

CSCI 1377

Tools for Thought

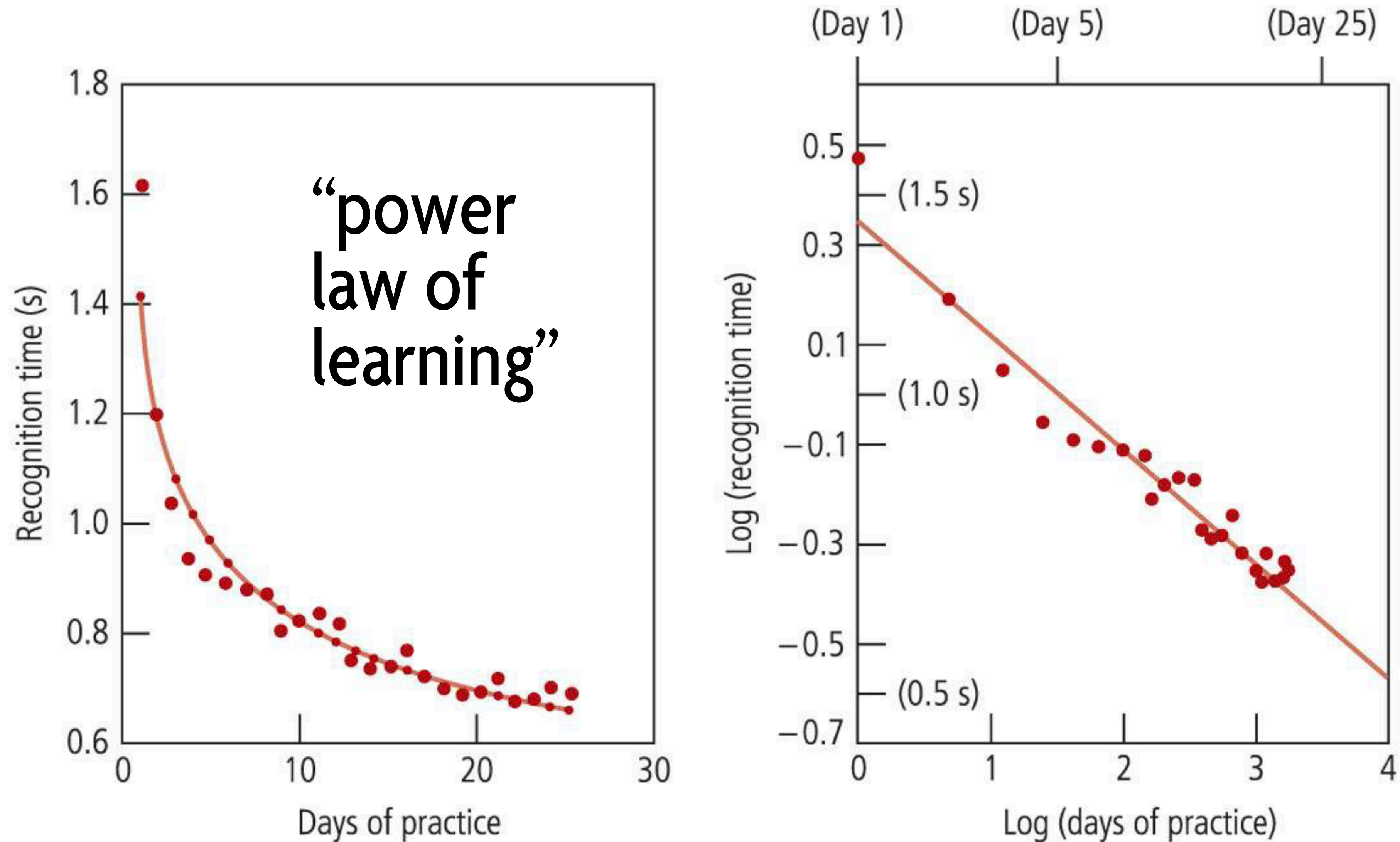
Learning I

Educational Psychology

The speaker, and the schoolmaster, and the third grown person present, all backed a little, and swept with their eyes the inclined plane of little vessels then and there arranged in order, ready to have imperial gallons of facts poured into them until they were full to the brim.

— Charles Dickens, *Hard Times* (1854)

Long-term memories form upon repeated exposure



Word recognition can become automatic

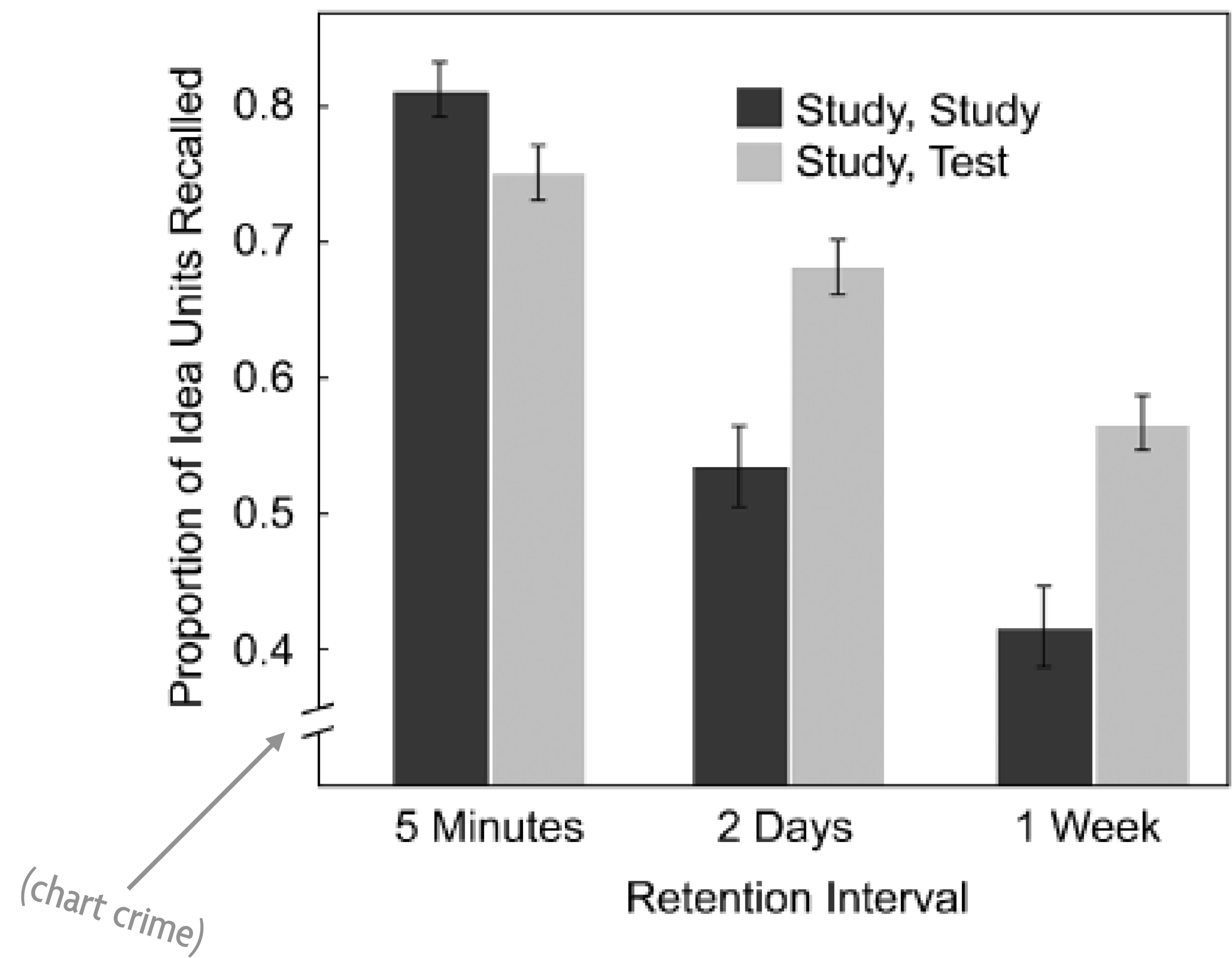
Quick: recognition improves with practice following power law of learning

Effortless: can perform other tasks concurrently with little penalty

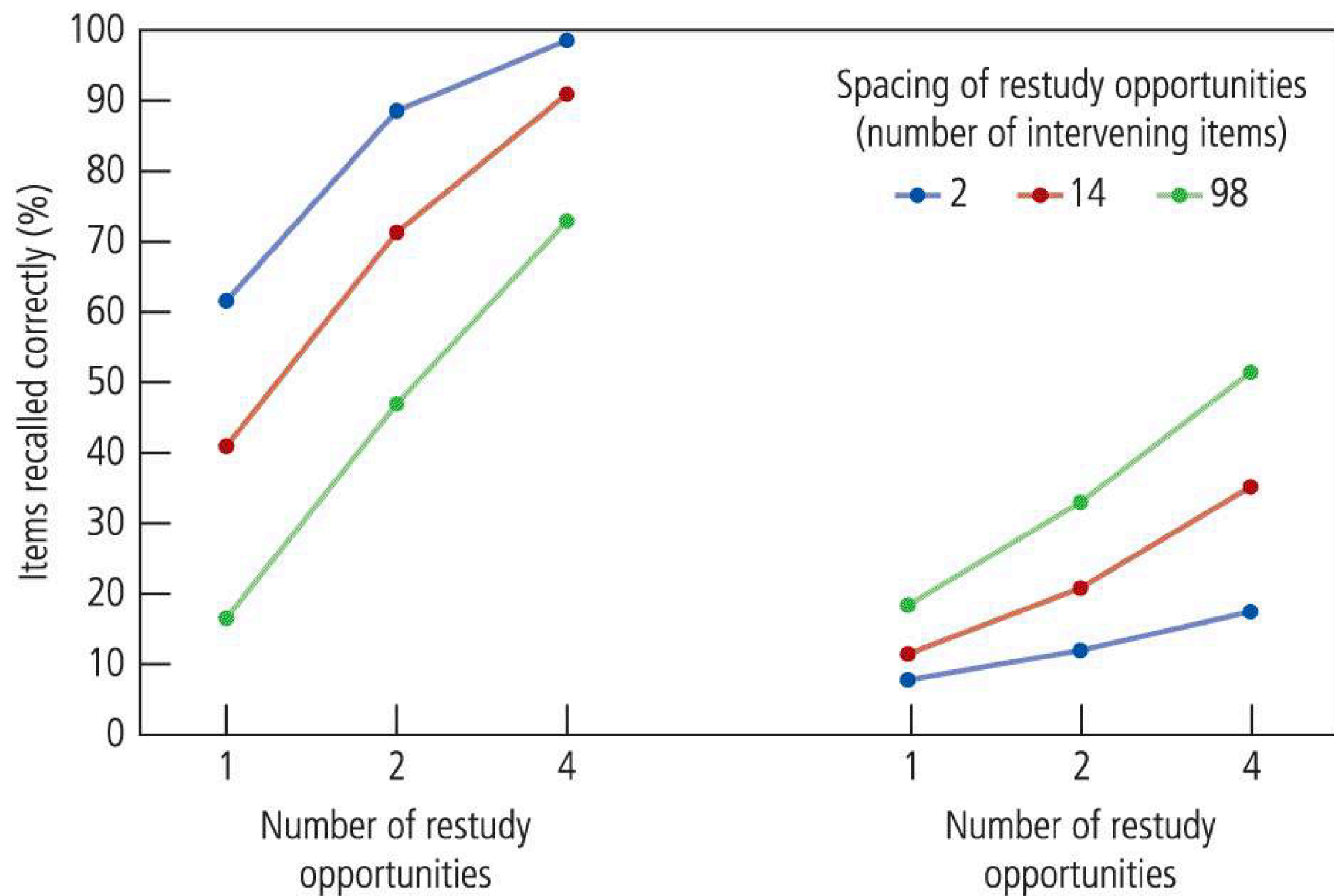
Autonomous: happens without deliberate thought

Unaware: not conscious of the process occurring

Testing effect: tests improve recall over studying



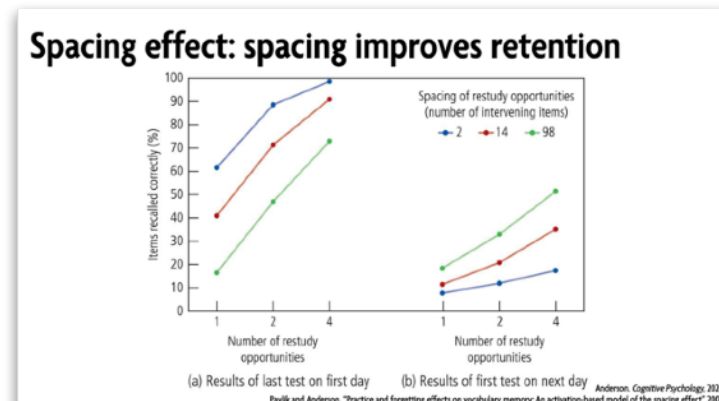
Spacing effect: spacing improves retention



(a) Results of last test on first day

(b) Results of first test on next day

Last seen 9/15/26

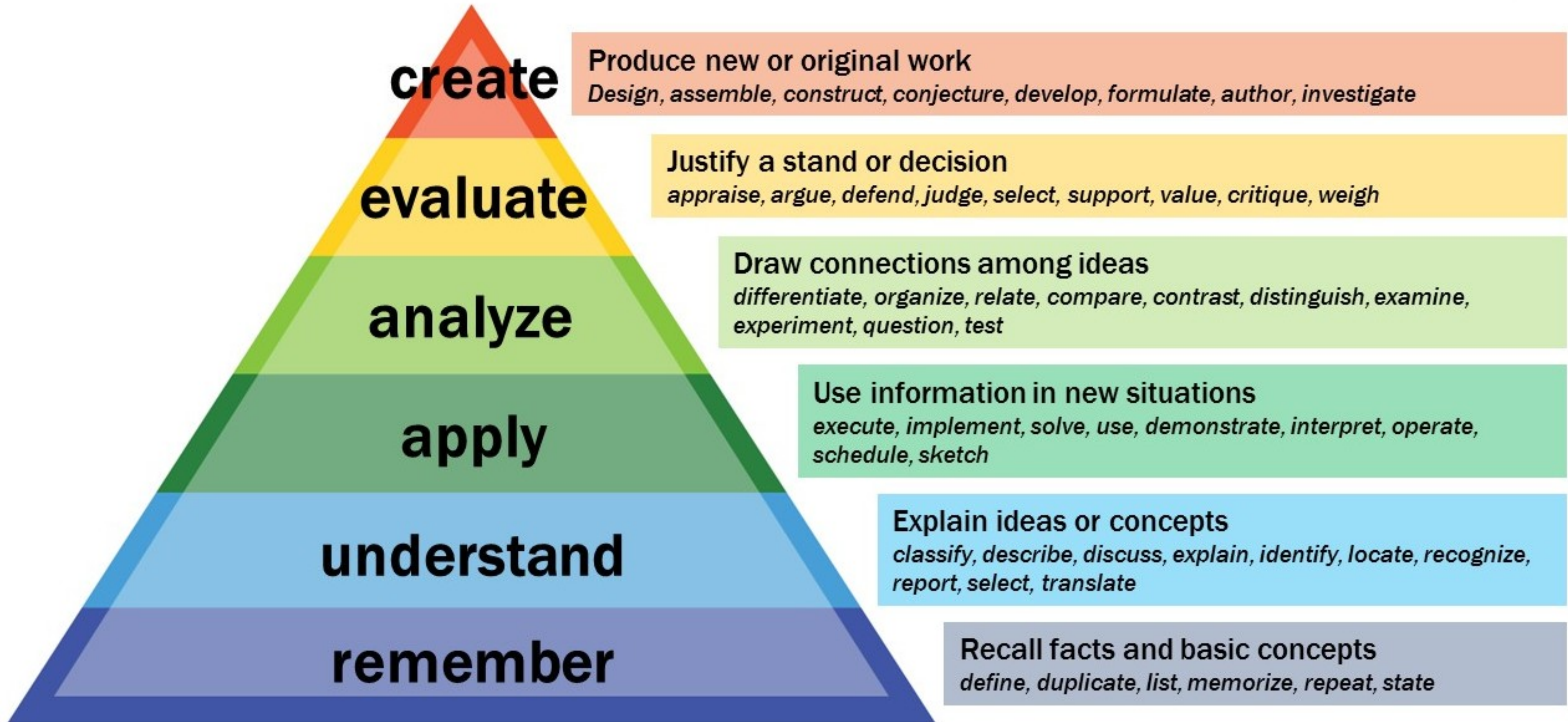


Anderson. *Cognitive Psychology*. 2020

Pavlik and Anderson. "Practice and forgetting effects on vocabulary memory: An activation-based model of the spacing effect" 2005

1. Learning beyond remembering

Bloom's Taxonomy



Bloom's extended taxonomy, part 1

- **Remember:** retrieve relevant knowledge from long-term memory
 - **Recognizing:** is July 4th an important date in US history?
 - **Recalling:** what are the important dates in US history?
- **Understand:** construct meaning from instructional messages
 - **Interpreting:** how would you paraphrase Lincoln's Gettysburg Address?
 - **Exemplifying:** what is an example of an impressionist painting?
 - **Summarizing:** what ideas are in this 3B1B video?
 - **Inferring:** what is the general rule for using a comma in English?
 - **Comparing:** what is similar and different between Trump and Mussolini?
 - **Explaining:** what caused the Industrial Revolution?

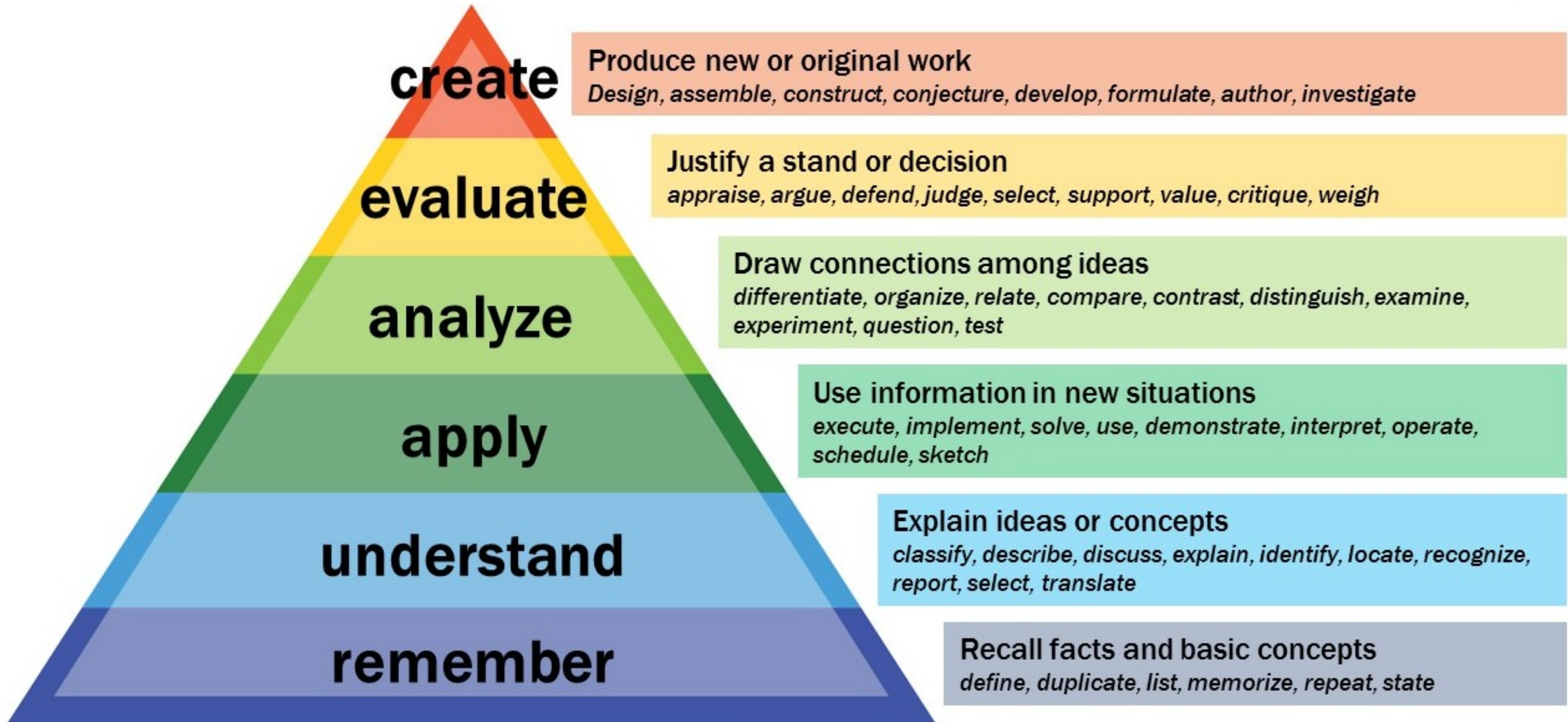
Bloom's extended taxonomy, part 2

- **Apply:** carry out or use a procedure in a given situation
 - **Executing:** what is the result of $168/8$?
 - **Implementing:** which of Newton's laws is appropriate for this problem?
- **Analyze:** break material into constituent parts and determine how parts relate to one another
 - **Differentiating:** in this math word problem, which numbers are relevant or irrelevant?
 - **Organizing:** given these descriptions of the conditions prior to 1812, what were the principal causes of the War of 1812?
 - **Attributing:** how does Will's experience as a PL researcher shape Tools for Thought?

Bloom's extended taxonomy, part 3

- **Evaluate:** make judgments based on criteria and standards
 - **Checking:** does this paper's conclusions follow from its results?
 - **Critiquing:** which of two possible architectures is most suitable for this software?
- **Create:** put elements together to form a whole
 - **Generating:** what could explain Elizabeth Holmes' behavior in YCSE?
 - **Planning:** how would you run a research project on the impact of AI in education?
 - **Producing:** go build habitats for certain species for certain purposes

Bloom's Taxonomy



Multimedia principle: People learn better from words and pictures than from words alone

Retention tests

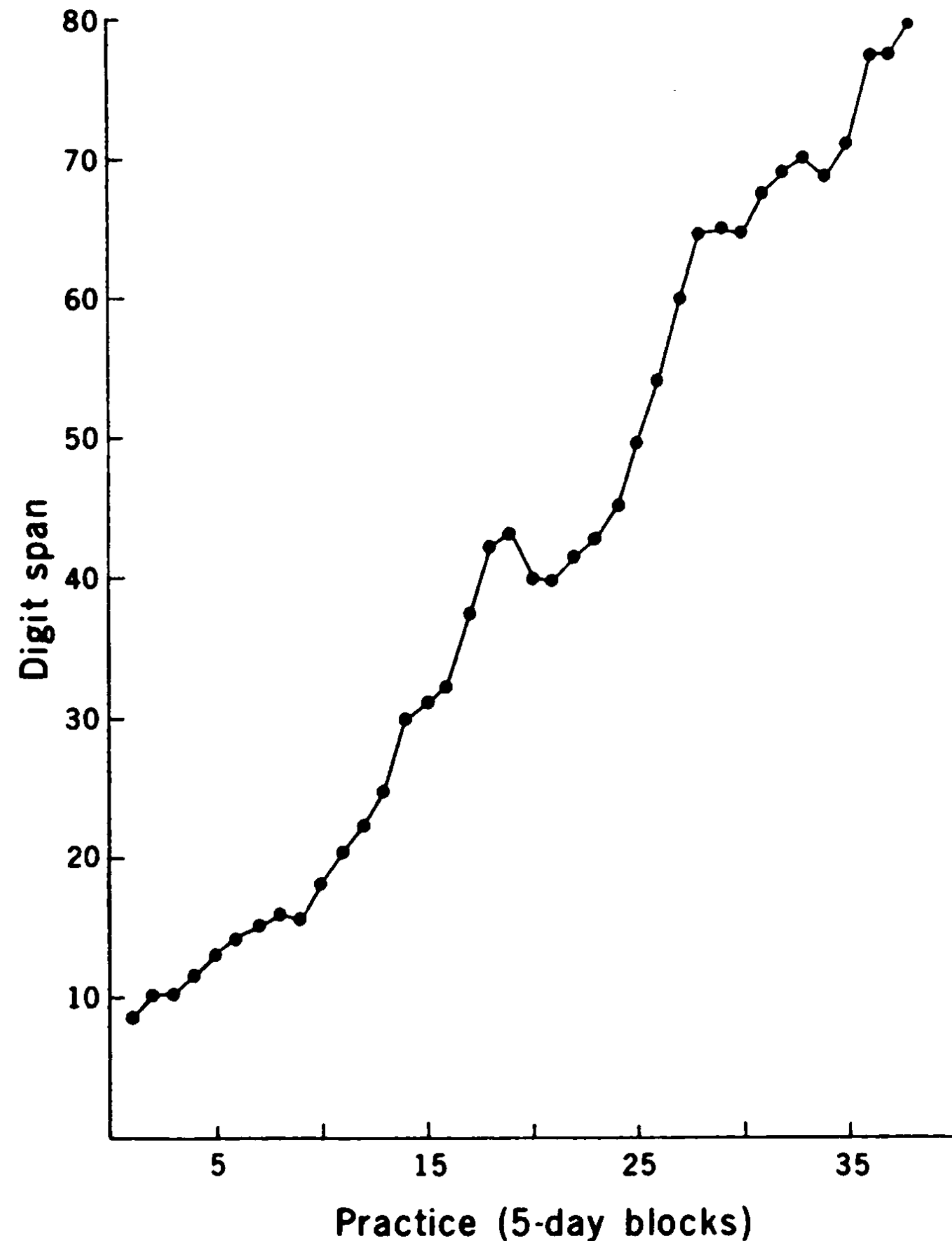
“What happens when the driver steps on the car’s brake pedal?”

“in 13 out of 13 tests, learners who received text and illustrations or narration and animation performed better on transfer tests than did learners who received text alone or narration alone (single representation group), with a median effect size is $d = 1.35$ ”

Transfer tests

“Suppose you press on the brake pedal in your car but the brakes do not work. What could have gone wrong?”

Most intelligence is less general than we'd like



“Finally, there is other evidence to suggest that short-term memory capacity did not increase with practice. [...] There was no increase in [subject’s] consonant letter span with practice on digits.”



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Wason selection task

Rule: If the card shows an even number on one face, then its opposite face must be blue.

Task: Determine which cards must be flipped to check whether they satisfy the rule.



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Wason selection task, drinking variant

~10% → ~75%!

Rule: If the receipt shows a beer, then the age on the other side must be 18 or over.

Task: Determine which cards must be flipped to check whether they satisfy the rule.

A small country was ruled from a strong fortress by a dictator. The fortress was situated in the middle of the country, surrounded by farms and villages. Many roads led to the fortress through the countryside. A rebel general vowed to capture the fortress. The general knew that an attack by his entire army would capture the fortress. He gathered his army at the head of one of the roads, ready to launch a full-scale direct attack. However, the general then learned that the dictator had planted mines on each of the roads. The mines were set so that small bodies of men could pass over them safely, since the dictator needed to move his troops and workers to and from the fortress.

However, any large force would detonate the mines. Not only would this blow up the road, but it would also destroy many neighboring villages. It therefore seemed impossible to capture the fortress. However, the general devised a simple plan. He divided his army into small groups and dispatched each group to the head of a different road. When all was ready he gave the signal and each group marched down a different road. Each group continued down its road to the fortress so that the entire army arrived together at the fortress at the same time. In this way, the general captured the fortress and overthrew the dictator.

Suppose you are a doctor faced with a patient who has a malignant tumor in his stomach. It is impossible to operate on the patient, but unless the tumor is destroyed the patient will die. There is a kind of ray that can be used to destroy the tumor. If the rays reach the tumor all at once at a sufficiently high intensity, the tumor will be destroyed. Unfortunately, at this intensity the healthy tissue that the rays pass through on the way to the tumor will also be destroyed. At lower intensities the rays are harmless to healthy tissue, but they will not affect the tumor either. What type of procedure might be used to destroy the tumor with the rays, and at the same time avoid destroying the healthy tissue?

People may not spontaneously transfer to analogous situations

Principle:

[The general attributed his success to an important principle:] If you need a large force to accomplish some purpose, but are prevented from applying such a force directly, many smaller forces applied simultaneously from different directions may work just as well.

Hint: “use the prior story to help solve the radiation problem.”

No input: 10%

Analog or principle or both: 30%

Analog + hint: 80%

“Significant transfer is probably rare and accounts for very little human behavior. Studies that claim transfer often tell subjects to transfer or use a ‘trick’ to call the subject’s attention to the similarity of the two problems. Such studies cannot be taken as evidence for transfer. We generally do what we have learned to do and no more. The lesson learned from studies of transfer is that, if you want people to learn something, teach it to them. Don’t teach them something else and expect them to figure out what you really want them to do.”

2. Teaching beyond transmission

People have long bemoaned direct instruction

Instead of communicating, the teacher issues communiques and makes deposits which the students patiently receive, memorize, and repeat. This is the "banking" concept of education, in which the scope of action allowed to the students extends only as far as receiving, filing, and storing the deposits.

— Paulo Freire, *Pedagogy of the Oppressed* (1970)

‘Now, what I want is, Facts. Teach these boys and girls nothing but Facts. Facts alone are wanted in life. Plant nothing else, and root out everything else. You can only form the minds of reasoning animals upon Facts: nothing else will ever be of any service to them. This is the principle on which I bring up my own children, and this is the principle on which I bring up these children. Stick to Facts, sir!’

— Charles Dickens, *Hard Times* (1854)

“transmissionism,” “instructionism,” “drill and kill,” ...

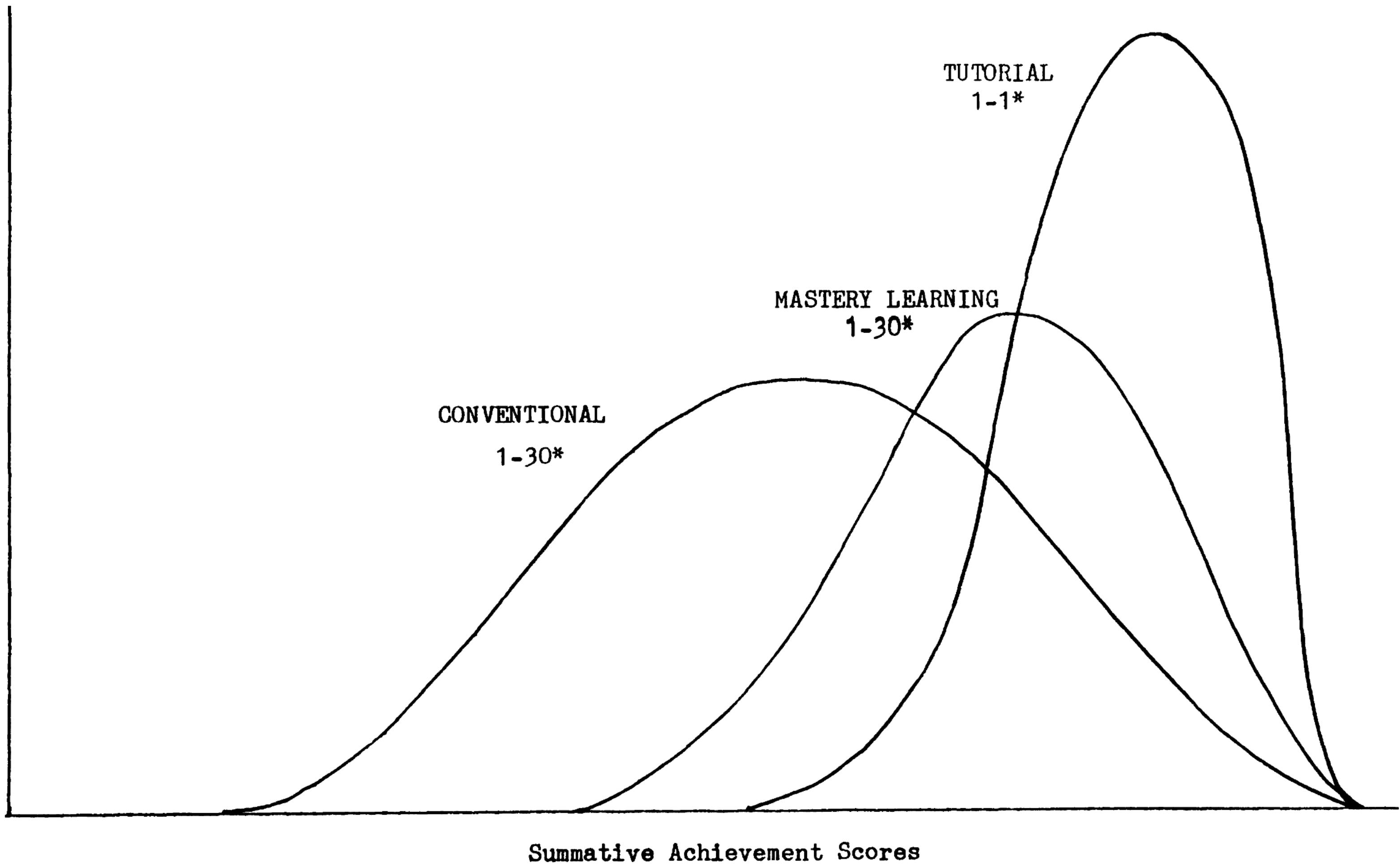
Active learning requires learner participation

TABLE 1
Examples of Learning Activities by Mode of Engagement

	PASSIVE <i>Receiving</i>	ACTIVE <i>Manipulating</i>	CONSTRUCTIVE <i>Generating</i>	INTERACTIVE <i>Dialoguing</i>
LISTENING to a lecture	Listening without doing anything else but oriented toward instruction	Repeating or rehearsing; Copying solution steps; Taking verbatim notes	Reflecting out-loud; Drawing concept maps; Asking questions	Defending and arguing a position in dyads or small group
READING a text	Reading entire text passages silently/aloud without doing anything else	Underlining or highlighting; Summarizing by copy-and-delete	Self-explaining; Integrating across texts; Taking notes in one’s own words	Asking and answering comprehension questions with a partner
OBSERVING a video	Watching the video without doing anything else	Manipulating the tape by pausing, playing, fast-forward, rewind	Explaining concepts in the video; Comparing and contrasting to prior knowledge or other materials	Debating with a peer about the justifications; Discussing similarities & differences

being taught is not the same as *learning!!!*

Bloom’s “2 sigma problem” claimed a high ceiling for effects of tutoring



“Under the best learning conditions we can devise (tutoring), the average student is 2 sigma above the average control student taught under conventional methods of instruction.”

*Teacher-student ratio

...but “2 sigma” is a misleading estimate

- Bloom’s work rested on two narrow studies of tutoring over three weeks w/ various confounders
- Broader meta-analyses of tutoring studies find a positive change of 0.3 - 0.5 sigma
- As we’ll see on Thursday, that doesn’t stop “2 sigma” from being an enduring meme

Deliberate practice falls in a similar bucket

- *Deliberate practice* is teacher-designed individualized training between sessions/lectures
 - As opposed to free play, and questionably opposed to student-designed practice
- Ericsson et al. 93 argued that deliberate practice explained differences between expert musicians and athletes
 - This would inspire Malcolm Gladwell's "10,000-hour rule", which Ericsson would later explicitly disavow
- Subsequent analyses dispute the definition & impact
 - "deliberate practice accounted for only 1% of the variance in performance among elite-level performers"

Flipped classrooms and mastery learning introduce personalization into the classroom



youtu.be/z9VojlfFZyE

Mastery learning can improve learning outcomes

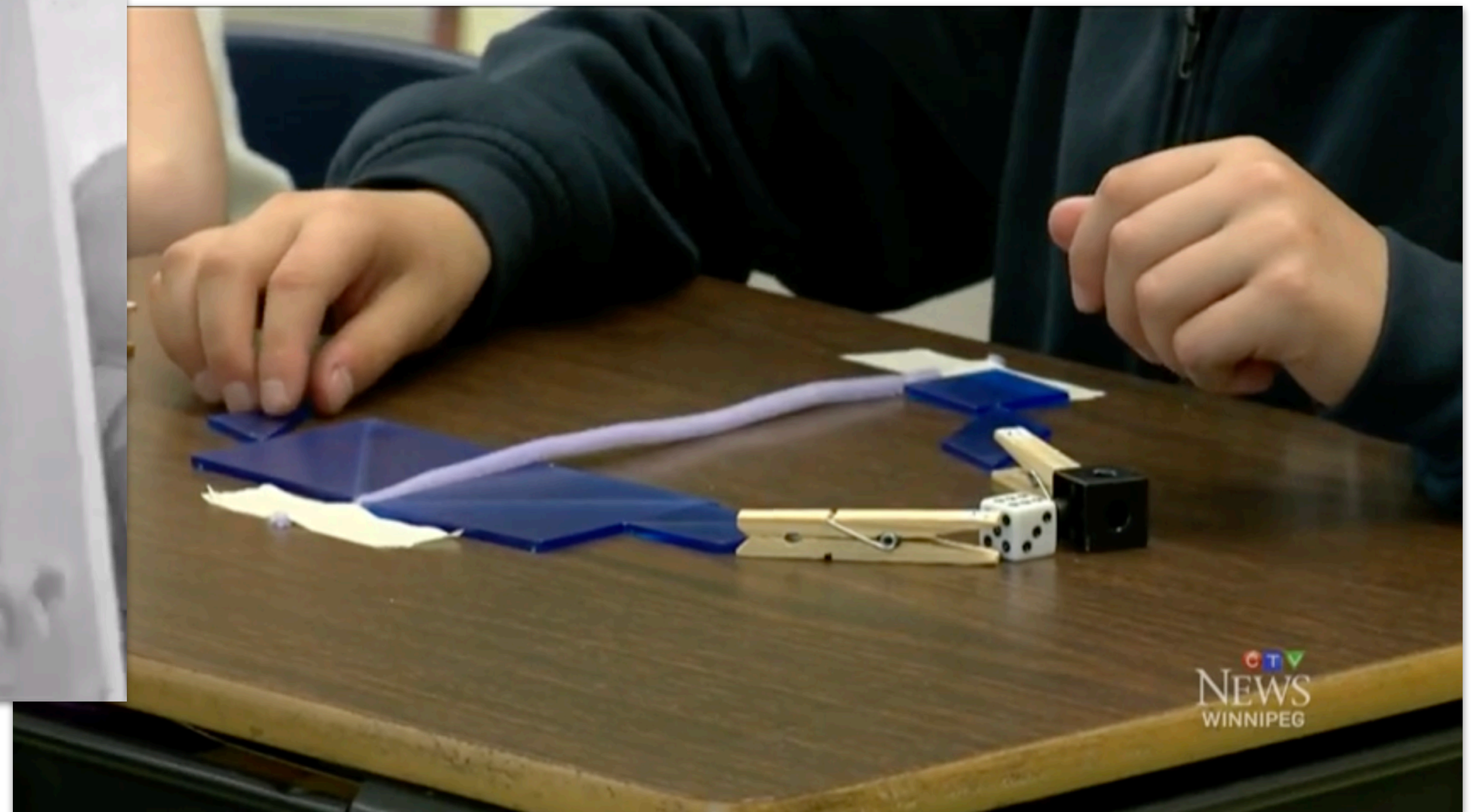
- On average, raises exam scores by 0.5 sigma
- Key indicators of large effect sizes:
 - Subject was social science rather than math, natural science, or humanities
 - Used locally developed rather than nationally standardized tests
 - Required students to move through content at a pace dictated by the teacher
 - Required students to do very well on mastery quizzes before proceeding
 - Baseline offers less feedback on quizzes
- Greater effect for low-baseline students vs. high-baseline

Discovery learning emphasizes the interactive construction of knowledge

youtu.be/QH5JMsDFXUA



youtu.be/pZuHz49CYOA

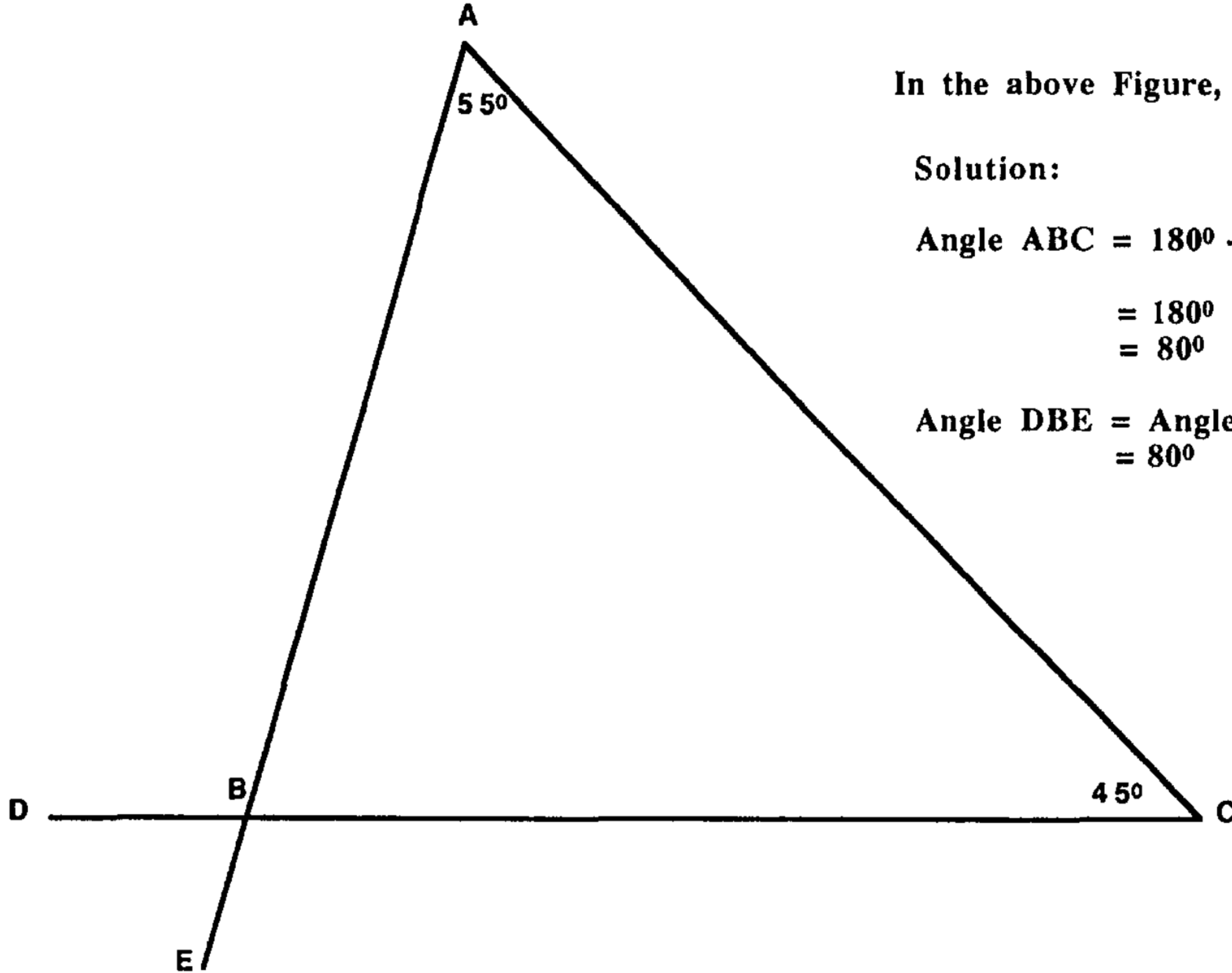


“After a half-century of advocacy associated with instruction using minimal guidance, it appears that there is no body of research supporting the technique. In so far as there is any evidence from controlled studies, it almost uniformly supports direct, strong instructional guidance rather than constructivist-based minimal guidance during the instruction of novice to intermediate learners. Even for students with considerable prior knowledge, strong guidance while learning is most often found to be equally effective as unguided approaches. Not only is unguided instruction normally less effective; there is also evidence that it may have negative results when students acquire misconceptions or incomplete or disorganized knowledge.”

— Kirschner, Sweller, and Clark.
“Why Minimal Guidance During Instruction Does Not Work” (2010)

3. Induction over instruction

Worked examples illustrate problem solving



In the above Figure, find a value for Angle DBE.

Solution:

Angle ABC = $180^\circ - \text{Angle BAC} - \text{Angle BCA}$ (Internal angles of a triangle sum to 180°)

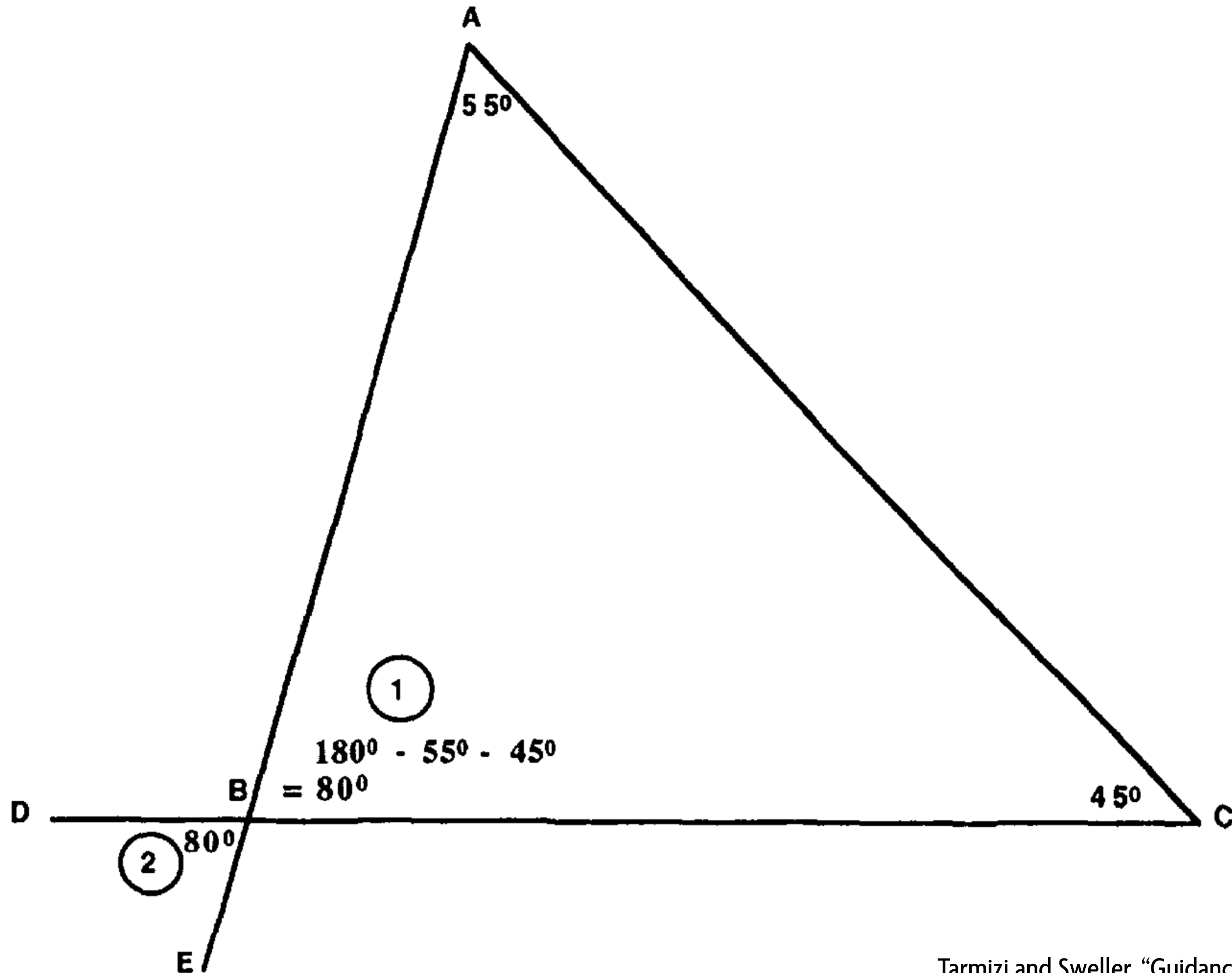
$$= 180^\circ - 55^\circ - 45^\circ$$

$$= 80^\circ$$

Angle DBE = Angle ABC (Vertically opposite angles are equal)

$$= 80^\circ$$

But only some worked examples are effective



Conventional

A vehicle moving from rest reaches a speed of 40 m/s after 20 seconds. What is the acceleration of the vehicle?

$$u = 0 \text{ m/s}$$

$$v = 40 \text{ m/s}$$

$$t = 20 \text{ s}$$

$$v = u + at$$

$$a = (v - u)/t$$

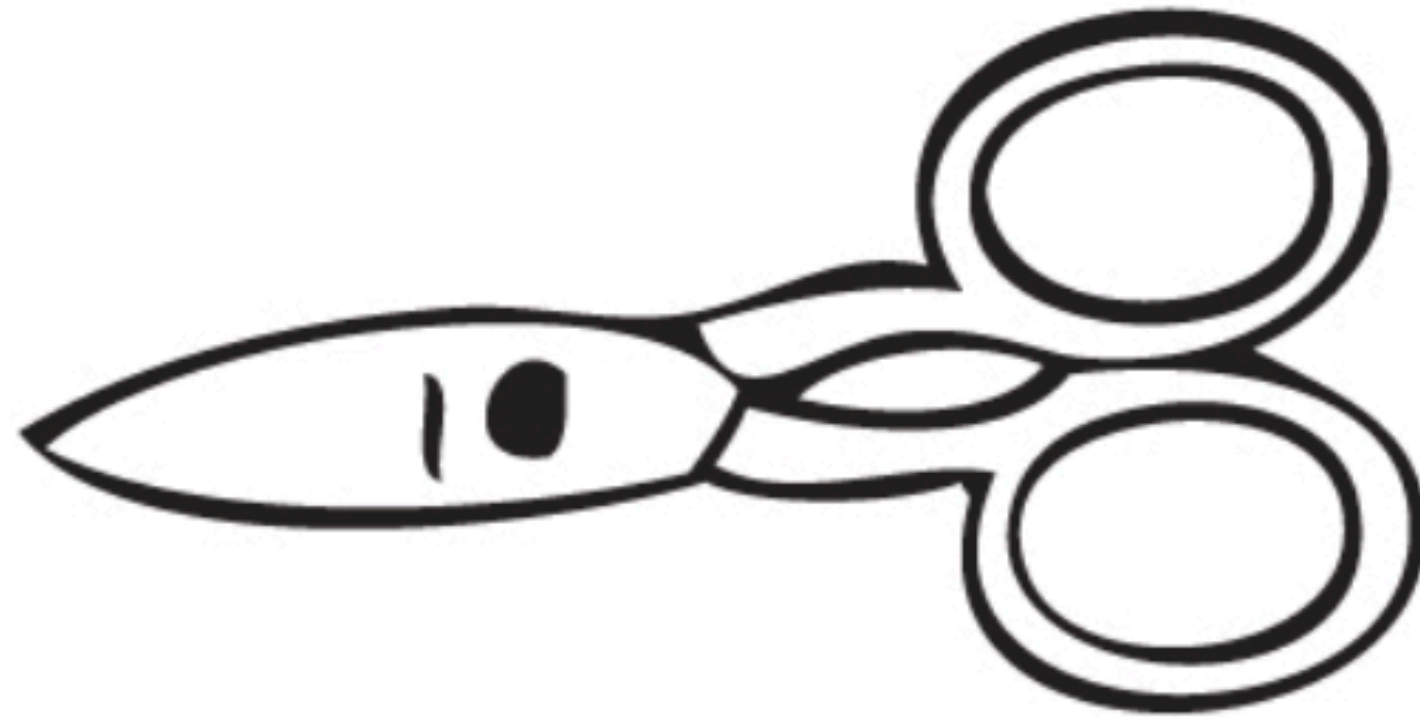
$$a = (40 - 0)/20$$

$$a = 2 \text{ m/s}^2$$

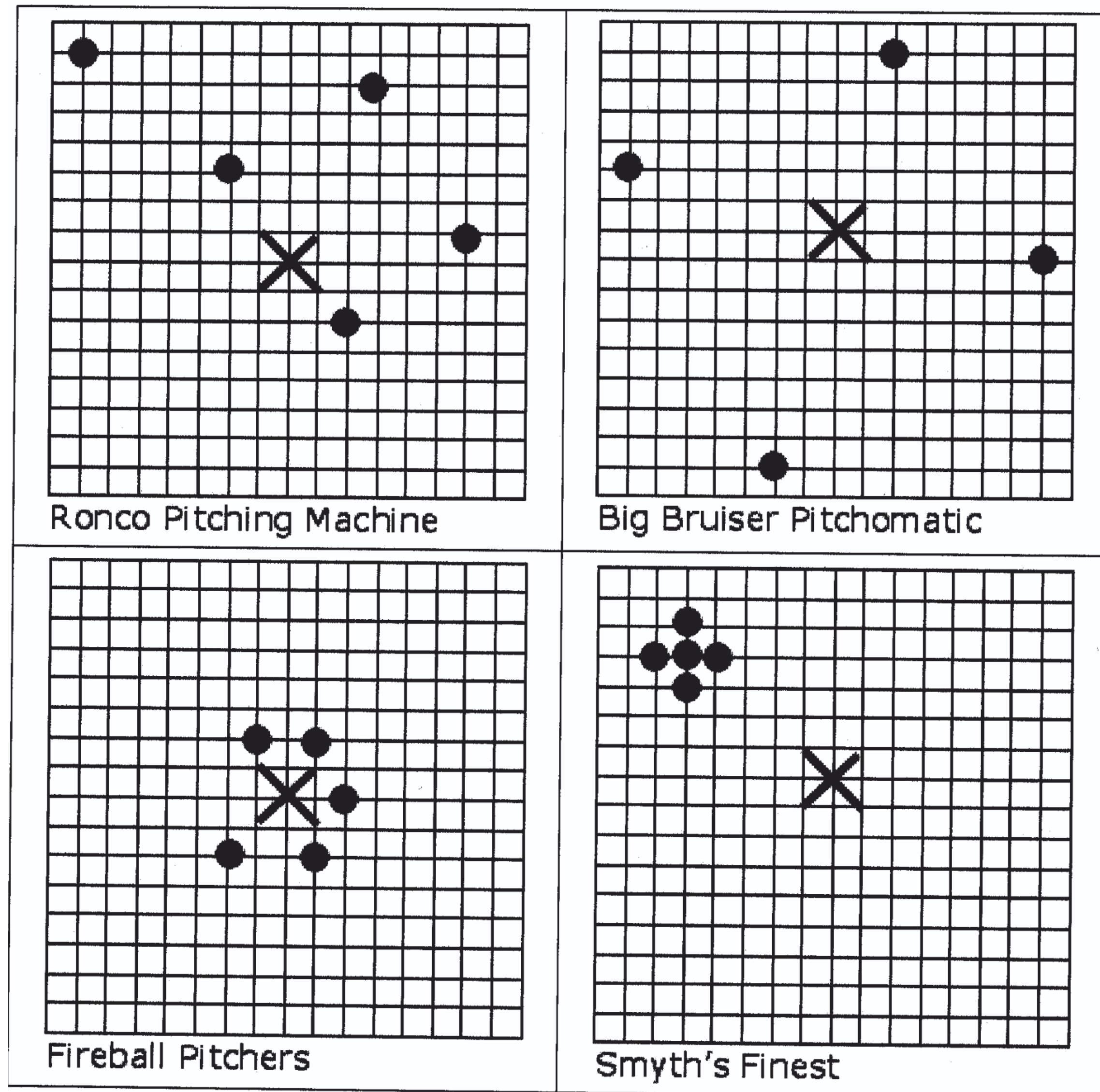
Integrated

A vehicle moving from rest (u) reaches a speed of 40 m/s (v) after 20 seconds (t): [$v = u + at$, $a = (v - u)/t = (40 - 0)/20 = 2 \text{ m/s}^2$]. What is the acceleration of the vehicle?

Contrasting cases highlight subtle differences

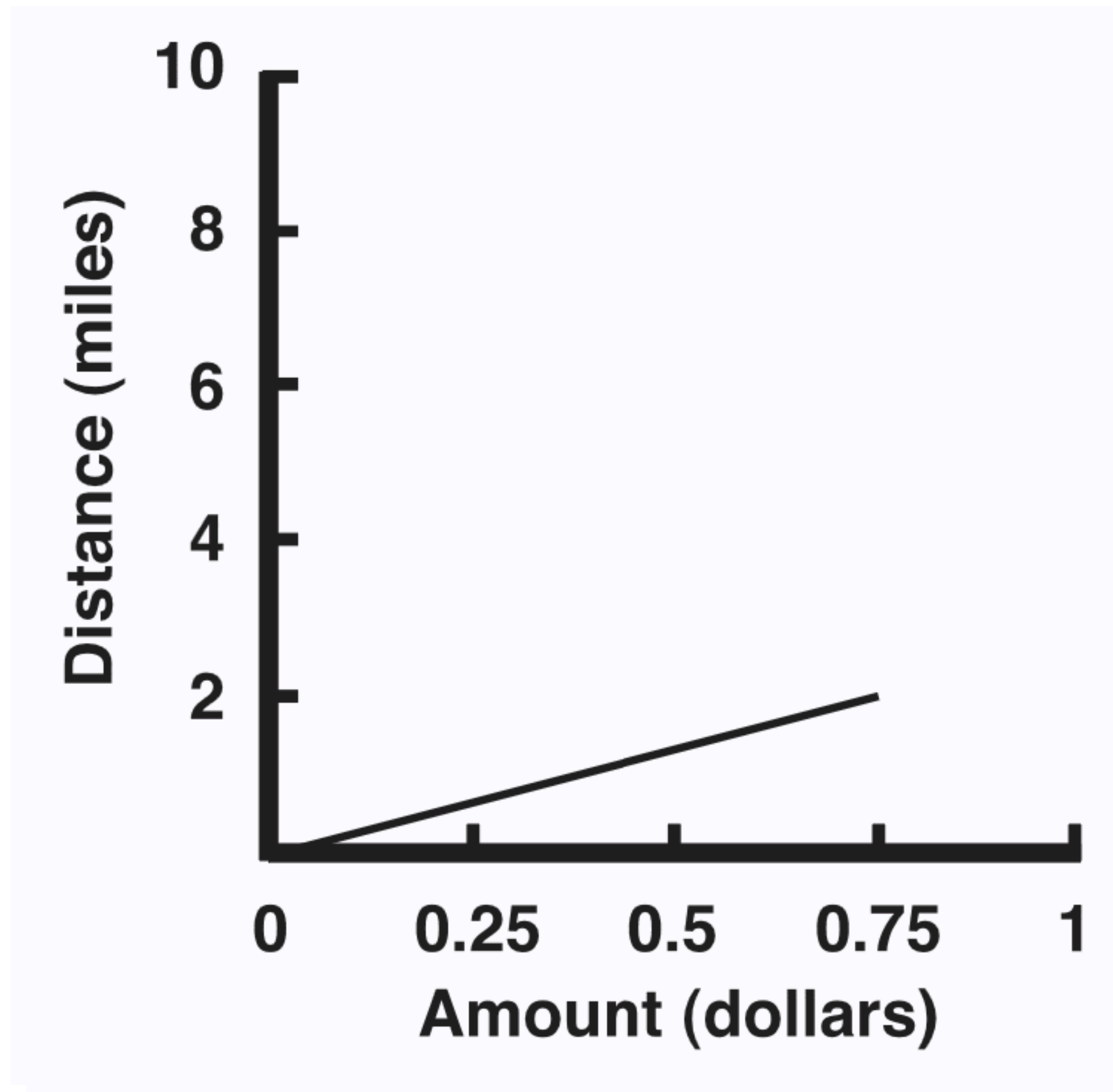


Contrasting cases provoke deeper reasoning



“Here are four grids showing the results from four different pitching machines. The X represents the target and the black dots represent where different pitches land. Your task is to invent a procedure for computing a reliability index for each of the pitching machines. There is no single way to do this, but you have to use the same procedure for each machine, so it is a fair comparison between the machines.’

“Perceptual learning modules” use contrasting cases to teach algebraic representation



$$\text{A: } y = \frac{-0.75}{2}x + 10$$

$$\text{B: } y = \frac{2}{0.75}x$$

$$\text{C: } y = \frac{0.75}{2}x$$

PLMs improve learning vs. conventional practice

