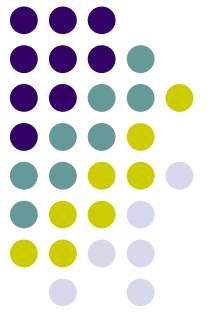


- **A 72 year old female has been diagnosed with an aneurysm (dilatation) of the aorta. The doctor tells her that if it grows to 5 cm in diameter she will need surgery to prevent bleeding. Explain why the increasing diameter is a problem.**

Average Score

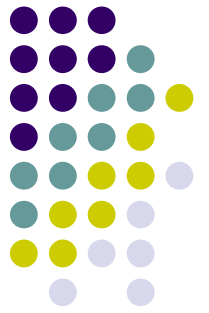


$$15.2/36 = 42\%$$



Typical teaching strategies

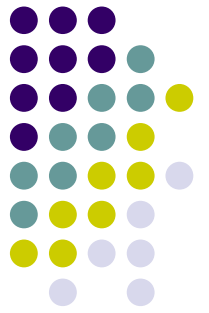
- Teach the principle and assume they can apply it
- Teach the principle, then give an example
- Teach the principle then give several examples to “solve” (end of chapter)



Effectiveness of Transfer

- Principle alone 5%
- Principle + Example 25%
- Principle + Multiple Examples 47%

(Quilici, 1996, Catrambone, Gentner 2003)



Example case + Principle:

e.g. $\Pr(D|S) = \Pr(S|D)/\Pr(D)$

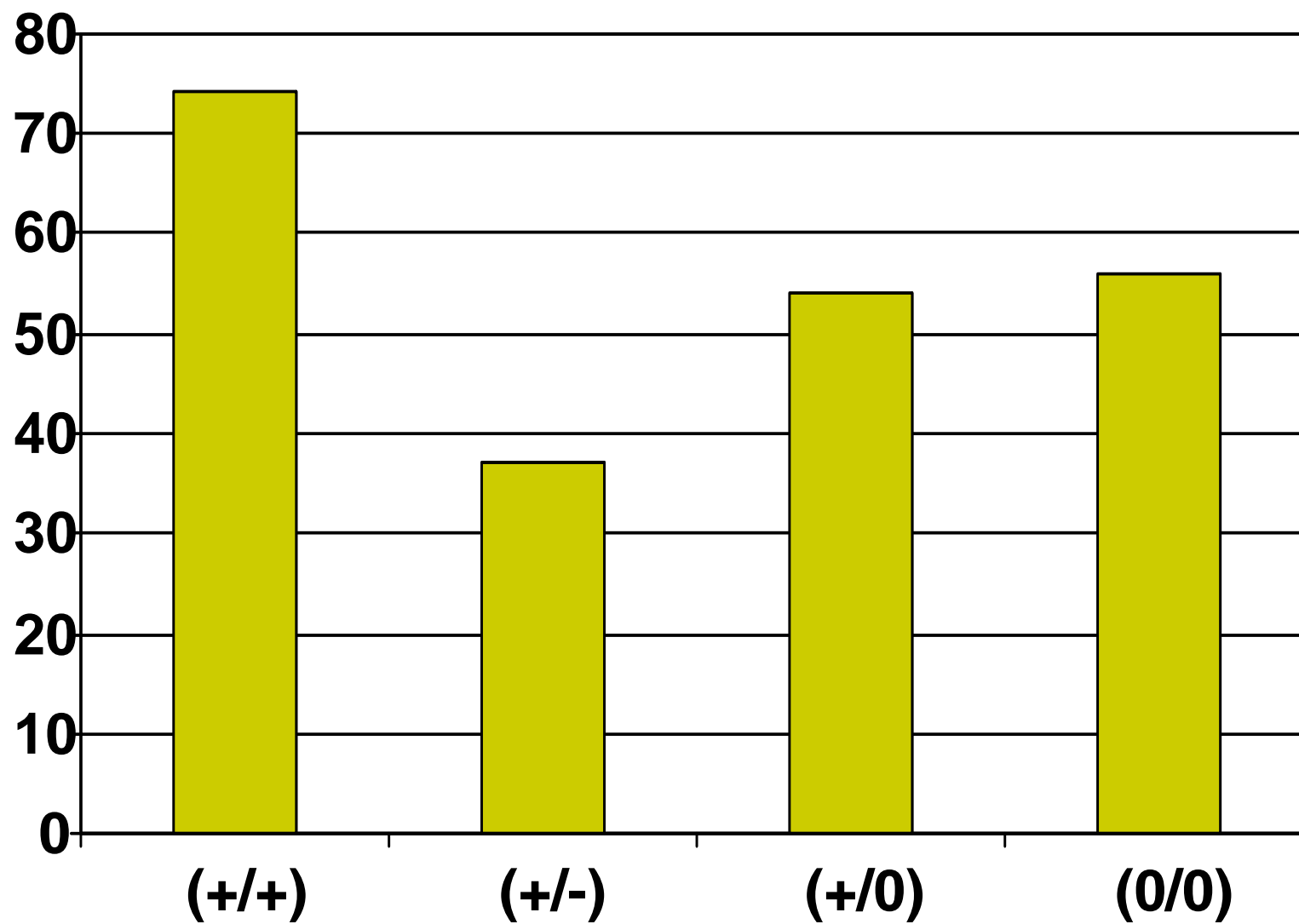
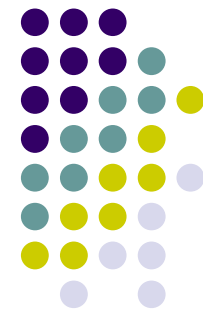
Test Cases:

(+ / +) same situation, consistent solution

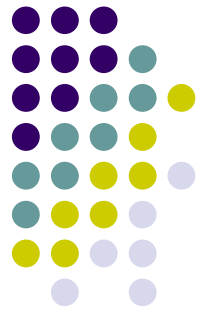
(+ / -) same situation, inconsistent sol'n

(+ / 0) same situation, unrelated sol'n

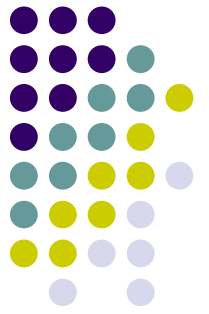
(0 / 0) diff situation, diff solution



Why is it so hard to transfer?



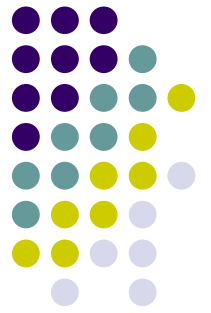
- An example (Holyoak, 1985)



Practice problem

- A general wishes to capture a fortress located in the centre of a country. There are many roads radiating from the fortress. All have been mined so that, while small groups of men can pass over the roads safely, a large force will detonate the mines. A full-scale direct attack is therefore impossible. The general's solution is to divide the army into small groups, send each down a different road, and have the groups converge simultaneously on the fortress.

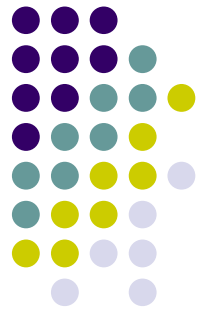
Test problem



You are a doctor faced with a patient who has a malignant tumour in his stomach. It is impossible to operate on the tumour. X-rays can be used to destroy the tumour. If sufficient rays reach the tumour all at once, the cancer cells will be killed, but surrounding tissue will be damaged as well. How can you arrange the procedure to destroy the tumour cells without severely damaging the surrounding tissue.

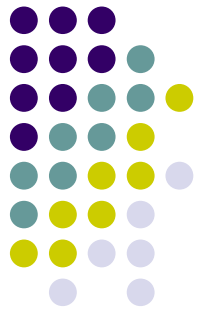
Gick & Holyoak, 1980

Transfer and Context Specificity



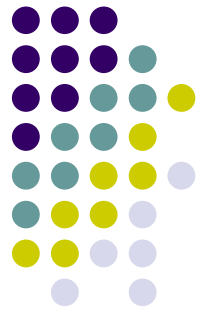
- The initial solution (multiple simultaneous paths) was learned in, and stored with the problem context (fortress and army).
- To solve the new problem, must recognize that the old problem was analogous to the new, despite different contexts
- To recognize analogy, we must recognize similarity in deep structure

this rarely happens.....



“...during early learning, the principle is only understood in terms of the earlier example... the principle and example are bound together. Even if learners are given the principle or formula, they would use the details of the earlier problem in figuring out how to apply that principle to the current problem”
(Ross, 1987)

Why are the examples so seductive?



DUAL - PROCESSING THEORIES

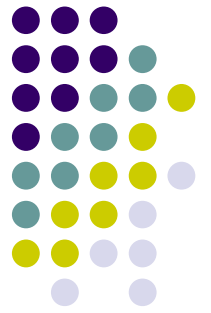
Substantial evidence that categorization / concept formation proceeds by two distinct neural mechanisms:

System 1: Fast, unconscious, perceptual,
contextualized/concrete

System 2: Slow, conscious, analytical, rule-based,
abstract

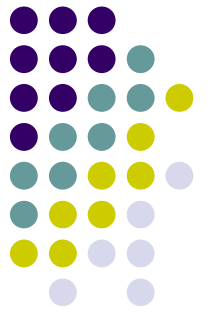
To transfer, 2 >>1

Transfer and “Deep Processing”



- Teaching strategies must be directed at encouraging learner to use System 2 process:
 - approach the problem at the level of “deep structure” - concepts, principles, mechanisms
 - Try to understand the problem, not just memorize it
 - Ignore specific surface details

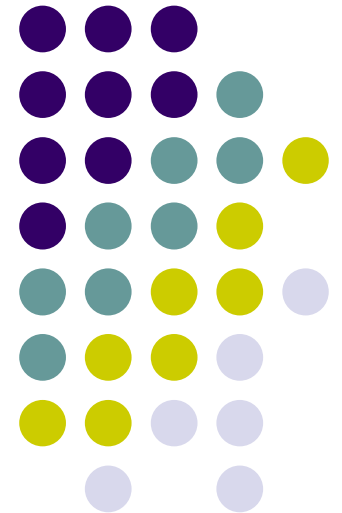
How do we achieve this?

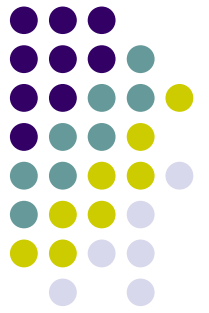


Effective Strategies

- For teaching
- For illustrative examples
- For practice
- For assessment

Teaching Strategies

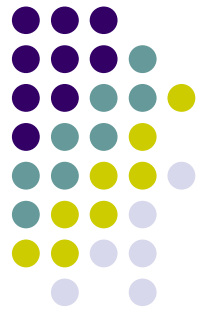




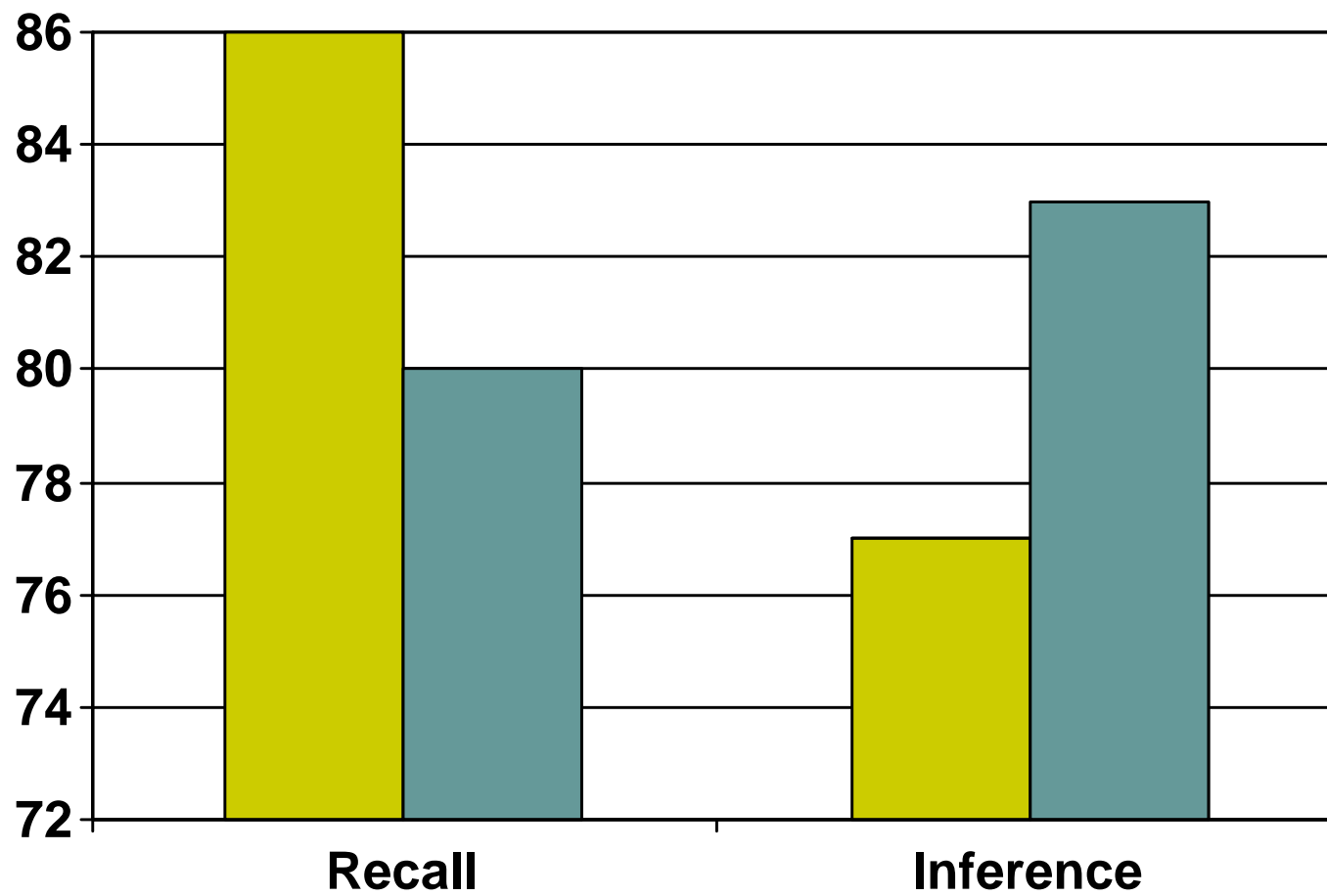
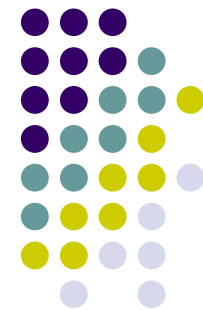
Effective Teaching Strategies

- Analogy
 - Donnelly & McDaniel, 1993; Krebs, Dore & Norman
- Imbedding principle in example
 - Ross & Kilbane, 1997
- Active Learning/ PBL
 - Needham & Begg, 1987

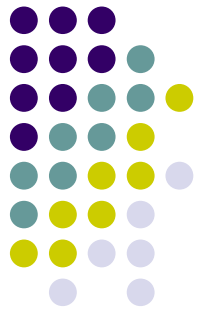
Analogy in Learning Science (Donnelly & McDaniel, 1993)



- 48 students, 12 concepts
- Literal description of concept vs. description + analogy in familiar domain
 - (e.g. pulsar star and lighthouse)
- 24 MCQs; 4/concept, 12 basic +12 inference



■ Literal
■ Lit + Anal

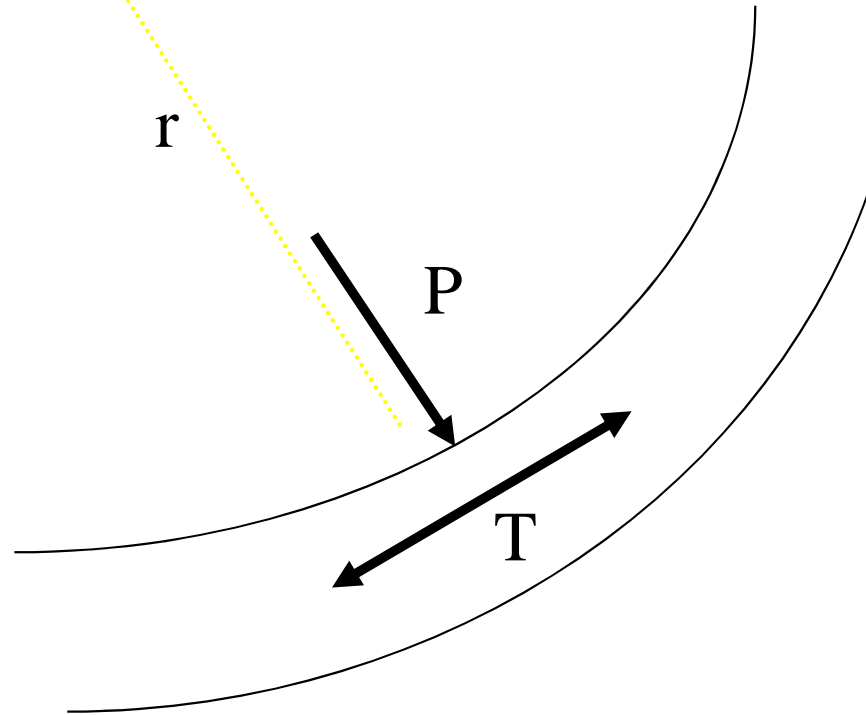
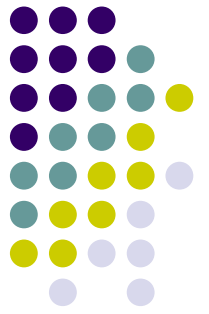


Use of Mechanical Metaphor in Medical Education

(Krebs, Dore, Norman, 2006)

- Three “Laws”
 - Laplace , Right Heart Strain, Starling
- Intervention
 - Mechanical + Biological Active Comparison
 - vs.
 - Biological explanation only
- Test 9 diagnostic cases
- Sample -- undergrad psych students

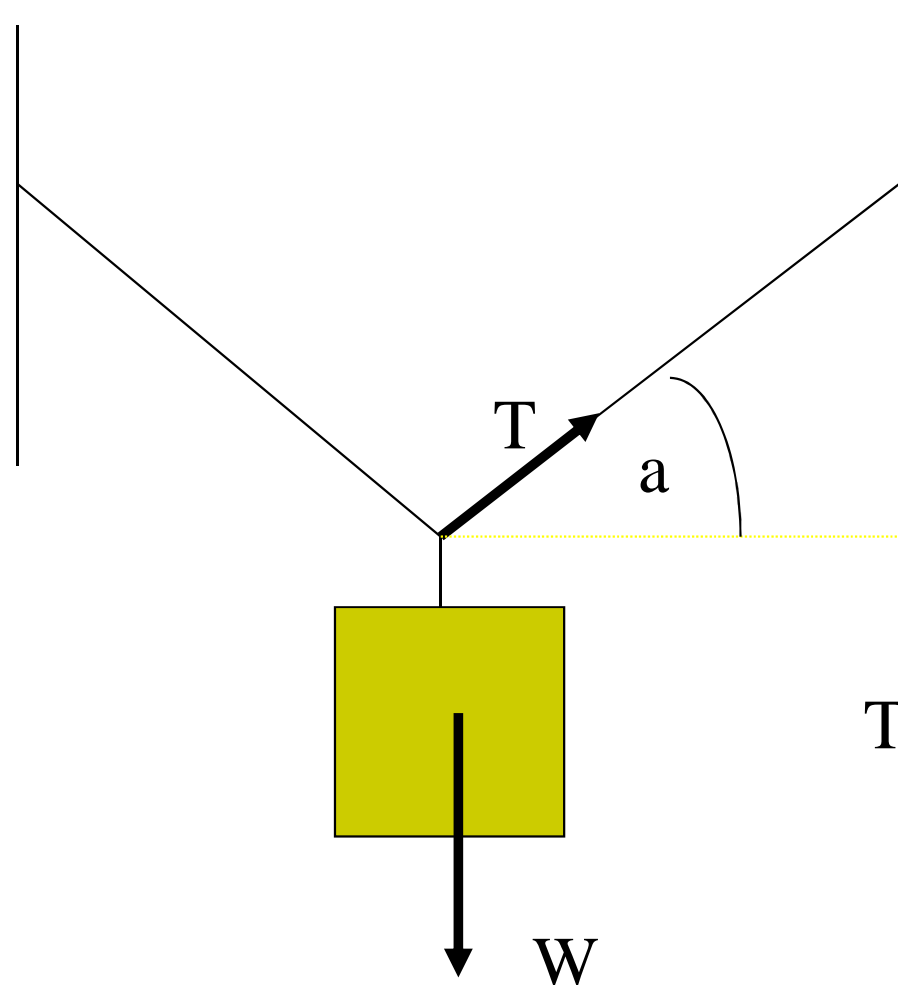
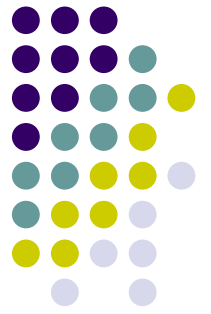
Pressure and Tension on a Membrane



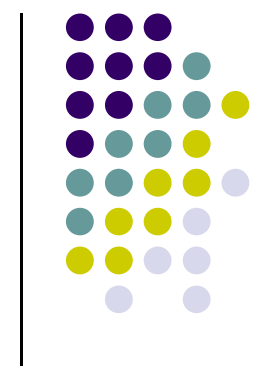
Law of Laplace

$$T = P * r$$

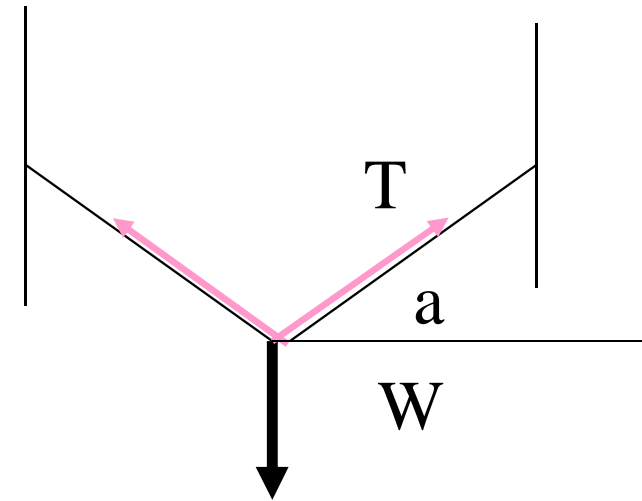
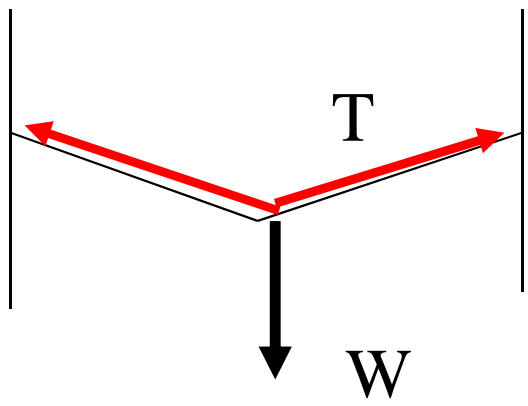
The “weight and string” problem

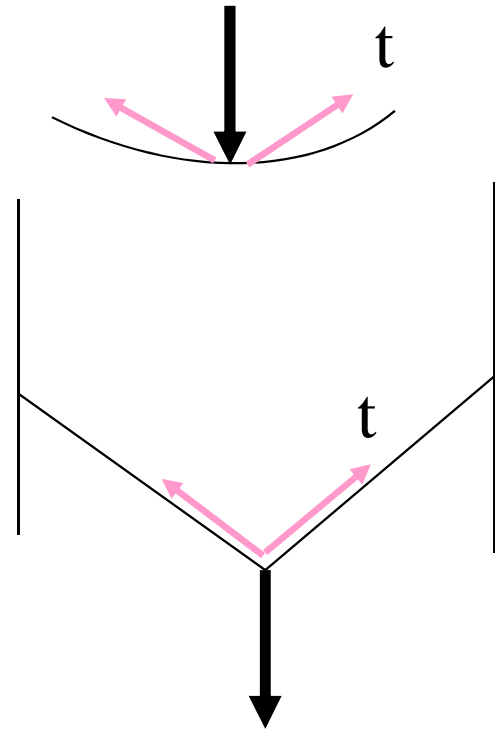
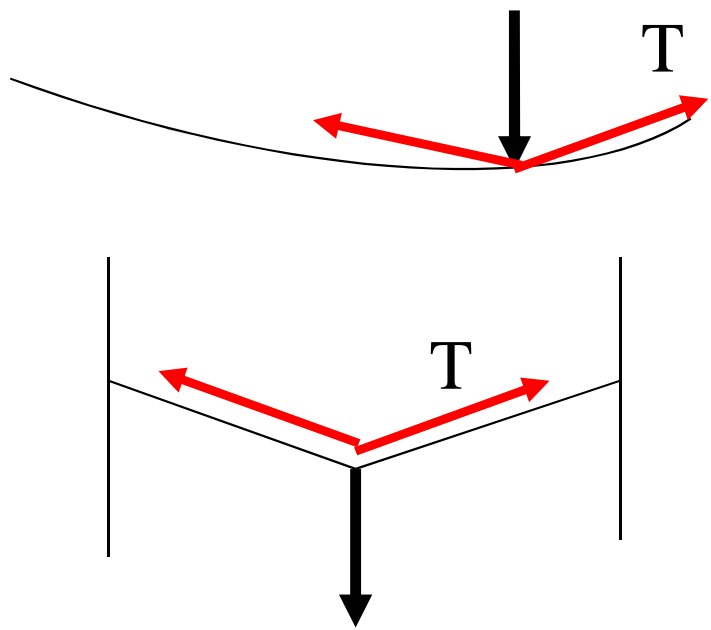
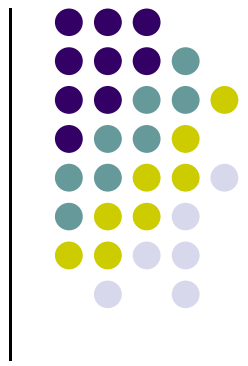


$$T = W / 2 \sin(a)$$

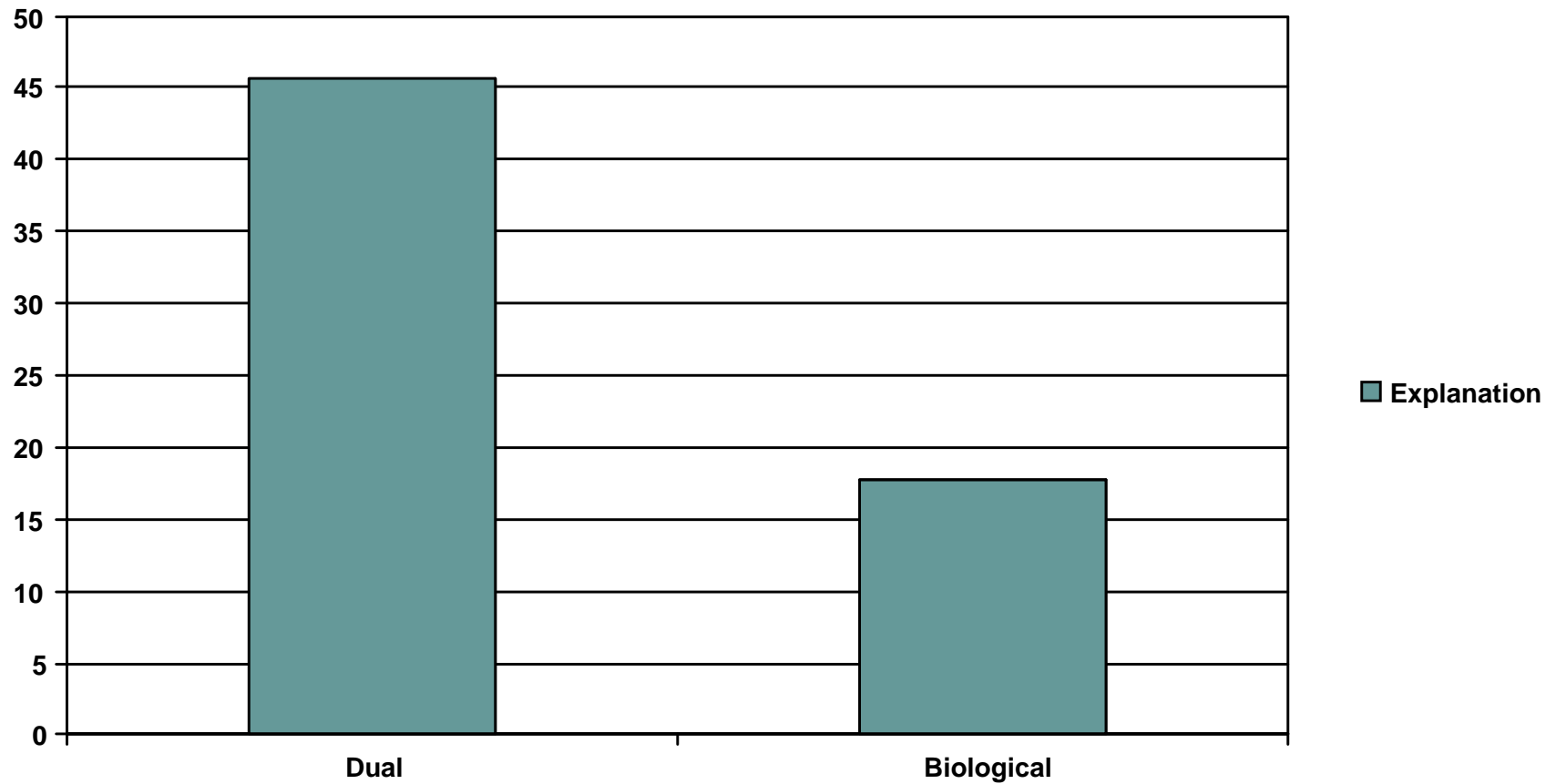
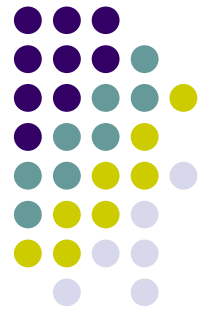


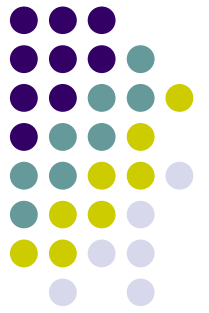
$$T = W / 2 \sin(\alpha)$$





Percent Correct





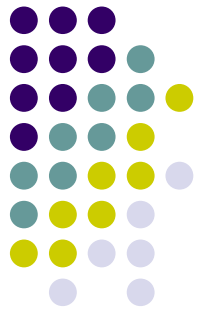
Imbedding Principle in Problem

(Ross & Kilbane, 1997)

Practice and Test problems with:

- **SEQUENTIAL**
 - Principle explanation, then problem example
- **IMBEDDED**
 - Principle imbedded in problem, explanation as part of problem

“Reversal” = using original principle incorrectly



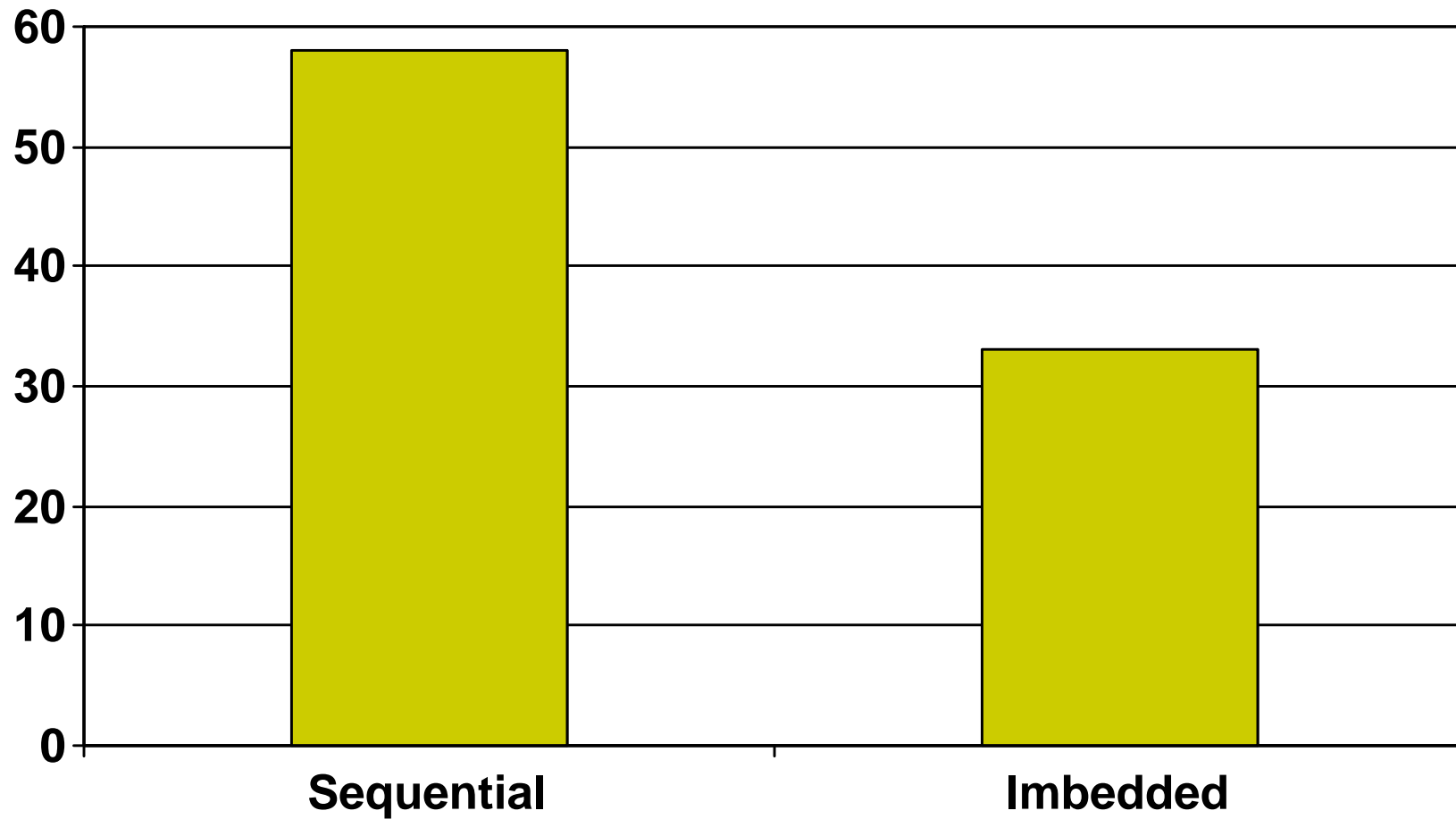
Imbedding in a problem

The tire on a racing bicycle is usually inflated to a pressure of 500 kPa. The wall thickness is about 1mm. and it weighs about 1 kg. Tire pressure for a typical car tire is about 220 kPa. The wall thickness is about 1 cm. and it weighs about 10 kg. Both tires are constructed similarly, with rubber over a cloth net.

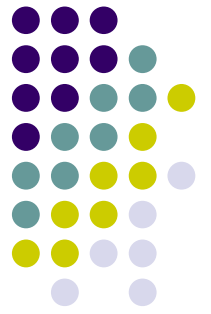
Why is the car tire so much thicker?

If you think about the wall tension inside the tire, for the car tire it's acting almost at right angles to the pressure, so it takes much more tension to contain the same pressure difference.

Conceptual Errors



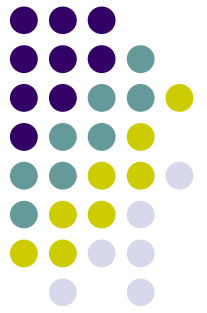
Effect of active, problem-oriented processing



- Intro psychology students, 5 classic problems
- “Try to solve these difficult problems”
(27% successful)

vs.

“Remember the problem and solution so you can solve some additional problems”
(21% successful)



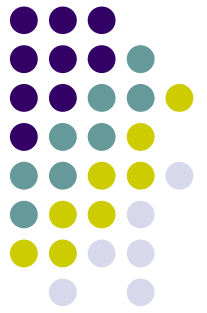
Active Learning vs Memorization

The tire on a racing bicycle is usually inflated to a pressure of 500 kPa. The wall thickness is about 1mm. and it weighs about 1 kg. Tire pressure for a typical car tire is about 220 kPa. The wall thickness is about 1 cm. and it weighs about 10 kg. Both tires are constructed similarly, with rubber over a cloth net and both wheels are about 1 m. across.

Why is the car tire so much thicker?

Then after student attempts to work out the solution:

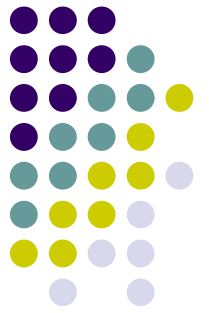
It all relates to the diameter of the cross section of the tire. The pressure has to be contained by a tension in the wall. If the tire has a large radius, the tension is almost at right angles to the pressure, so it takes a lot of tension to hold the pressure. But for the small radius, the tension is more in line with the pressure against the wall, so less is required.



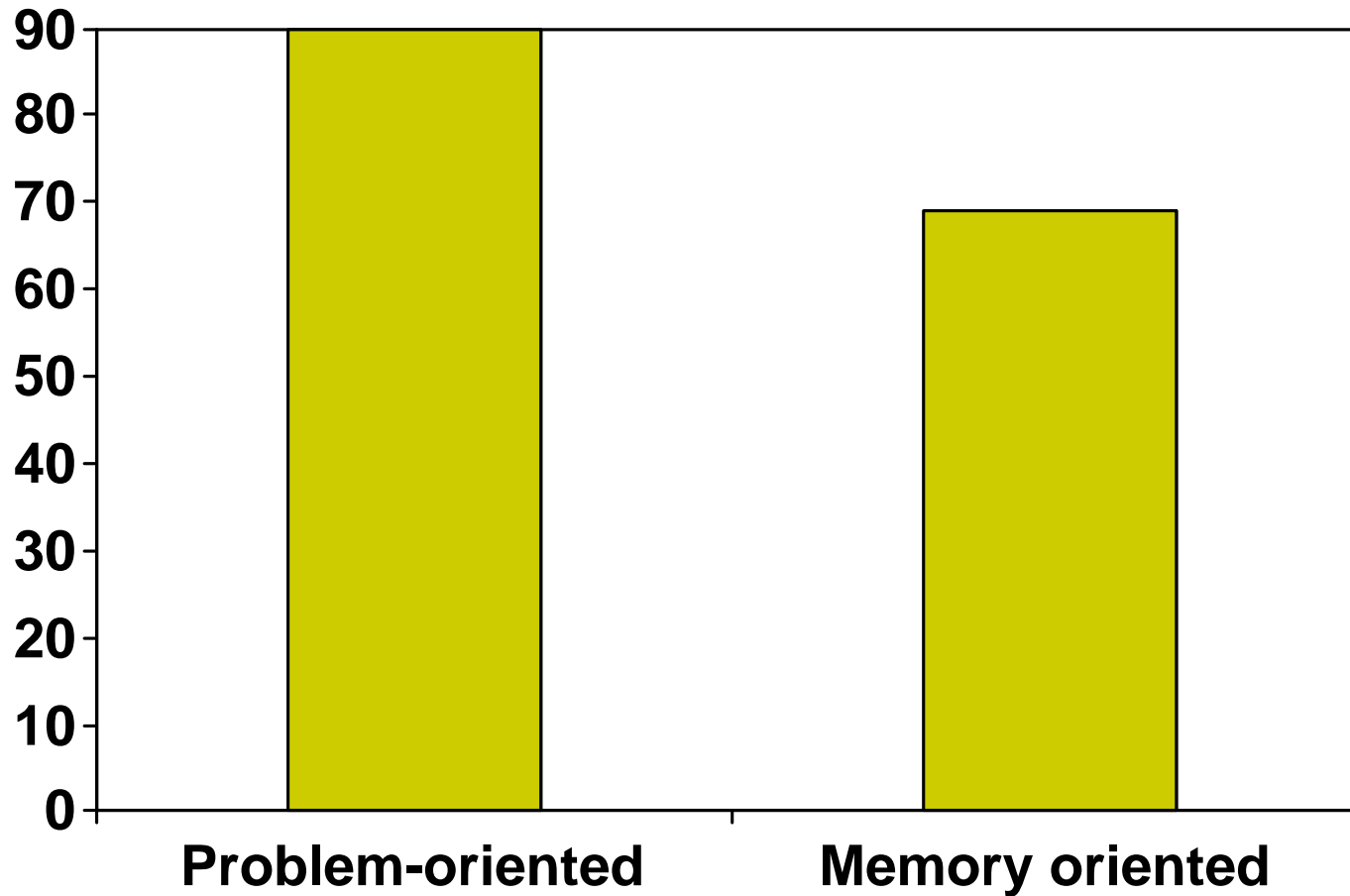
Versus:

The tire on a racing bicycle is usually inflated to a pressure of 500 kPa. The wall thickness is about 1mm. and it weighs about 1 kg. Tire pressure for a typical car tire is about 220 kPa. The wall thickness is about 1 cm. and it weighs about 10 kg. Both tires are constructed similarly, with rubber over a cloth net, and both wheels are about 1 m in diameter.

The car tire is thicker because it has a larger cross sectional diameter. The pressure has to be contained by a tension in the wall. If the tire has a large radius, the tension is almost at right angles to the pressure, so it takes a lot of tension to hold the pressure. But for the small radius, the tension is more in line with the pressure against the wall, so less is required.

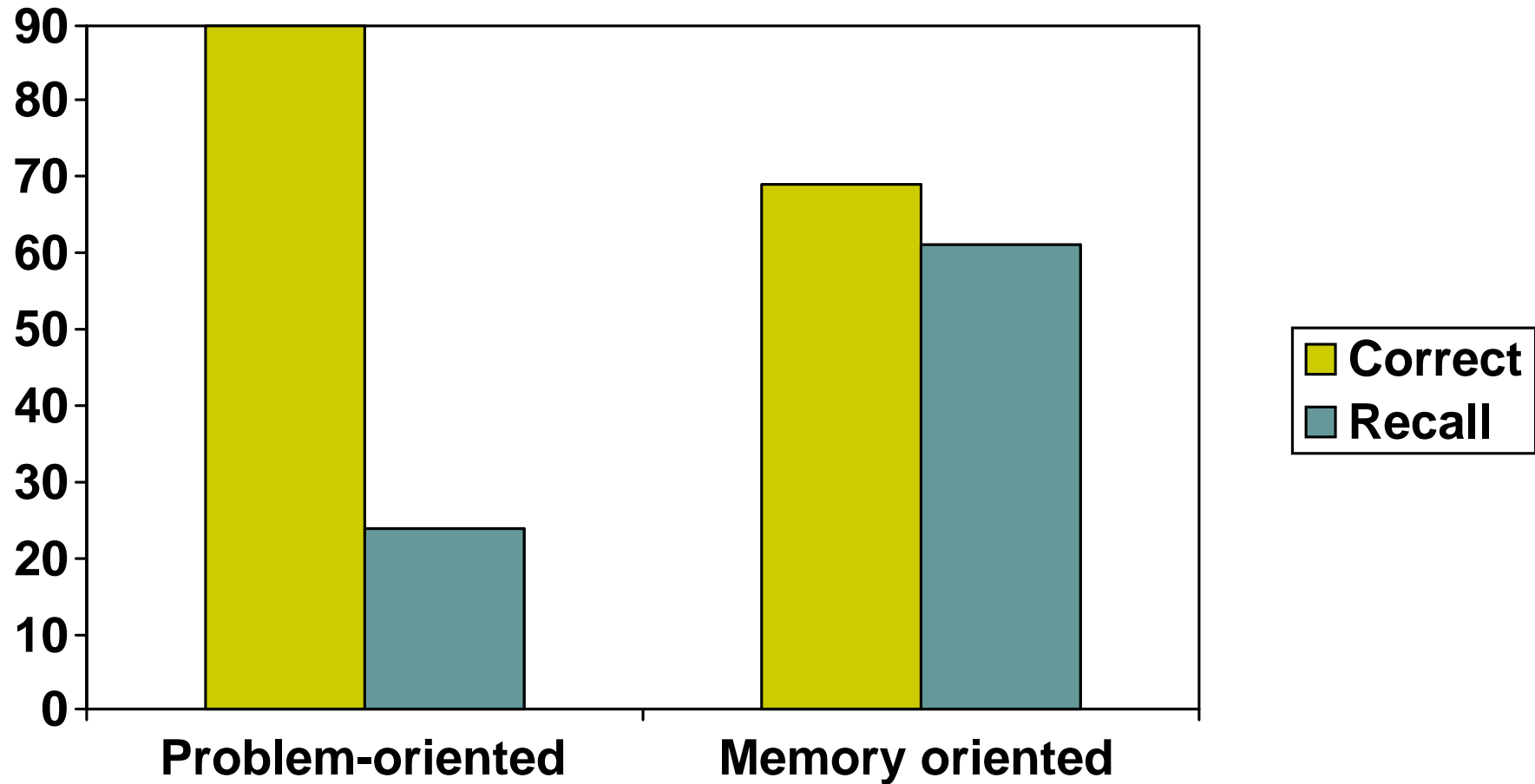
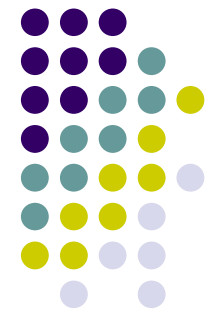


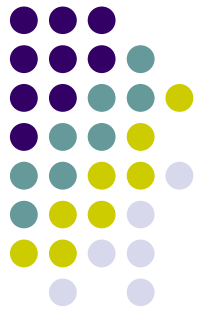
Effect of Active Problem-solving



Needham & Begg, 1991

Effect of Active Problem-Solving



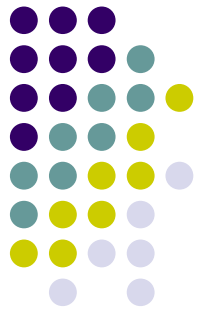


Implications for Teaching

- Transfer can be facilitated by use of examples during initial learning
 - multiple examples > principle + example
 - compare and contrast

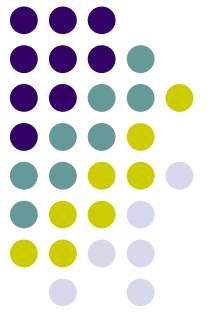


active seeking for deep structure



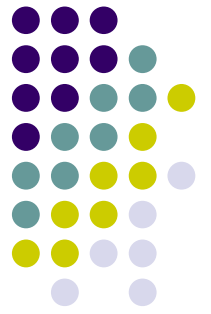
CHALLENGE 1

- Think of a concept that applies to multiple clinical problems (Laplace Law)
- Think of a common sense analogy for understanding
- Think of a challenge problem

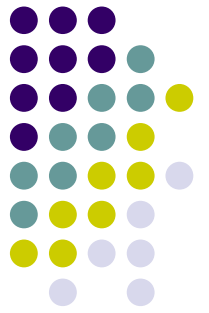


- Write an explanation (with diagrams) for teaching
- Write it with / without commonsense analogy
- Write it
 - imbedded in problem
 - sequential with example problem

Strategies for Teaching Examples

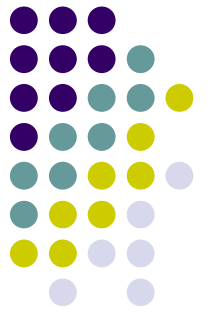


- Principle + Example vs. Two Examples
- Active Comparison vs. Sequential Examples



Effective Strategies

- FOR TEACHING EXAMPLES
- Multiple examples vs. “Principle + Example”
 - Gentner, 2003; Ross 1987
- Active comparison
 - Gentner, 2003
- Multiple learning examples vs. Single Example vs.
 - (Catrambone & Holyoak, 1989)



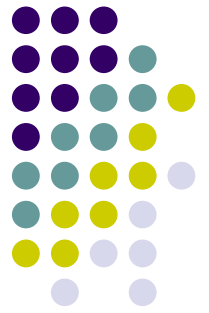
┆ TWO EXAMPLES

What do these two examples have in common?

- 1. A patient with shortness of breath is found to be suffering from heart failure. His chest x-ray shows a dilated left ventricle. He is offered cardiac surgery to remove part of the left ventricle and make it smaller. Why may this procedure improve the heart failure?**

1. A patient complained of vomiting large amounts at the end of each day. Investigations revealed she had a lax, poorly contracting stomach. She was given a drug that constricted the size of the stomach, resulting in more efficient emptying. How did the drug improve emptying?

PRINCIPLE + EXAMPLE



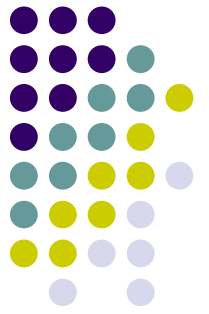
Laplace's Law

The tension in the vessel wall is proportional to the radius of the vessel and the pressure of the contents. This relationship can be explained by: $T=PR$ where T is the wall tension, P is the pressure, and R is the radius. Thus, a tube with a small radius will have relatively low wall tension, even if the pressure is high. Laplace's Law explains why in normal circumstances intestines don't rupture their contents and why in some conditions, like appendicitis or aortic aneurism, a weakened wall leads to increased radius and a rupture.

Example:

A patient complained of vomiting large amounts at the end of each day. Investigations revealed she had a lax, poorly contracting stomach. She was given a drug that constricted the size of the stomach, resulting in more efficient emptying.

The drug worked by effectively decreasing the radius of the stomach, so reducing the tension required to contract the stomach.



Multiple Examples vs. Principle + Example

- MBA Students , negotiation problem

Factor 1

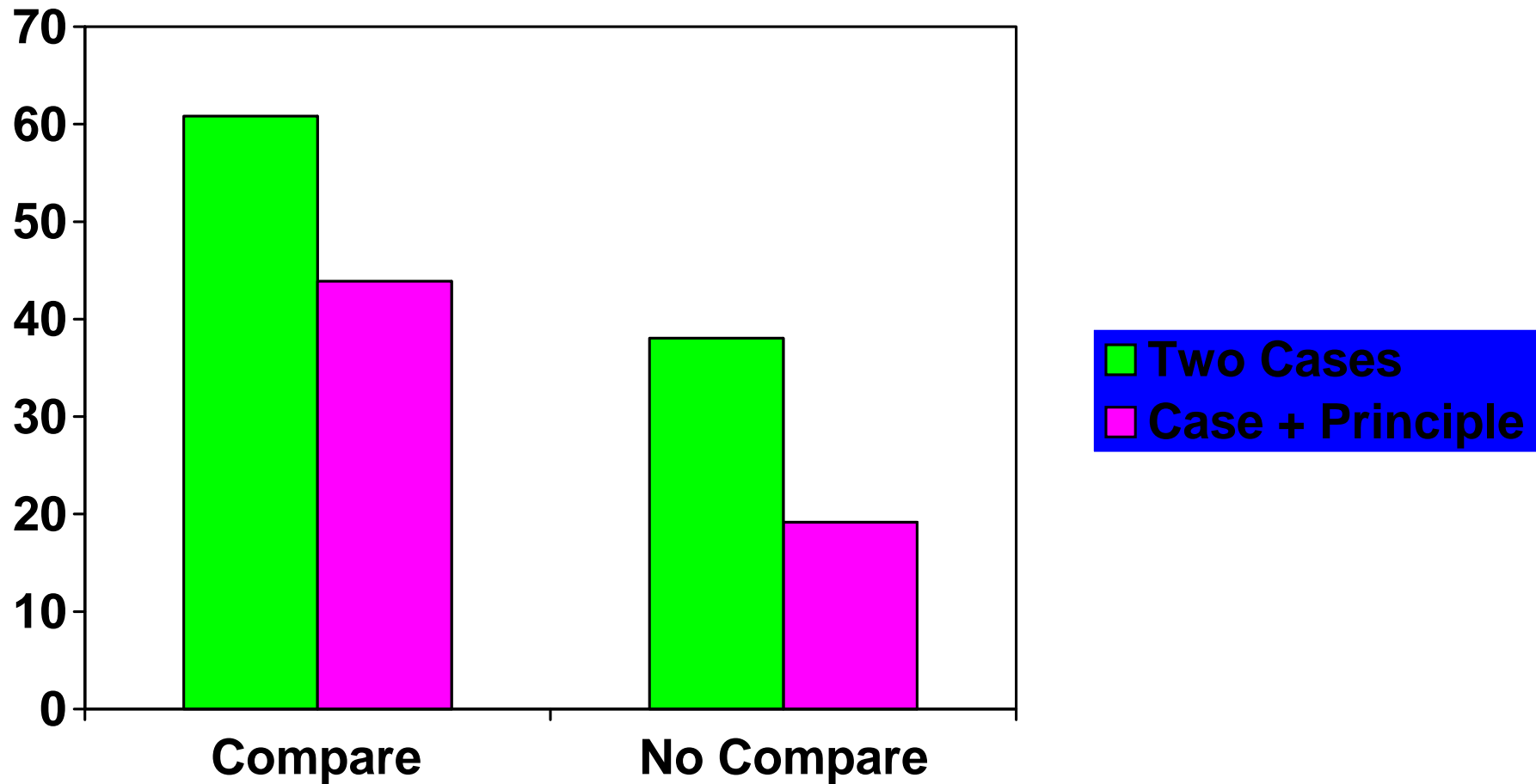
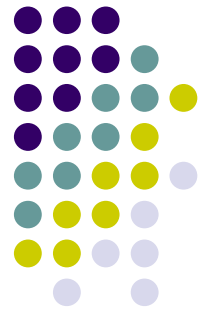
- Two cases, implicit principle vs. Principle + Case

Factor 2

- Read case and principle (on successive pages) vs. Compare Case and Principle

Loewenstein& Gentner, 2003

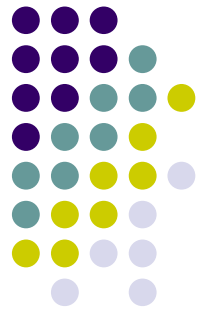
Effect of Examples and Comparisons



Gentner, 2003

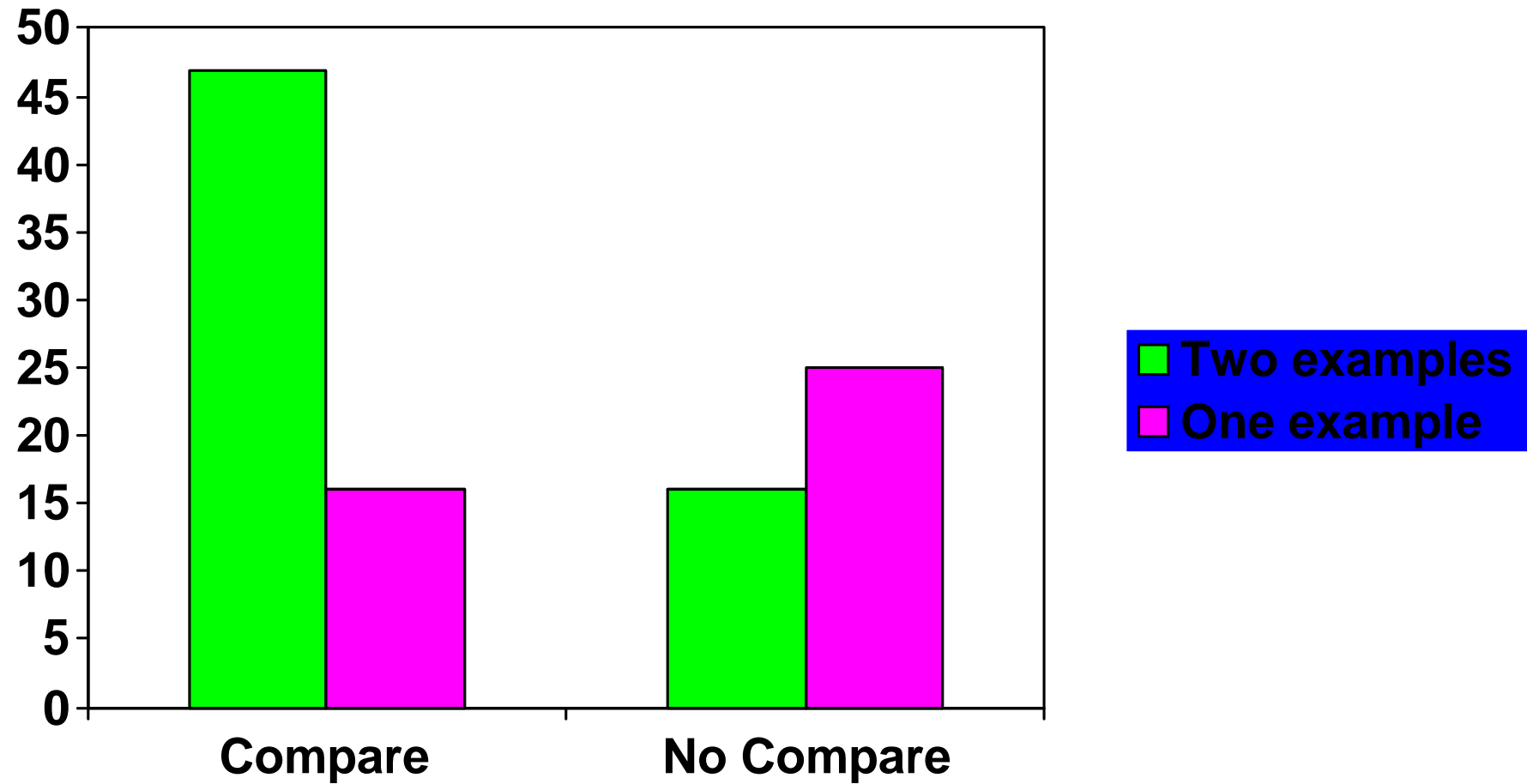
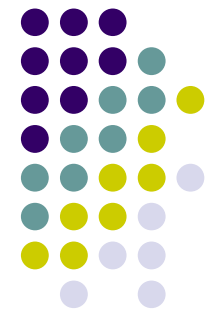
Two vs. One and Comparison

(Catrambone & Holyoak, 1989)

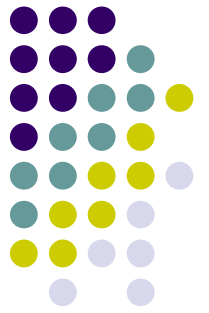


- Undergraduate psychology students,
- Two related examples vs. one example and control
- “Summarize the two stories”
vs.
“Describe the ways the two situations are similar”

Effect of Examples, Comparisons



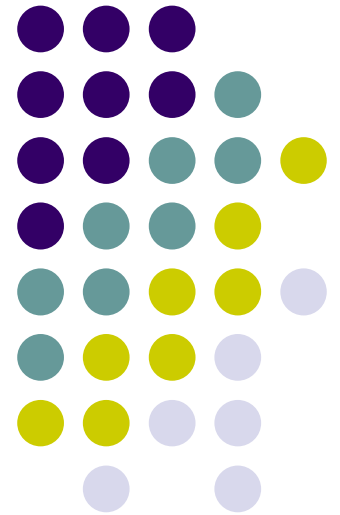
Catrambone & Holyoak, 1989

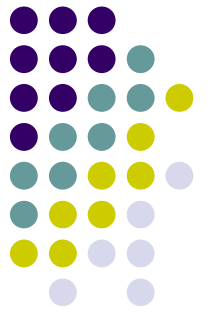


Challenge # 2

- Write 2 problems that look very different but both involve the same principle -- that you created in Challenge #1

Practice Examples





Mixed vs. Blocked Practice

Mixing examples from different categories

Distributed vs. Massed Practice

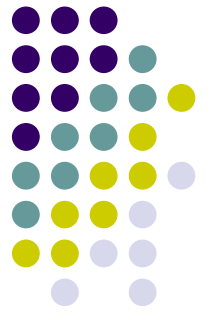
Distributing practice sessions over time

Mixed vs. Blocked Practice

In the face of ambiguous features (which are subject to reinterpretation), and multiple categories, students must learn the features which *discriminate* one category from another, not those which *support* a particular category.

This can be achieved by “mixed practice” -- examples from competing categories

What do you need to do stats?

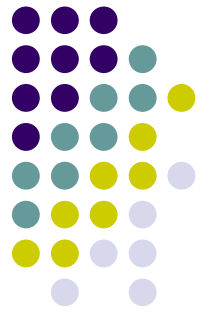


An Observation:

With the availability of sophisticated statistical software, the central issue facing the statistics student is “What test do I use?”

To learn this, students have to see data sets, think of possible strategies, and get feedback

What do you get in stats courses?



- Instructional time occupied by equation proving, formula remembering

SPSS knows the formulas

- Practice at end of chapter of the form:
“Do a t test on these data”

SPSS knows the formulas

Mixed vs. Blocked Practice

Rohrer, 2007

- Geometry - 4 categories
- 4 examples / category

Blocked

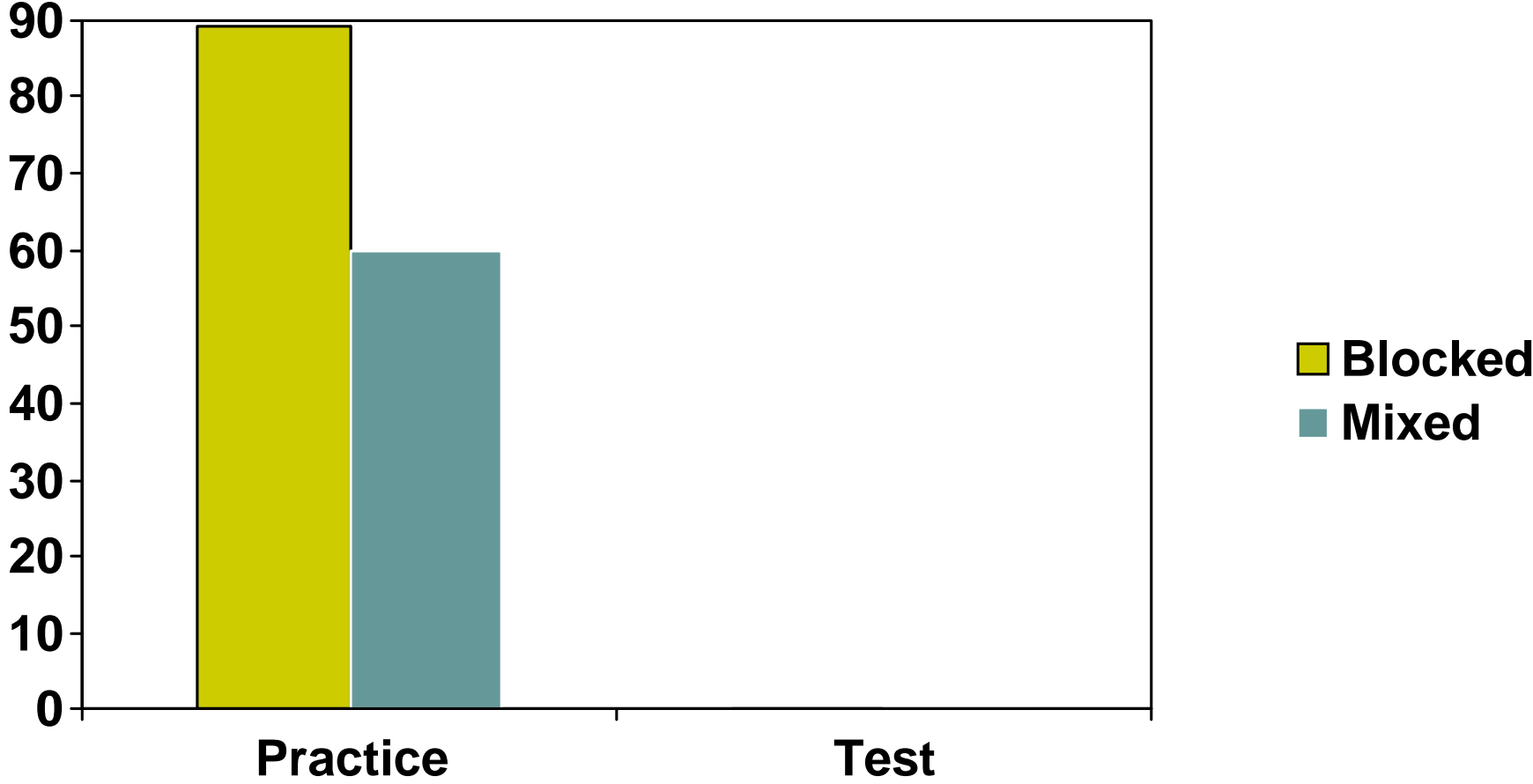
__Review each solution, then 4 examples/category

Mixed

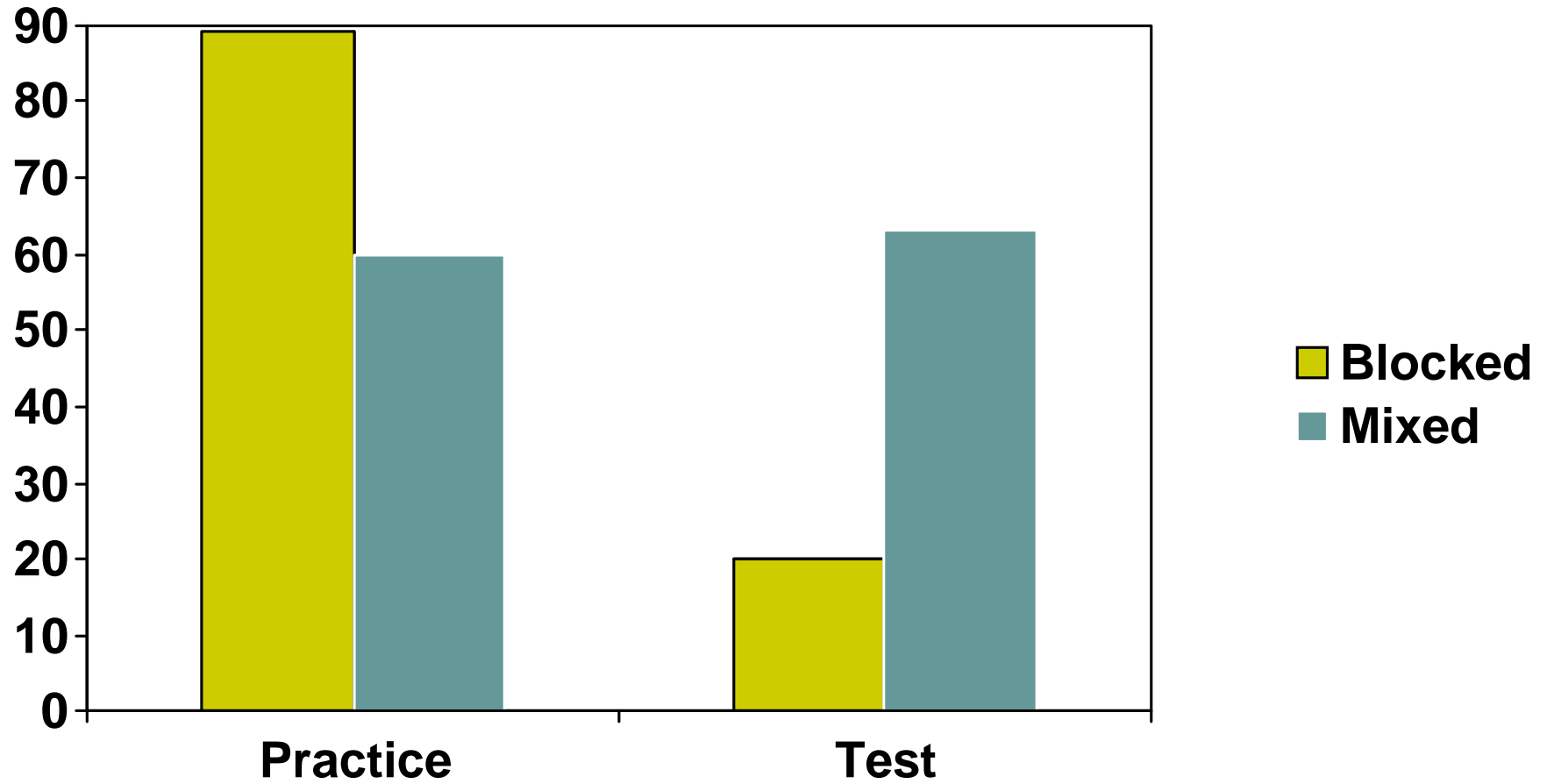
Review 4 solutions, 16 (4 x 4) practice

TEST 8 new problems

Accuracy -- %



Accuracy -- %



Mixed vs. Blocked Practice

Hatala, 2000

- ECG Diagnosis -- 3 categories
- 6 examples / category

Blocked

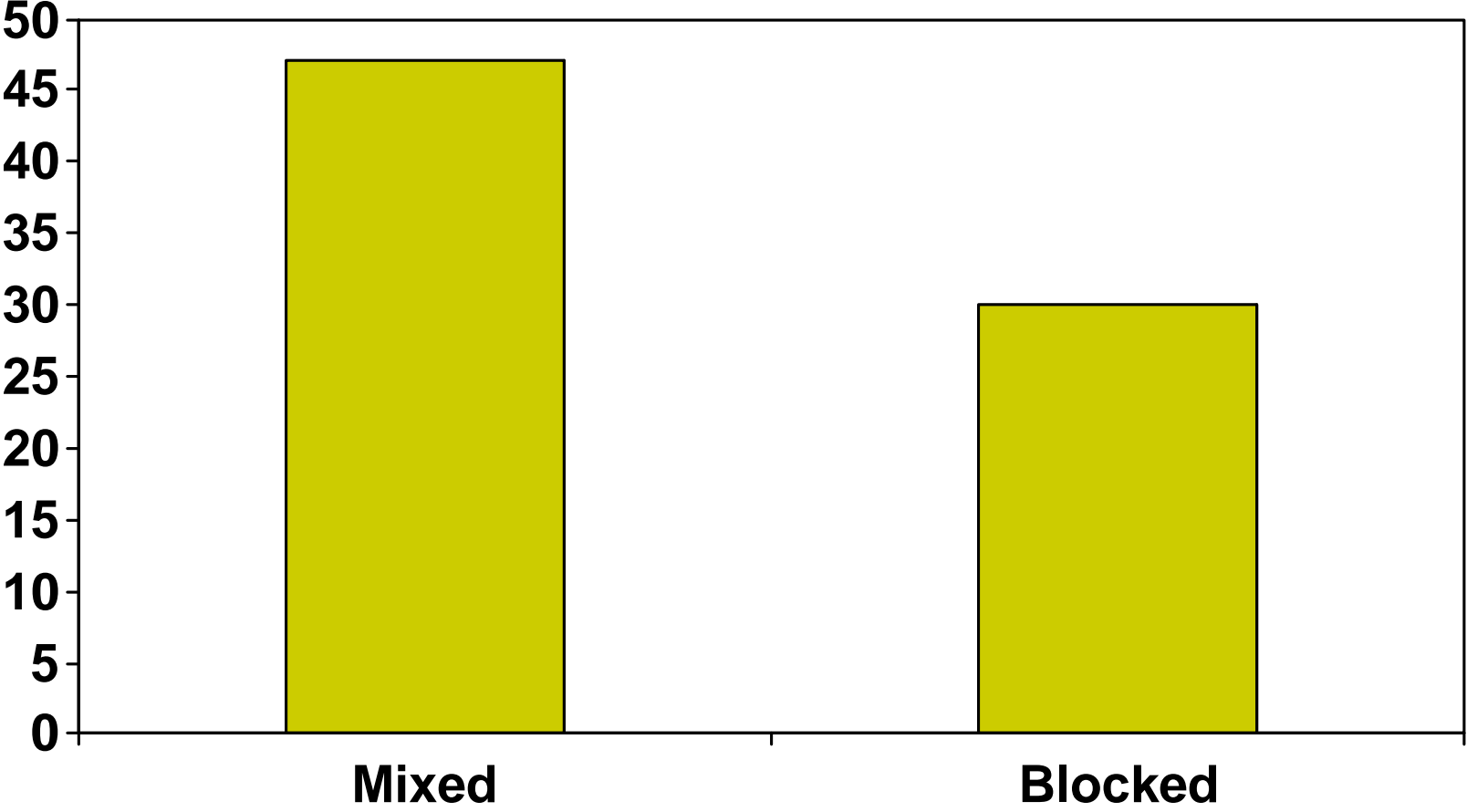
__Review, then 6 examples/category

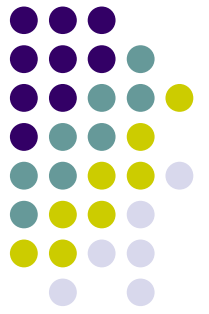
Mixed

Review, 2/category, 12 (4 x 3) practice

TEST 6 new ECGs

Accuracy -- %

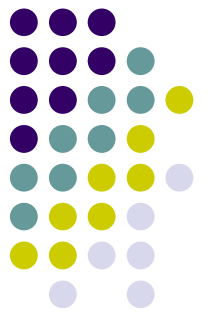




Massed vs. Distributed Practice

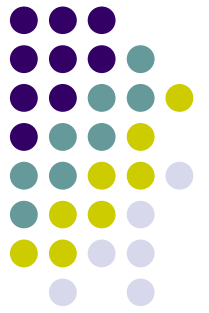
- Massed
 - All learning takes place at one time

- Distributed
 - Learning takes place over multiple occasions



Timing and Sequence of Learning

- Would you rather learn to skate (type, play violin, speak Spanish):
 - 1 hour/day, biweekly, for 60 weeks = 30
 - 1 hour / day for 3 days/wk for 10 wks = 30
 - 3 hours/day, 1 day/week, 10 weeks = 30
 - 6 hours/day, 5 days, 1 week = 30



Massed vs. Distributed Practice

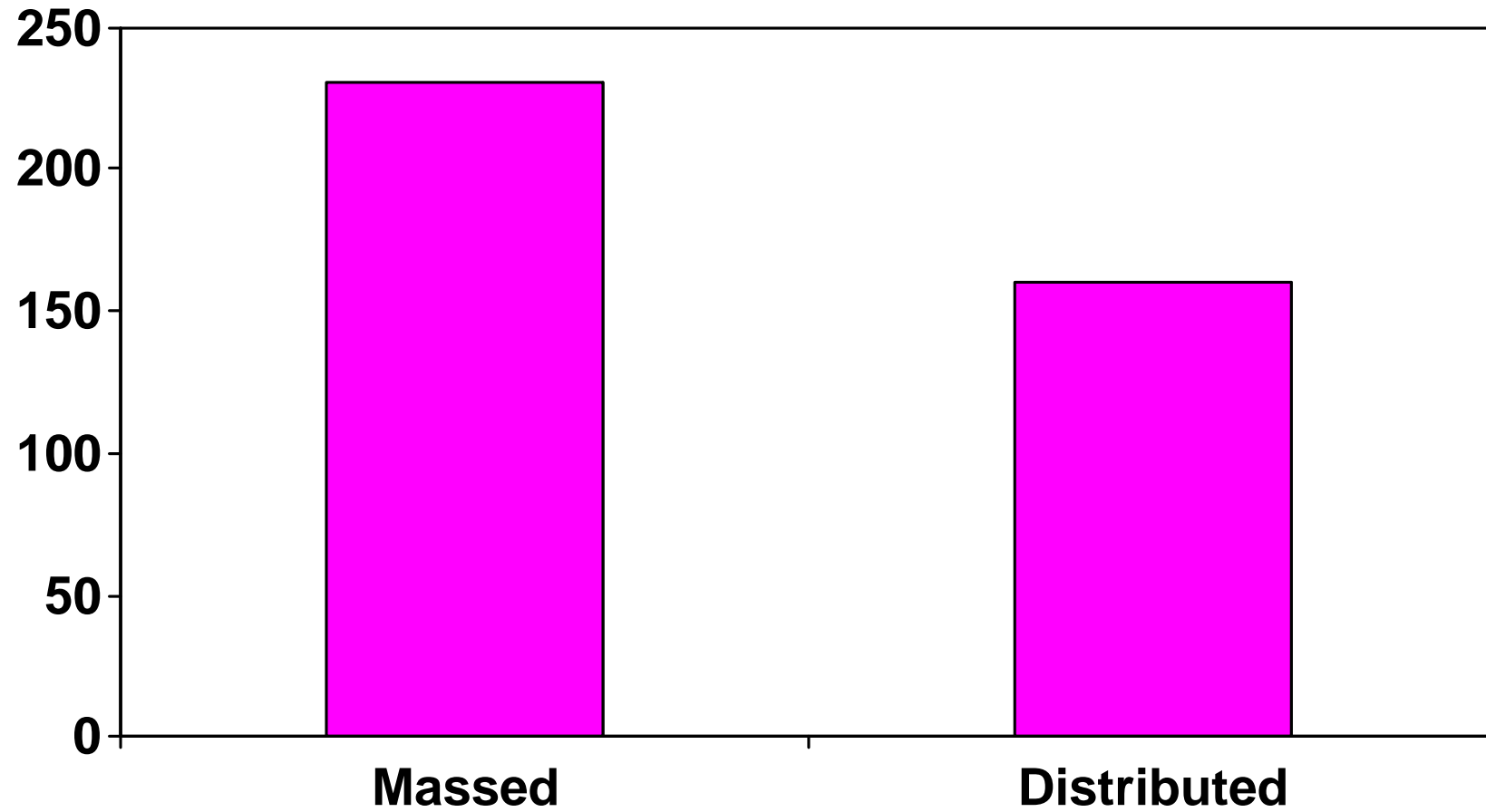
Shea et al., 2000

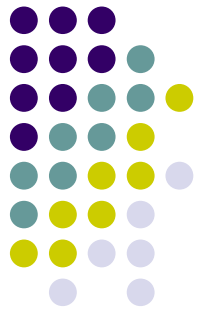
- 22 undergrads,
- Key pressing task

- 3 sessions 1 day vs 3 days

- Retention test after 24 hr.

Timing error (ms)





Landauer & Bjork, 1978

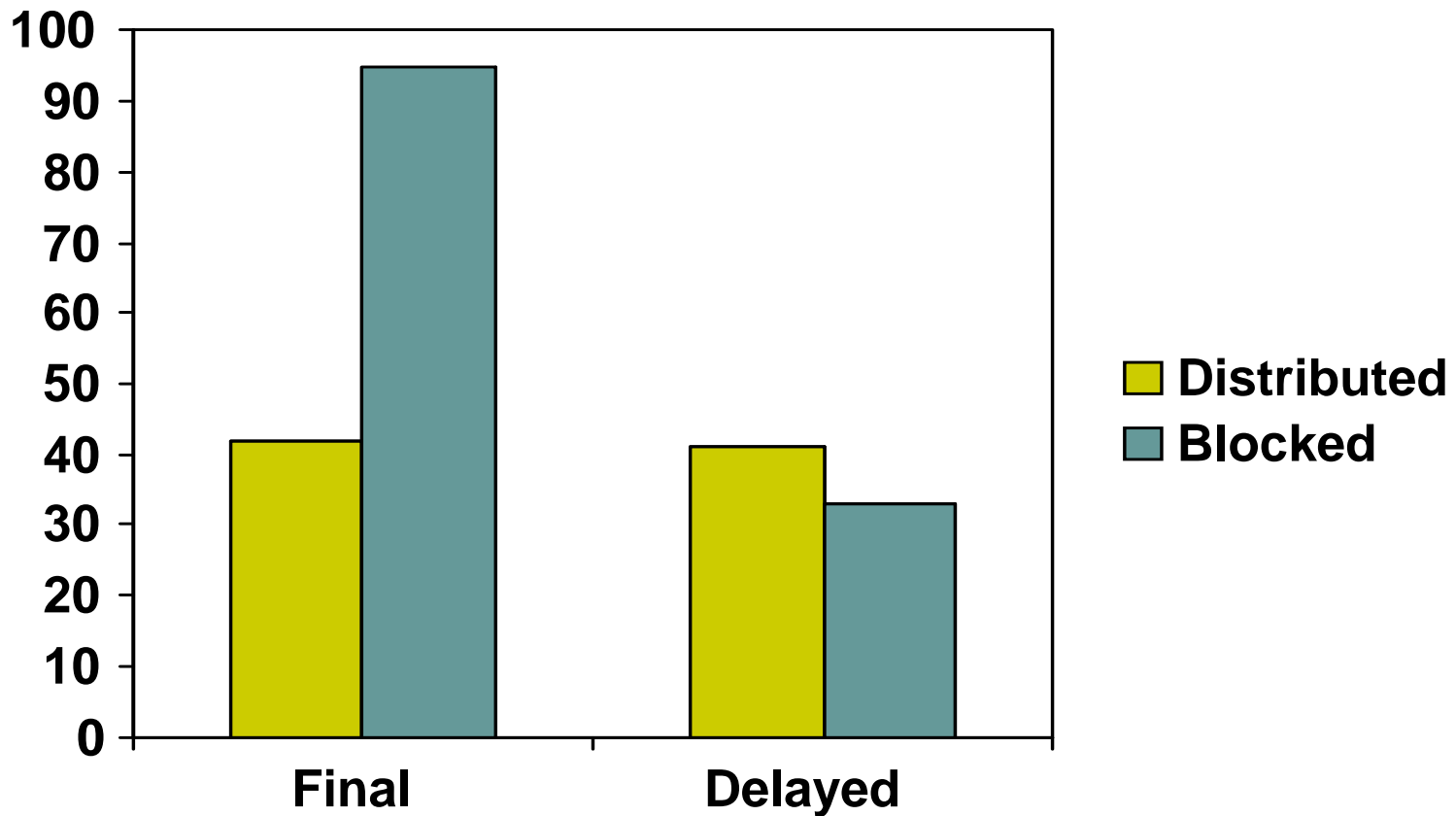
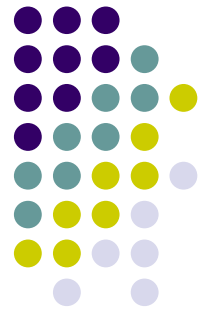
Memorize names of photos

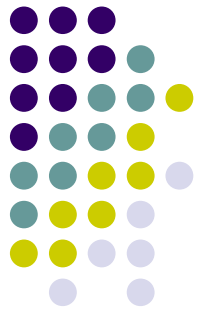
3 trials, spaced at 0 (massed) 4, 5

Retention test after 30 min

Distributed Practice

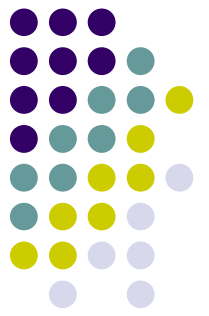
Landauer and Bjork, 1978





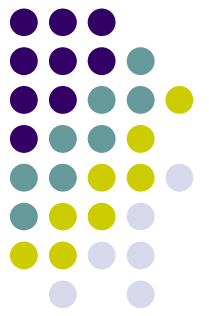
Practice and Assessment

- There is a difference between testing for knowledge and testing for transfer
- Testing can be used to encourage transfer



Concept Application Exercise

- Brief problem situations, with 3-5 line answers
- “why does this occur?”
- 18 questions, 1.5 hours



An example for transfer

A 60-year-old diabetic man who has been overweight for 35 years complains of tiredness. On examination you notice a swollen, painful looking right big toe with pus oozing from around the nail. When you show this to him, he is surprised and says he was not aware of it.

How does this man's underlying condition predispose him to infection. Why was he unaware of it?



Rating scale

"The student showed..

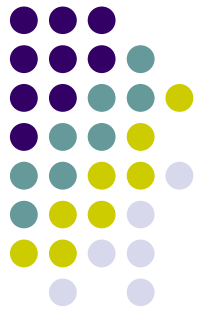
1	2	3	4	5	6	7
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No understanding

Some major mis-
conceptions

Ade- quate
explanation

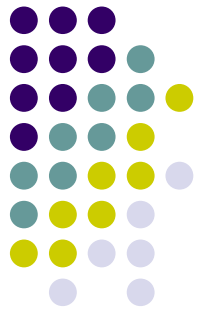
Complete and
thorough
under-standing



Equivalent knowledge question

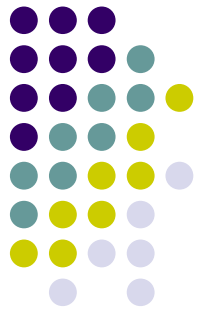
1) What of the following is a common complication of poorly controlled diabetes?

- a) Compromised eosinophil function
- b) Peripheral neuropathies
- c) Superficial thrombophlebitis
- d) Glaucoma



Challenge # 3

- Devise a multiple choice question that tests knowledge of the concept
- Devise a second question that imbeds the concept in a patient problem to test transfer



Summary / Conclusions

- Teaching facilitated by:
 - Familiar Metaphor
 - Active learning, problem-based
- Teaching Examples facilitated by:
 - Multiple examples
 - Active comparison
- Practice facilitated by
 - Mixed Practice
 - Distributed Practice
- Assessment should test transfer
 - Concept Application Exercise