ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

CS-411 : Digital Education & Learning Analytics

Chapter 3: Mastery learning

Pierre Dillenbourg

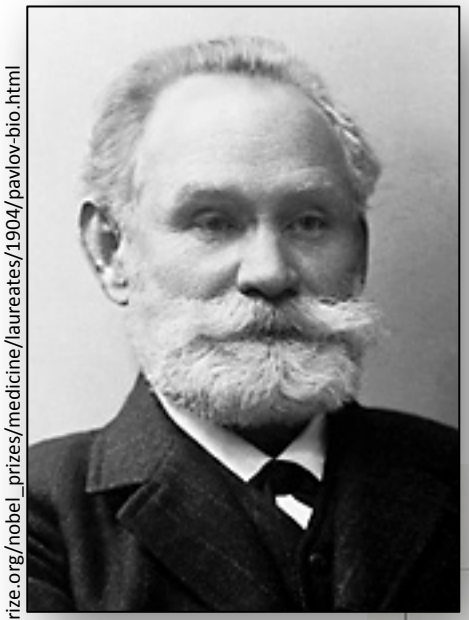
1. Sensory Memory
2. Working Memory
3. Articulatory loop
4. Verbal/Phonological Loop
5. Articulatory suppression
6. Visuo-spatial sketchpad
7. Long-Term Memory
8. Cognitive Load
9. Intrinsic Cognitive Load
10. Extrinsic Cognitive Load
11. Germane Cognitive Load
12. Cognitive Overload
13. Split-Attention Effect
14. ~~Induction~~
15. ~~Deduction~~
16. ~~Analogy~~
17. Fact
18. Class
19. Procedure
20. Law
21. System
22. Knowledge Taxonomy
23. Cognitive tasks taxonomy
24. Bloom's taxonomy
25. D'Hainaut's taxonomy

LAST WEEK

26. Pedagogical Objectives
27. Learning Outcomes
28. Declarative knowledge
29. Procedural knowledge
30. Elicitation
31. Proceduralisation
32. Compilation
33. Free recall
34. Recognition
35. Imitation
36. Conceptualisation
37. Application
38. Exploration
39. Mobilisation
40. Problem solving
41. Transversal skills
42. Heuristic Knowledge
43. Formal education
44. No-formal Education
45. Informal Education
46. Metacognition
47. Regulation
48. ~~Pre-requisites~~
49. ~~Pre-representations~~
50. ~~Instructional Engineering~~

dogs

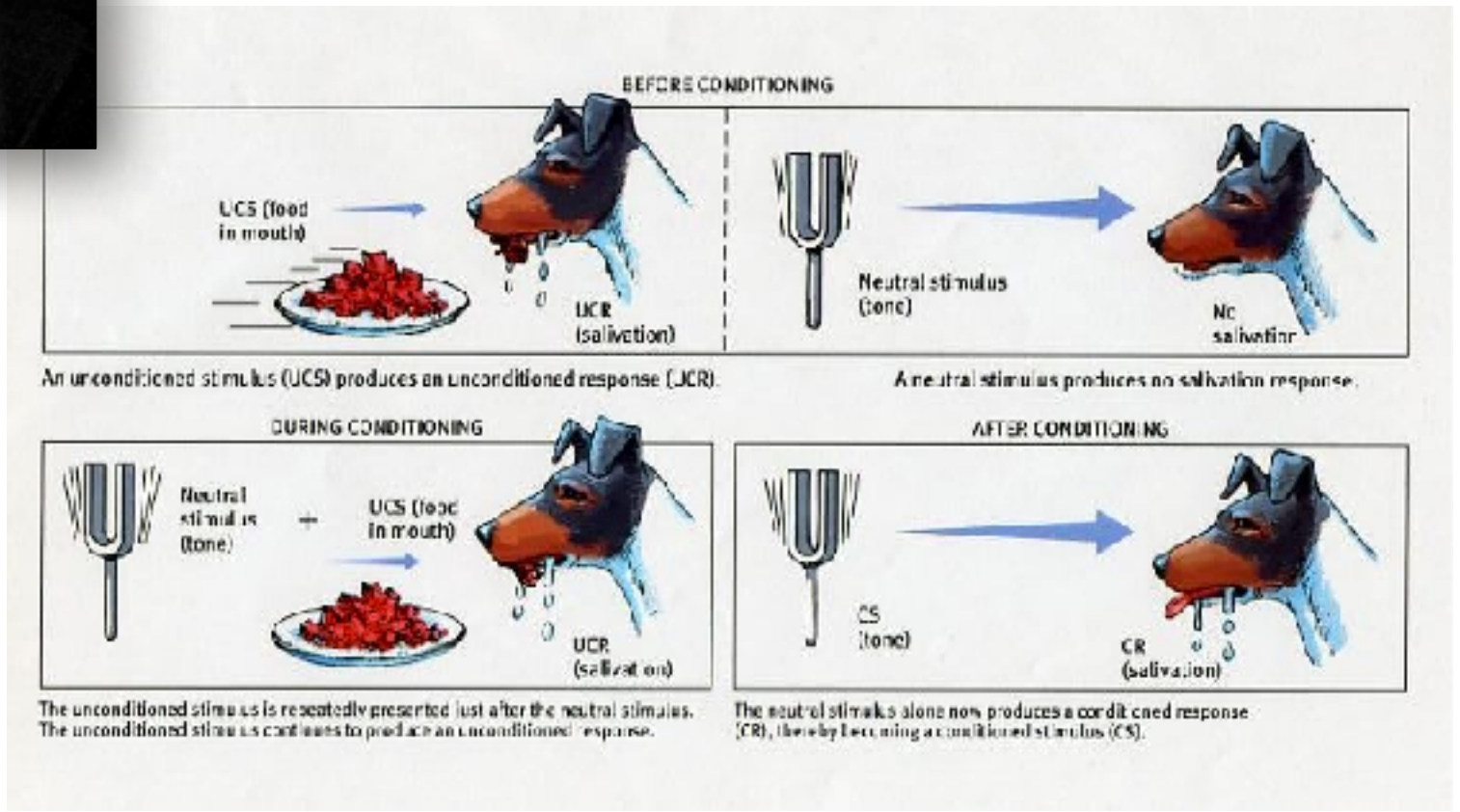
How do people learn ?



http://www.nobelprize.org/nobel_prizes/medicine/laureates/1904/pavlov-bio.html

Yvan Pavlov, 1849-1936

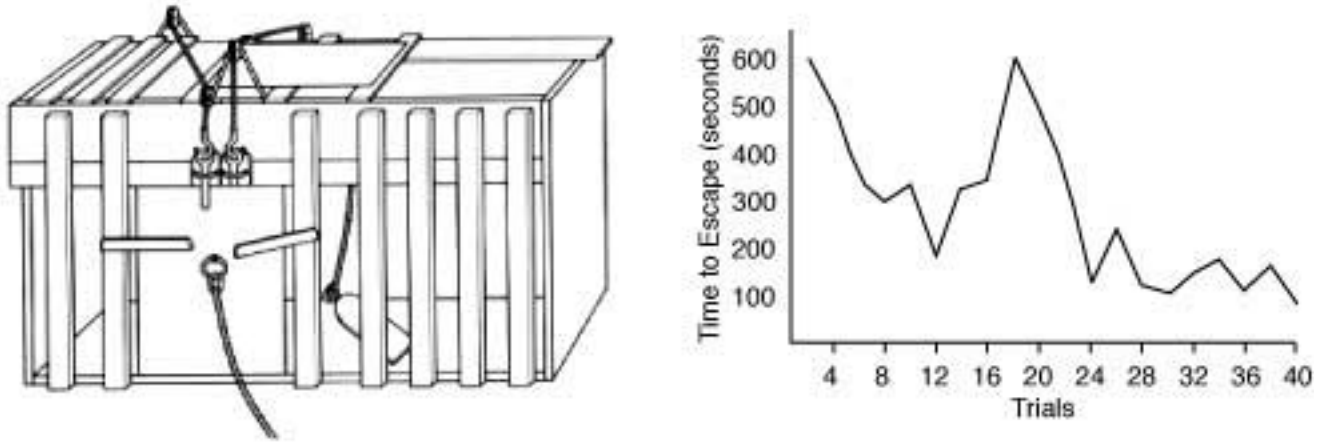
Classical Conditioning



http://www.rhsmpsychology.com/Handouts/classical_conditioning.htm

http://psychology.about.com/od/profilesmz/p/edward-thorndike.htm

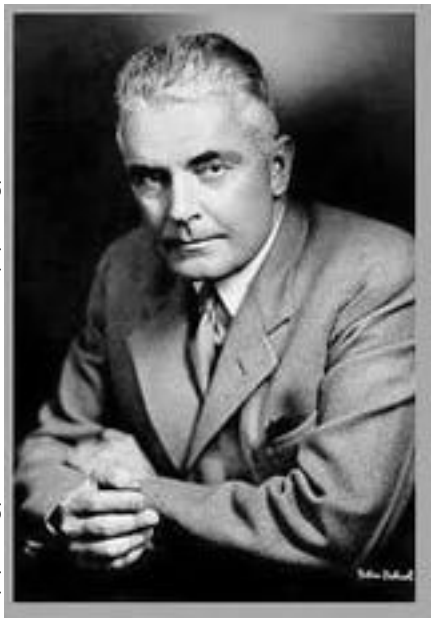
Edward L. Thorndike (1874 – 1949) The Law of Effect : any behavior that is followed by pleasant consequences is likely to be repeated, and any behavior followed by unpleasant consequences is likely to be stopped.



Adapted from Domjan, 1993 (modified from Thorndike, 1898 [left] and Imada & Imada, 1983 [right])

http://www.simplypsychology.org/edward-thorndike.html

Edward L. Thorndike, The Law of Effect, The American Journal of Psychology
Vol. 39, No. 1/4 (Dec., 1927), pp. 212-222: http://www.jstor.org/stable/1415413



http://psychology.about.com/od/behavioralpsychology/f/behaviorism.htm

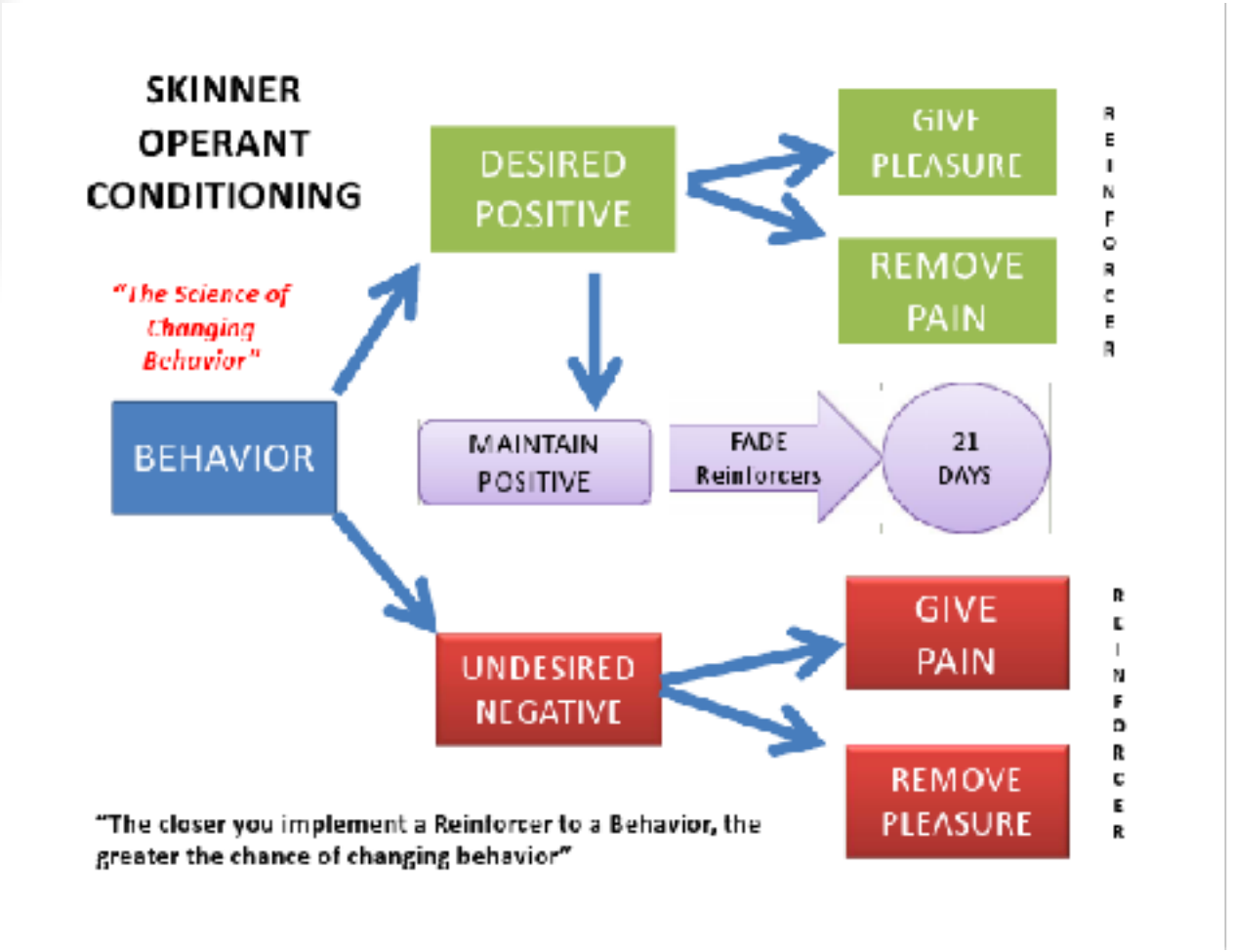
John Watson (1878- 1958) Behaviourism

"Give me a dozen healthy infants, well-formed, and my own specified world to bring them up in and I'll guarantee to take any one at random and train him to become any type of specialist I might select -- doctor, lawyer, artist, merchant-chief and, yes, even beggar-man and thief, regardless of his talents, penchants, tendencies, abilities, vocations, and race of his ancestors."

--John Watson, Behaviorism, 1930

The Little Albert Experiment

Burrhus Frederic Skinner (1904-1990), [Operant Conditonning]



https://sites.google.com/a/adams12.org/harp-mrhs-home-v1/06-powerpoint-section/skinner-s-operant-conditioning

Key ideas in behaviorism

① Psychology is becoming more scientific

② The brain is a black box; the focus is on behaviors

③ Learning is « engineered »

④ Association results from immediate feedback

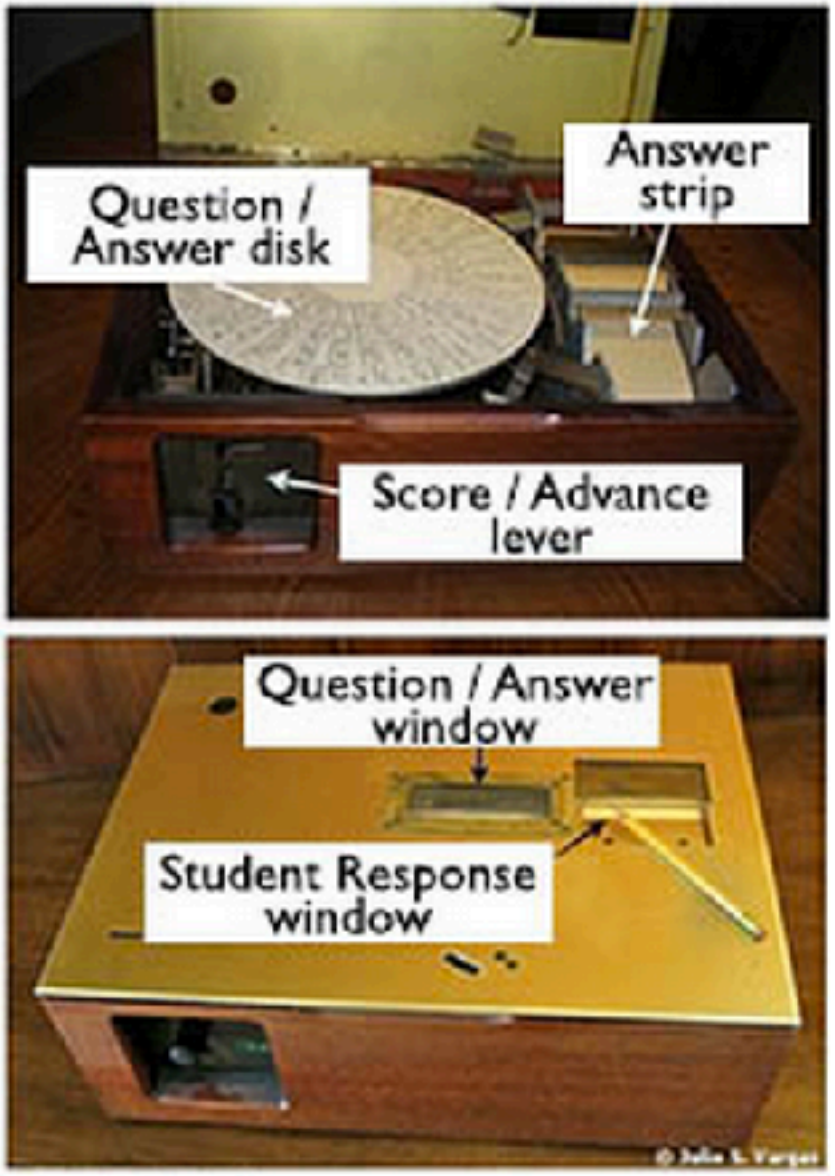
⑤ The learner is permanently active

⑥ Small steps increase the probability of positive feedback ➔ Programmed instruction

B. F. Skinner

FIG. 11. Student at work in the self-instruction room. Material appears in the left-hand window. The student writes his response on a strip of paper exposed at the right.

B.F. Skinner's Teaching Machine



(c) Julie S. Vargas

Instructional "disks" are placed inside the machine along with a strip or roll of paper. When the machine is closed, the student reads a question through a window and writes their response on the strip of paper. The student then compares their answer with the answer on the disk and presses the lever one way if their answer is correct or the other way if incorrect (the machine keeps score and advances).

Skinner proposed the machine improves learning by "taking into account the rate of learning for each individual learner." With this, Skinner formalizes "self-paced instruction" as part of programmed instruction.

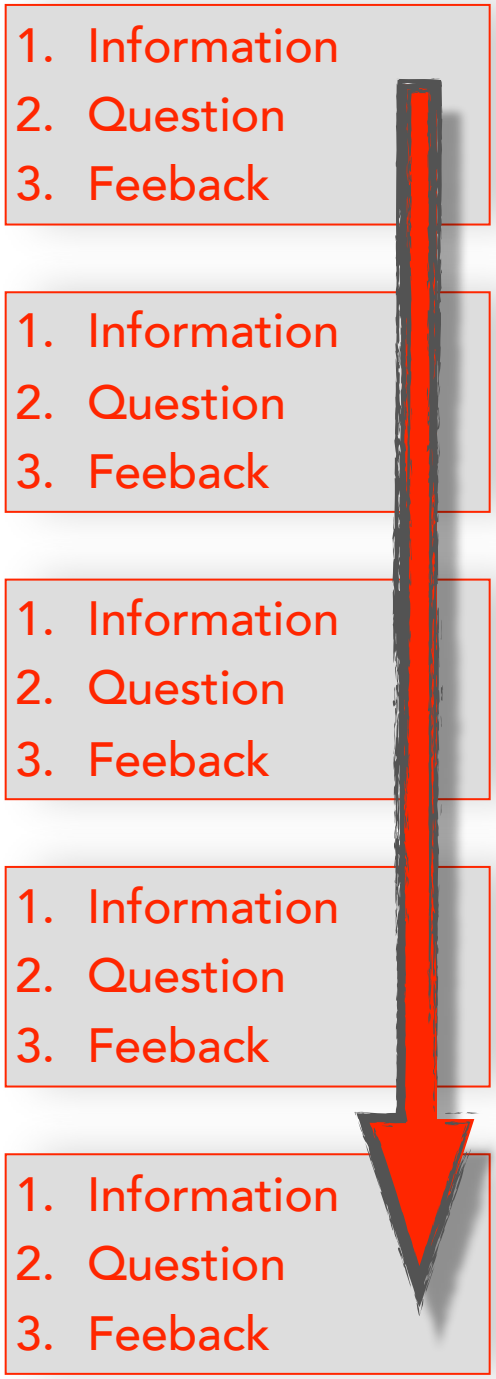
Linear Instruction

Table 2. PART OF A PROGRAM IN HIGH-SCHOOL PHYSICS

The machine presents one item at a time. The student completes the item and then uncovers the corresponding word or phrase shown at the right.

SENTENCE TO BE COMPLETED	WORD TO BE SUPPLIED
1. The important parts of a flashlight are the battery and the bulb. When we "turn on" a flashlight, we close a switch which connects the battery with the _____.	bulb
2. When we turn on a flashlight, an electric current flows through the fine wire in the _____ and causes it to grow hot.	bulb
3. When the hot wire glows brightly, we say that it gives off or sends out heat and _____.	light
4. The fine wire in the bulb is called a filament. The bulb "lights up" when the filament is heated by the passage of a(n) _____ current.	electric
5. When a weak battery produces little current, the fine wire, or _____, does not get very hot.	filament
6. A filament which is less hot sends out or gives off _____ light.	less
7. "Emit" means "send out." The amount of light sent out, or "emitted," by a filament depends on how _____ the filament is.	hot

http://66.31.107.147/~heines/academic/papers/2002elearn/images/Lumsdaine_Glaser/



Frame-Based Models / e-learning

1. Decomposition: Segmenting complex contents into a sequence of learning steps that contains an elementary piece of information
2. Keep the student active all the time, ask the student to process any new piece of information
3. Provide immediate feedback
4. Let the student move on at his or her own speed

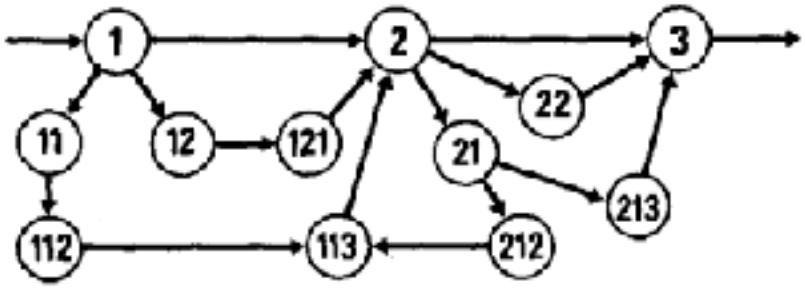
Feedback

is the 1st principle

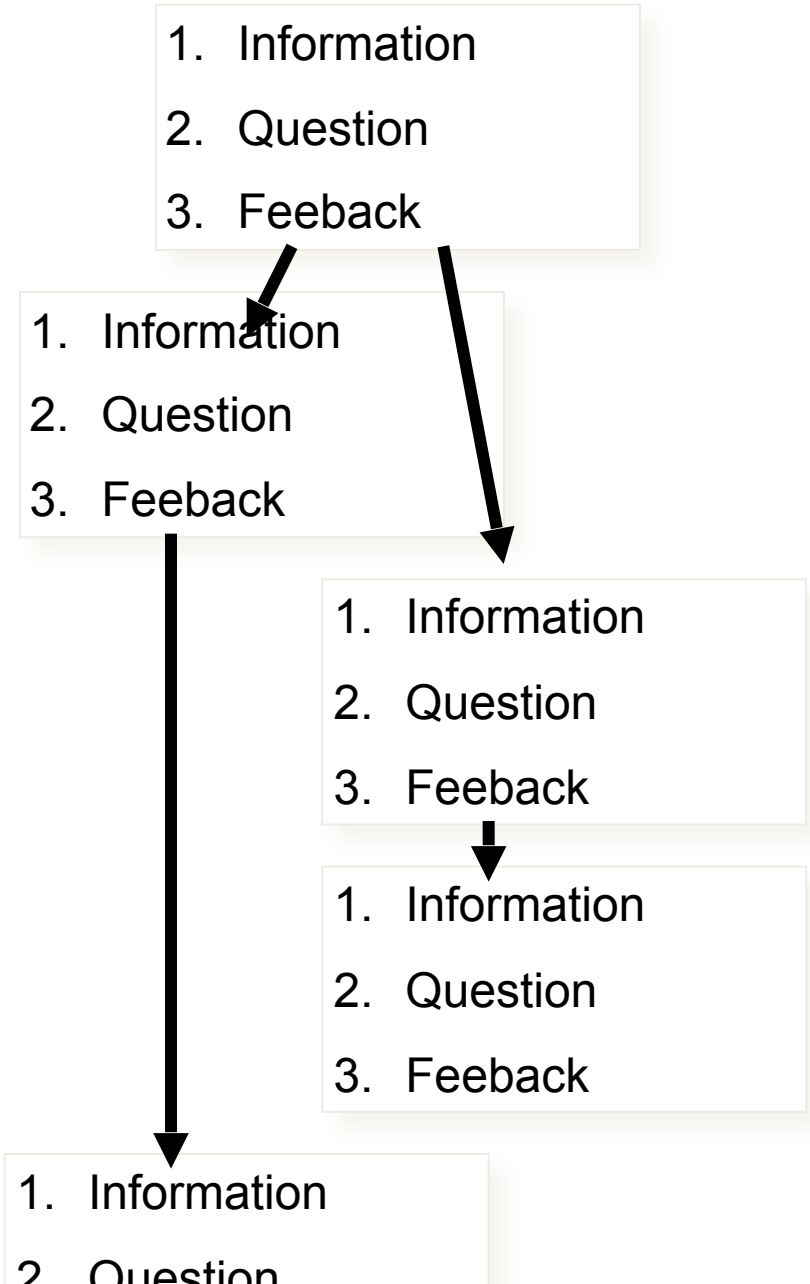
for pedagogical effectiveness

Branched Instruction

http://ute3.umh.ac.be/uticef/master/m341/partie_2.htm



AutoTutor, Crowder

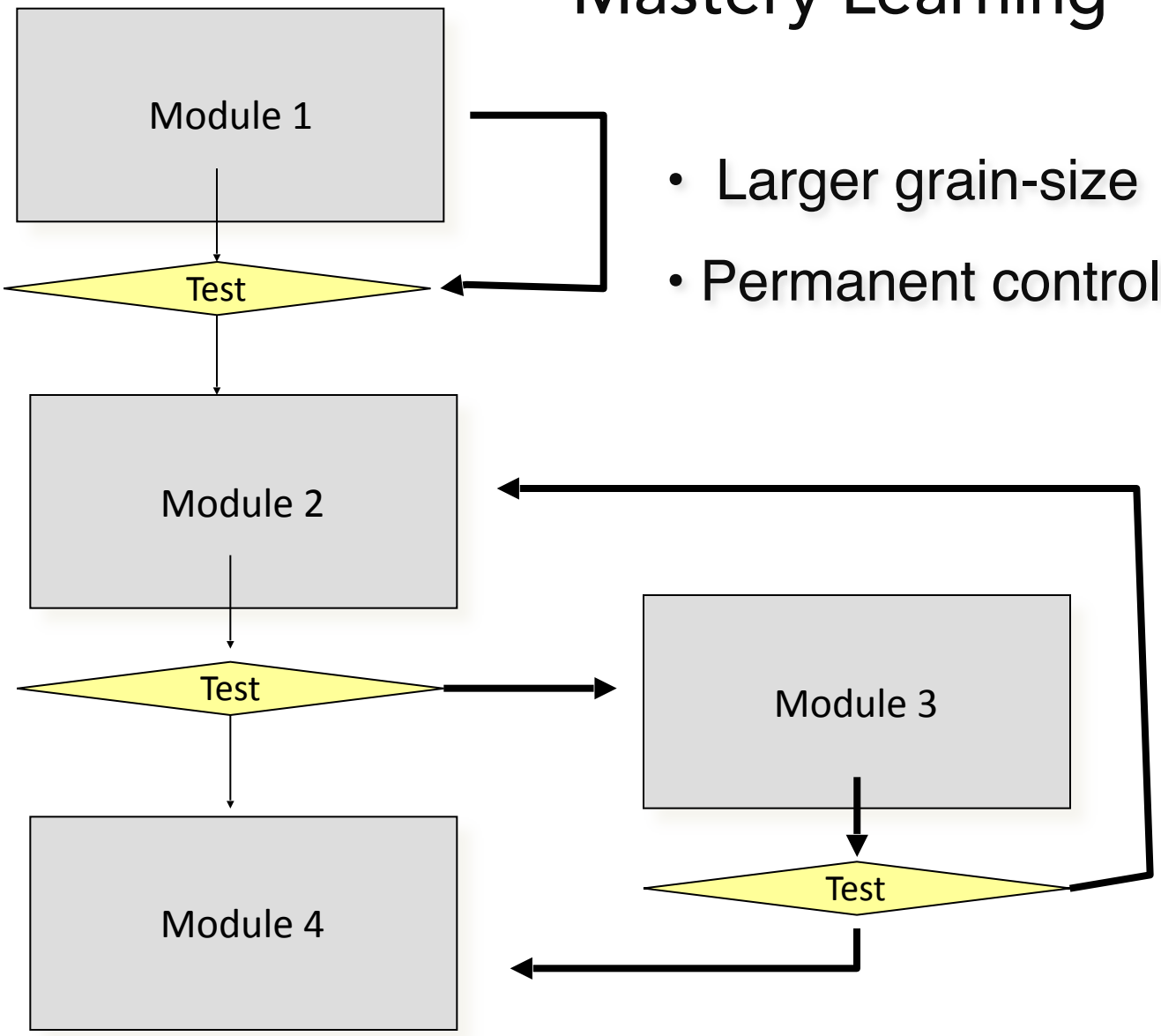


Frame-Based Models

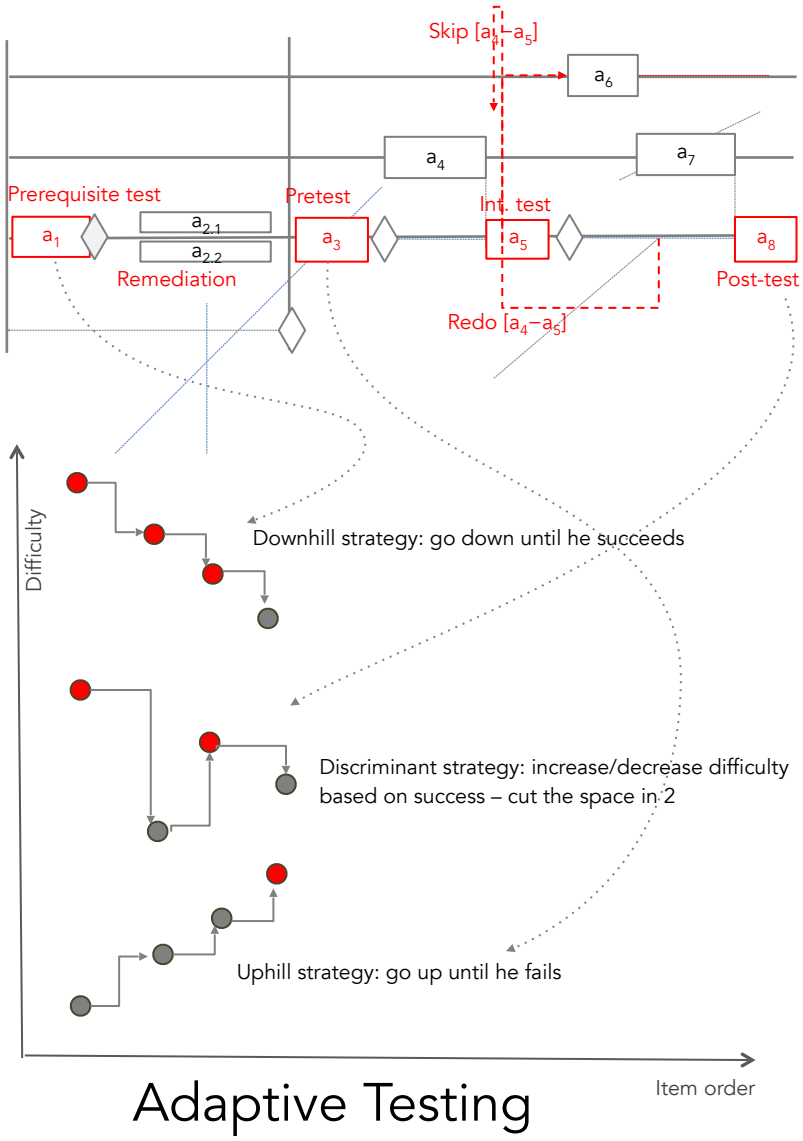
- **Decomposition**: Segmenting complex contents into a sequence of learning steps that contains an elementary piece of information
- Keep the student **active** all the time, ask the student to process any new piece of information
- Provide immediate **feedback**
- Let the student move on at his or her own speed.
- **Individualisation**: adapt instruction to the student needs

Based on behaviourism-inspired "programmed learning instruction"

Mastery Learning



- Larger grain-size
- Permanent control of effectiveness



Adaptive Testing

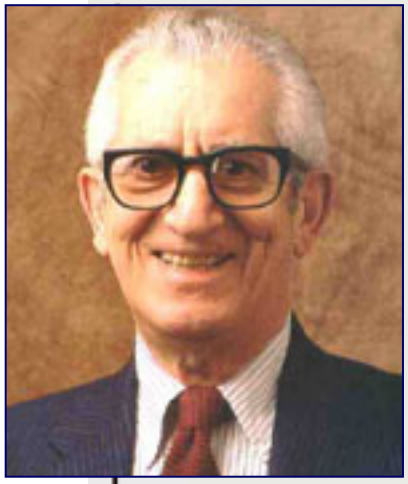
Modular Instruction

Pre-requisite test: Does the learner has the pre-requisite to start the course ?

Pre-test: Should the learner skip some modules ?

Intermediate-test: Didthe learner reach the objectives of this module ?

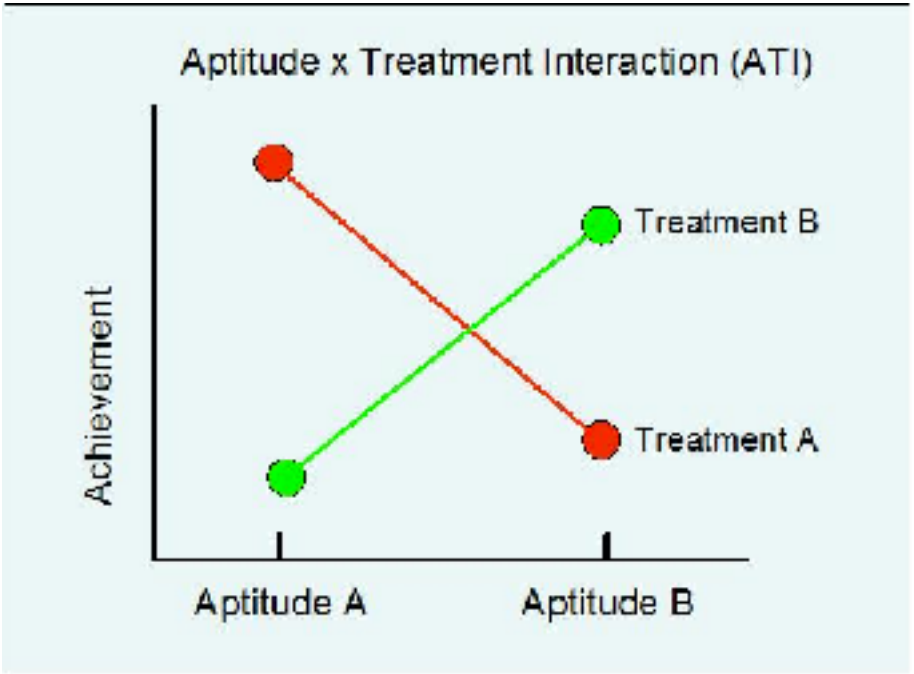
Post-test: Did the learner reach the objectives of this course?



B. Bloom

FIGURE 1. *Achievement distribution for students under conventional, mastery learning, and tutorial instruction.*

Bloom, B. (1984). "The 2 Sigma Problem: The Search for Methods of Group Instruction as Effective as One-to-One Tutoring", Educational Researcher, 13:6(4-16).



Aptitude- Treatment Interactions:

The effect of a pedagogical method varies for different learners profiles

Cronbach, L. & Snow, R. (1977). Aptitudes and Instructional Methods: A Handbook for Research on Interactions. New York: Irvington

The effect of a pedagogical method

varies for different learners profiles

CHAPTER 9

- Personalized Instruction
- Individual instruction
- Adaptive instruction
- …
- *Optimization in learning environments*

Mastery Learning Efficiency

Lisp Programming Tutor

- Cognitive Mastery vs. Fixed Curriculum:
  - 40% more problems
  - 14% more time
  - 25% greater accuracy on post-test
  - 570% increase in mastery
  - Effect size: *d*=0.65

Corbett, A. (2001). Cognitive computer tutors: Solving the two-sigma problem. In M. Bauer, P. J. Gmytrasiewicz, & J. Vassileva (Eds.), *Proceedings of the 8th International Conference on User Modeling, UM 2001* (pp. 137-147). Springer Berlin Heidelberg. doi:10.1007/3-540-44566-8_14

By courtesy of Vincent Aleven, CMU

Evaluations of Intelligent Tutoring Systems

- Study with 17,000 students showed that Cognitive Tutor Algebra (a curriculum + ITS) doubled students' algebra learning

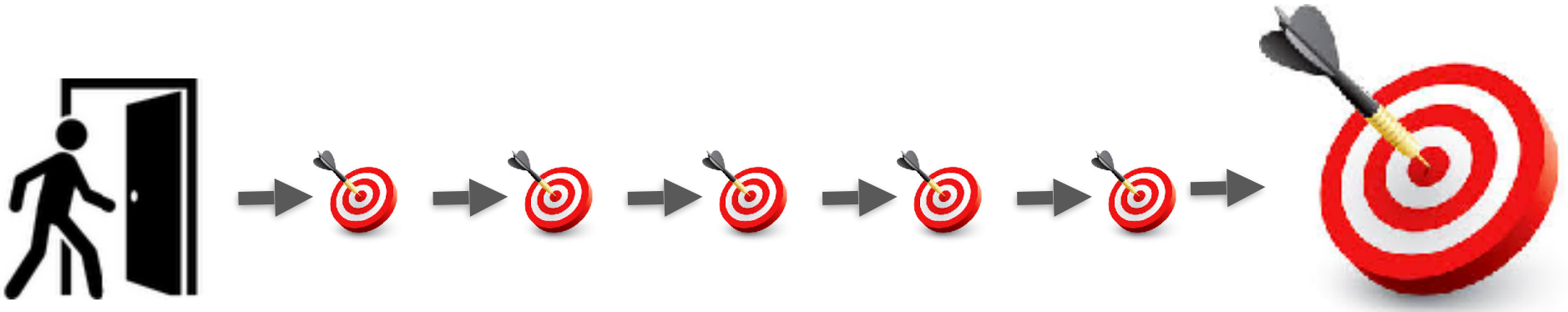
  (Pane et al., 2013)

- Meta-review indicates that ITSs are "nearly as effective as human tutoring" (VanLehn, 2011)

- Four meta-analyses show ITSs are often more effective than other forms of instruction

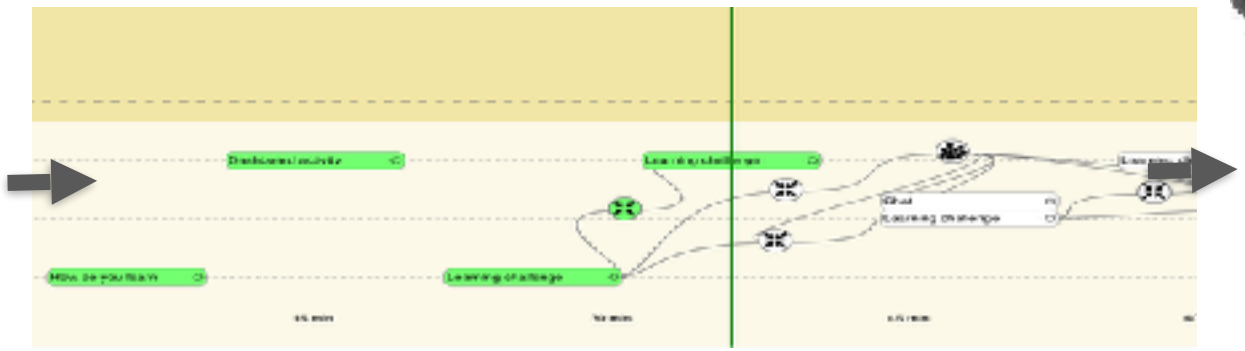
  (Kulik & Fletcher, 2015; Ma, Adesope, Nesbit, & Liu, 2014; Steenbergen-Hu & Cooper, 2013; 2014)

Mastery learning



Objectives

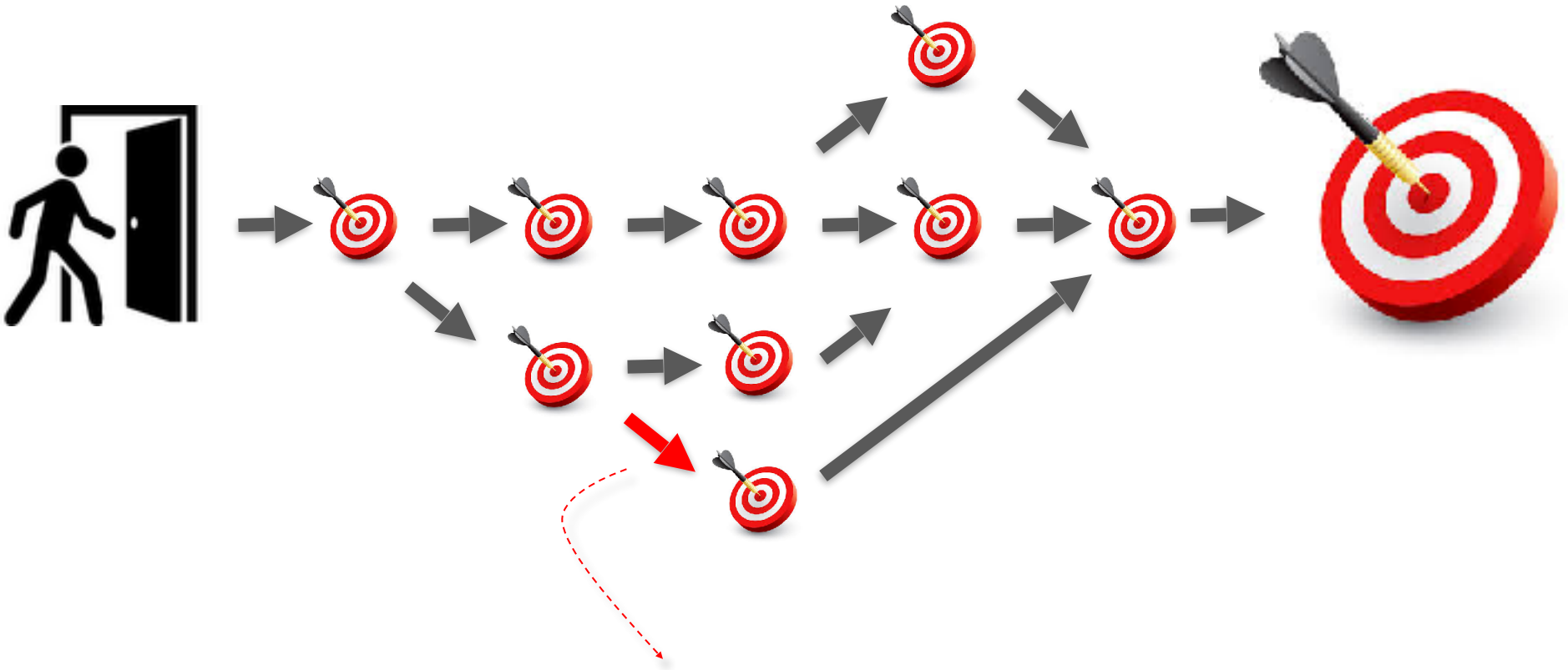
Mastery learning & Orchestration Graphs



Objectives

Why is an activity a_1 useful for an activity a_2?

Mastery learning



Why is an activity a_1 useful for an activity a_2?

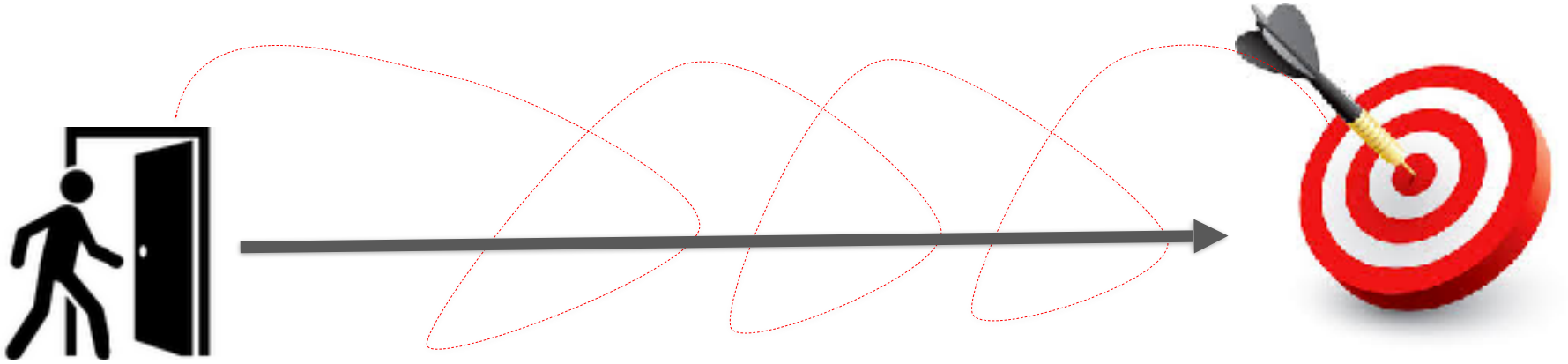
Why is an activity a_1 useful for an activity a_2?

Pre-requisite: {skills-a_1 } is a subset of {skills-a_2 }

Pre-requisites are common sense: You need to be able to do 5+7 (a_i), before trying 25+37 (a_j).

Nonetheless, a high portion of failure is explained the accumulation of small gaps in pre-requisites.

Mastery learning focused especially on this sequencing



What are they able to do
at the beginning

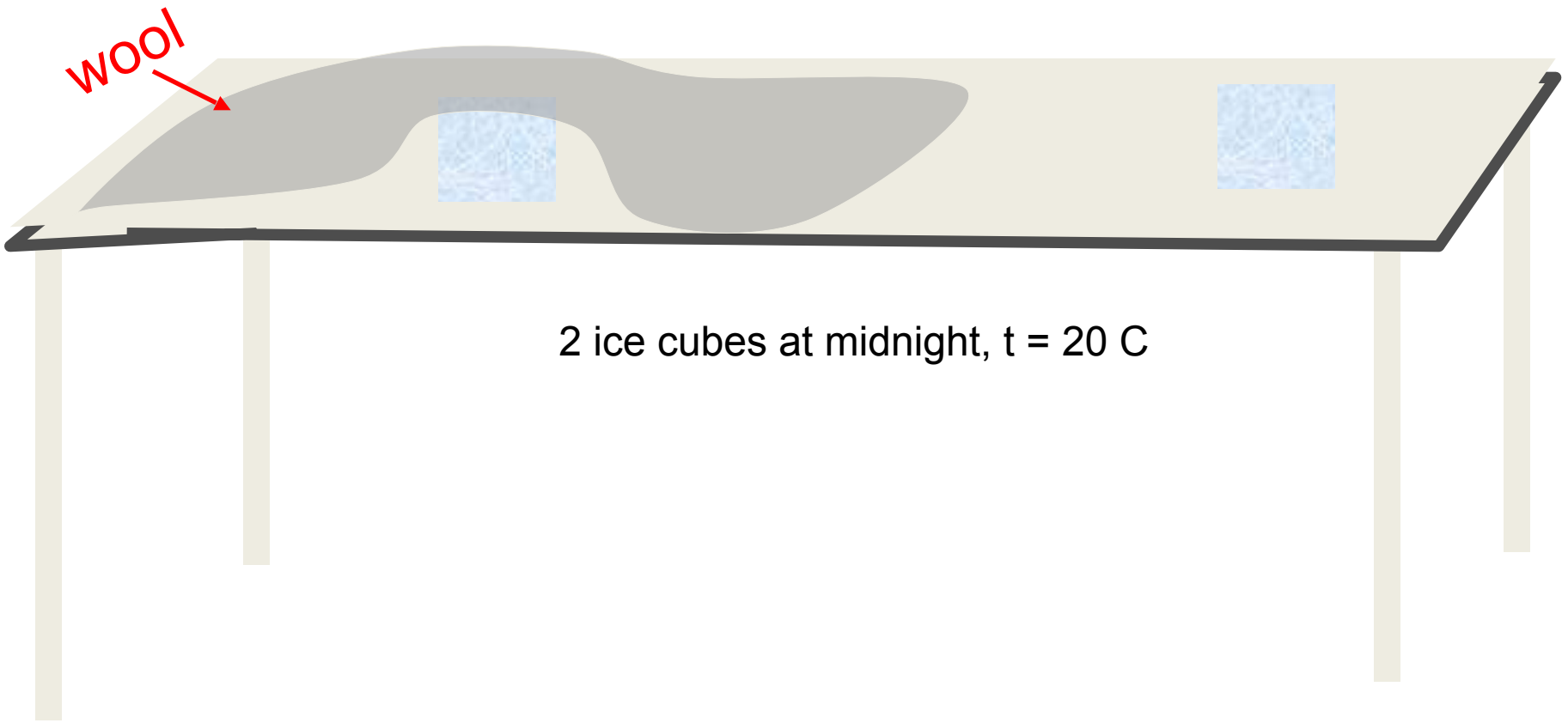
Pre-Requisites

What should learners be able to do at the end ?

(which they could not do
at the beginning)

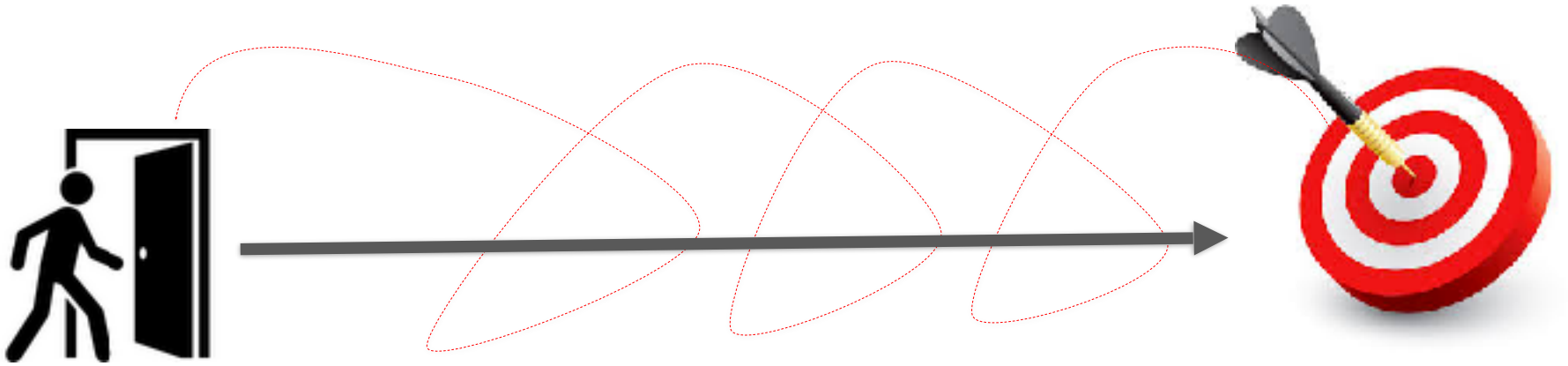
Objectives

Prior Knowledge can be wrong



Which ice cube will melt faster ?

Instructional design works backwards :



What are they able to do
at the beginning

Pre-Requisites

Pre-Representations

What should learners be able to do at the end ?

(which they could not do
at the beginning)

Objectives

Why is an activity a_1 useful for an activity a_2?

Advance organizer :

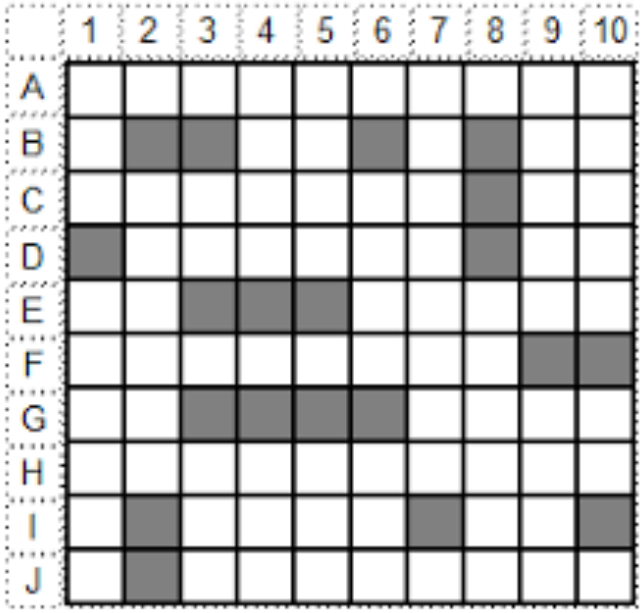
a_1 pre-activates structures for a_2

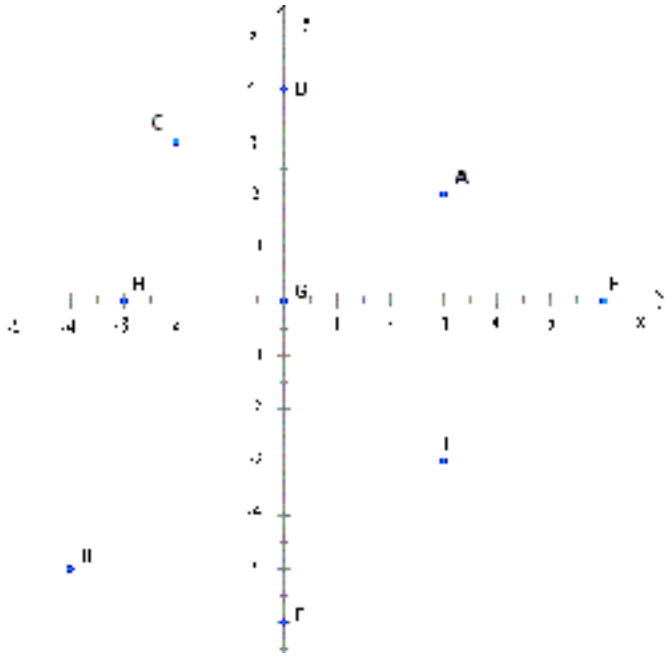
Which fruit do people eat in winter ?

Why is an activity a_1 useful for an activity a_2?

Advance organizer :

a_1 pre-activates structures for a_2

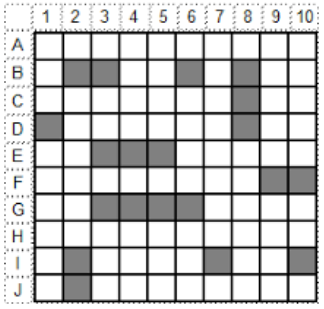




Why is an activity a_1 useful for an activity a_2?

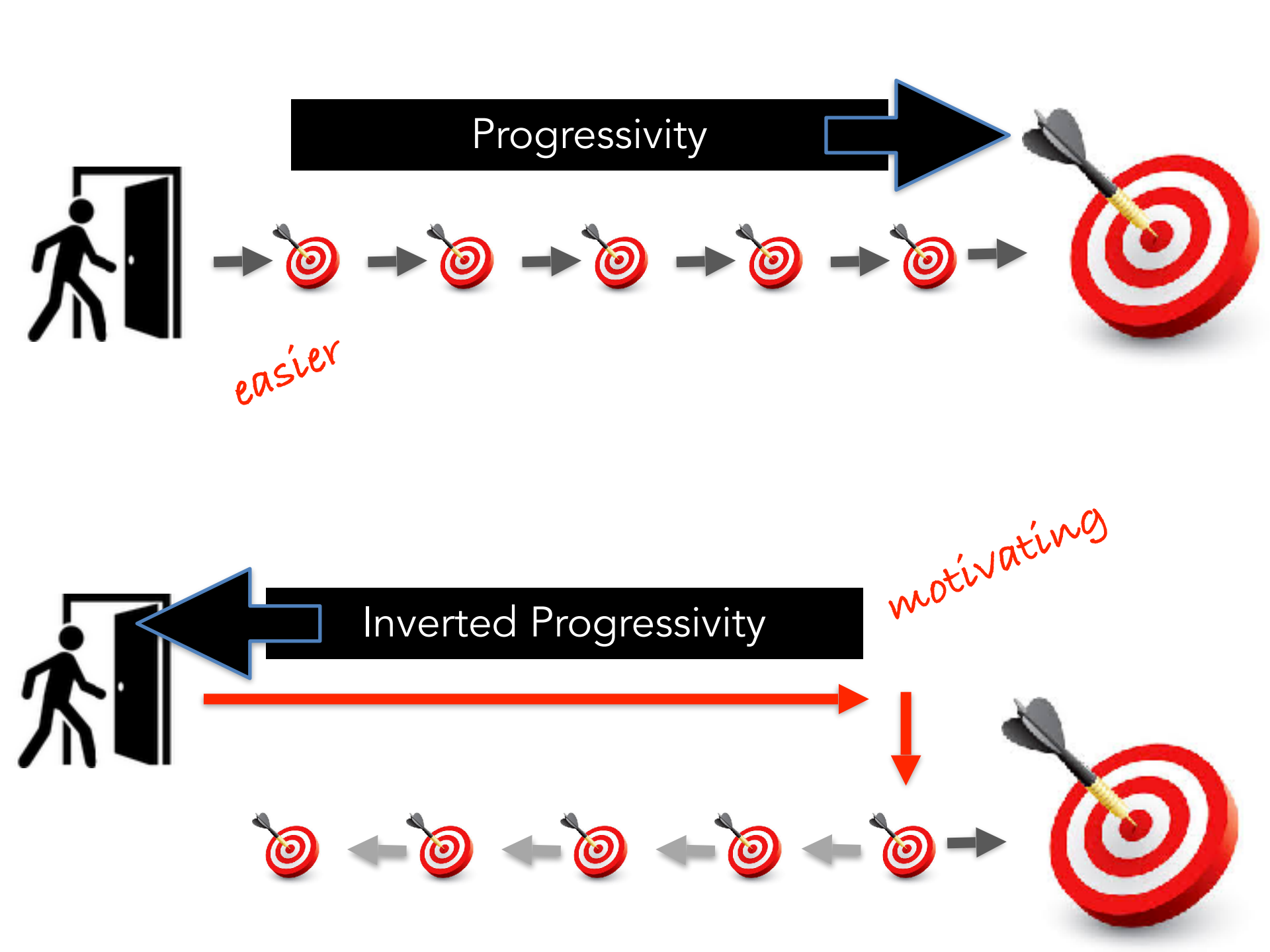
Motivation:

a_1 motivates learners to do a_2



a_1

« Let me show you an example of what you will be able to do at the end of this course »


Progressivity
easier
Inverted Progressivity
motivating

Types of Motivators

Extrinsic

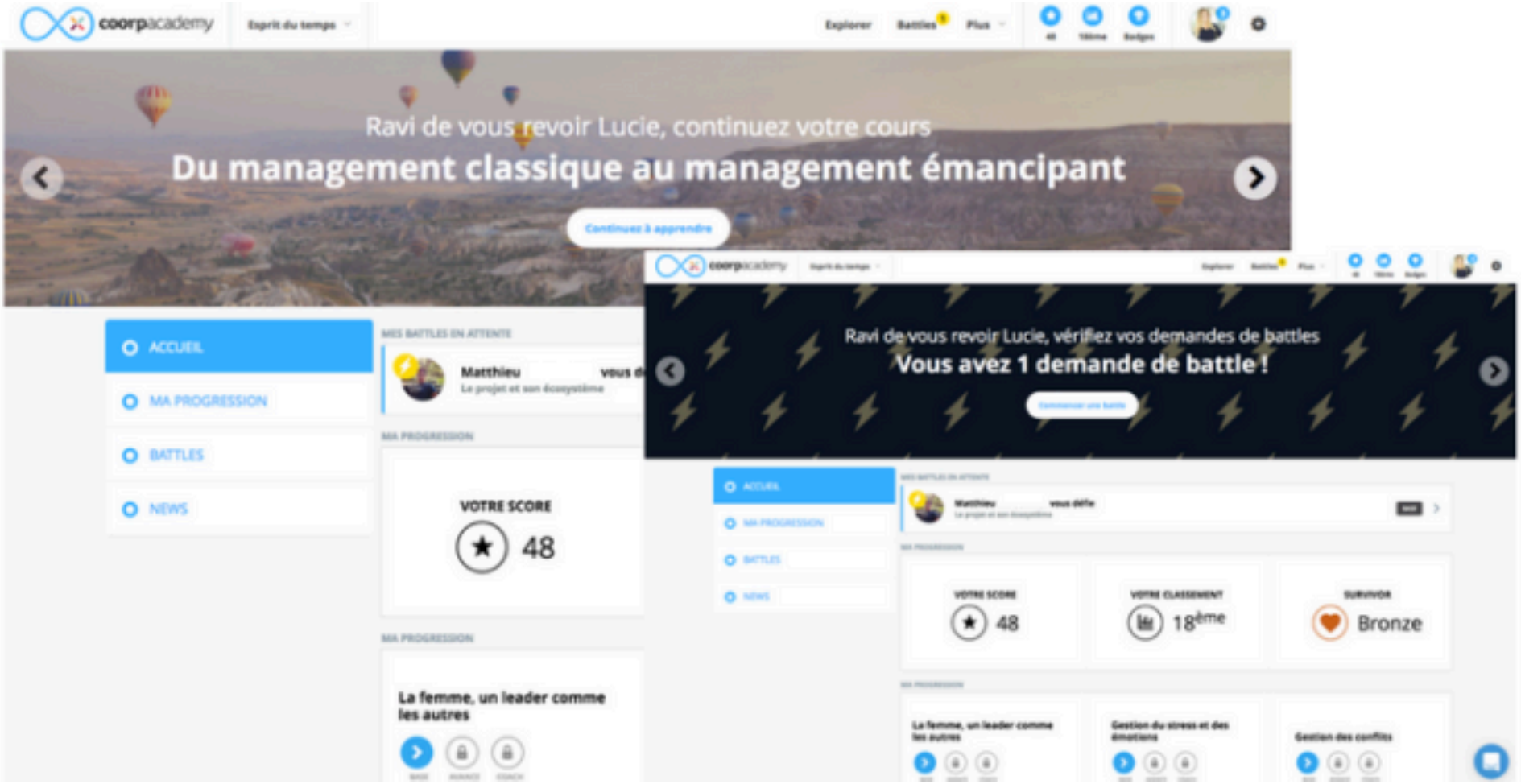
- badges
- competition
- fear of failure
- fear of punishment
- gold stars
- money
- points
- rewards
- ...

Intrinsic

- autonomy
- belonging
- curiosity
- love
- learning
- mastery
- meaning
- ...

Gamification

(even in corporate training)




Gamification

Why is an activity a_1 useful for an activity a_2?

Motivation:

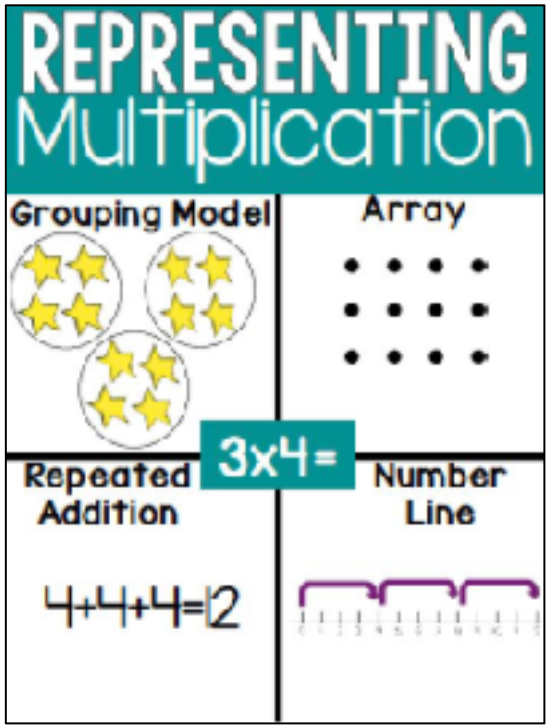
a_1 frustrate learners so that they want to do a_2

« what you learned before enabled you to solve problems so far, but here are new problems »

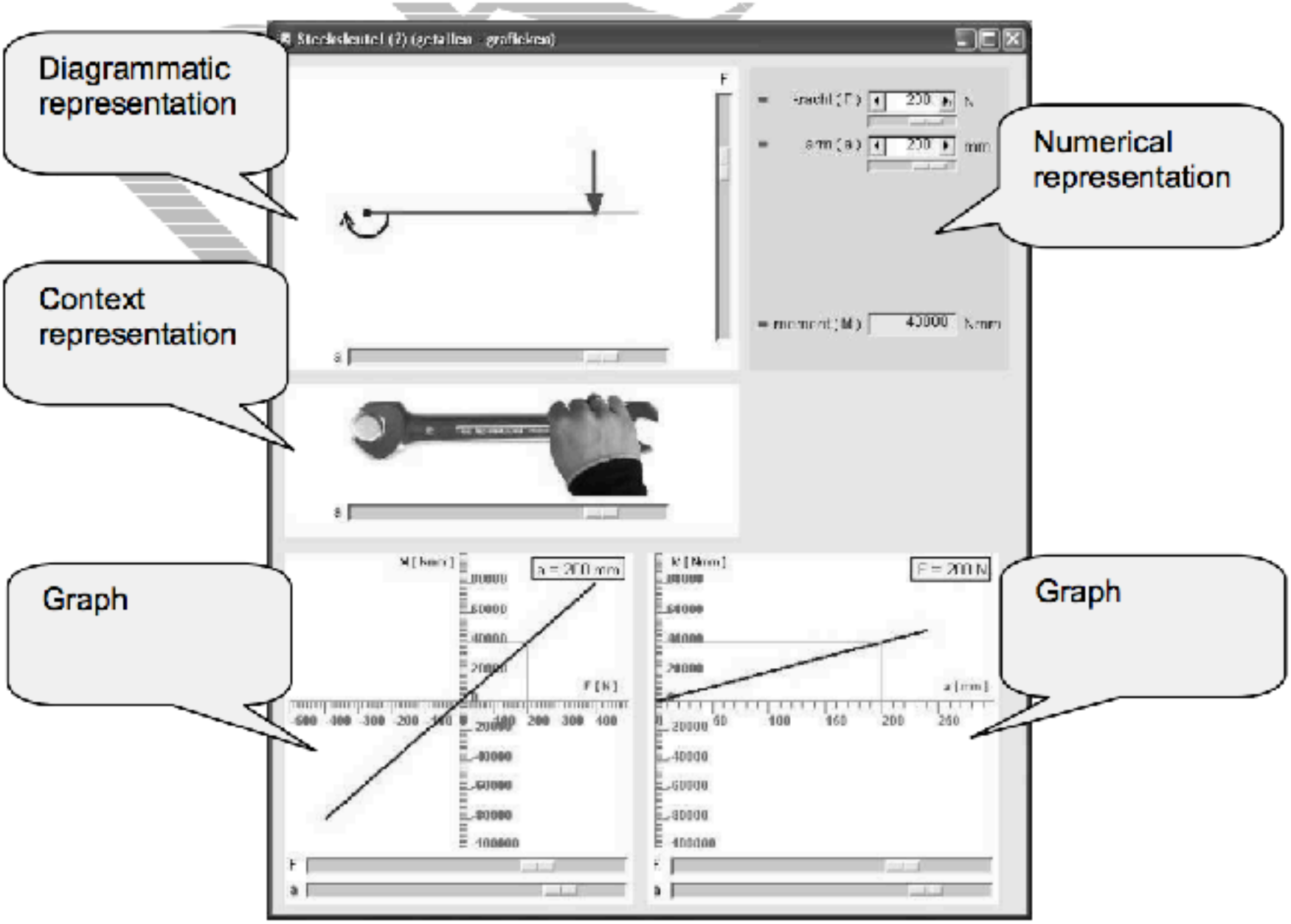
Why is an activity a_1 useful for an activity a_2?

Shift Representation:

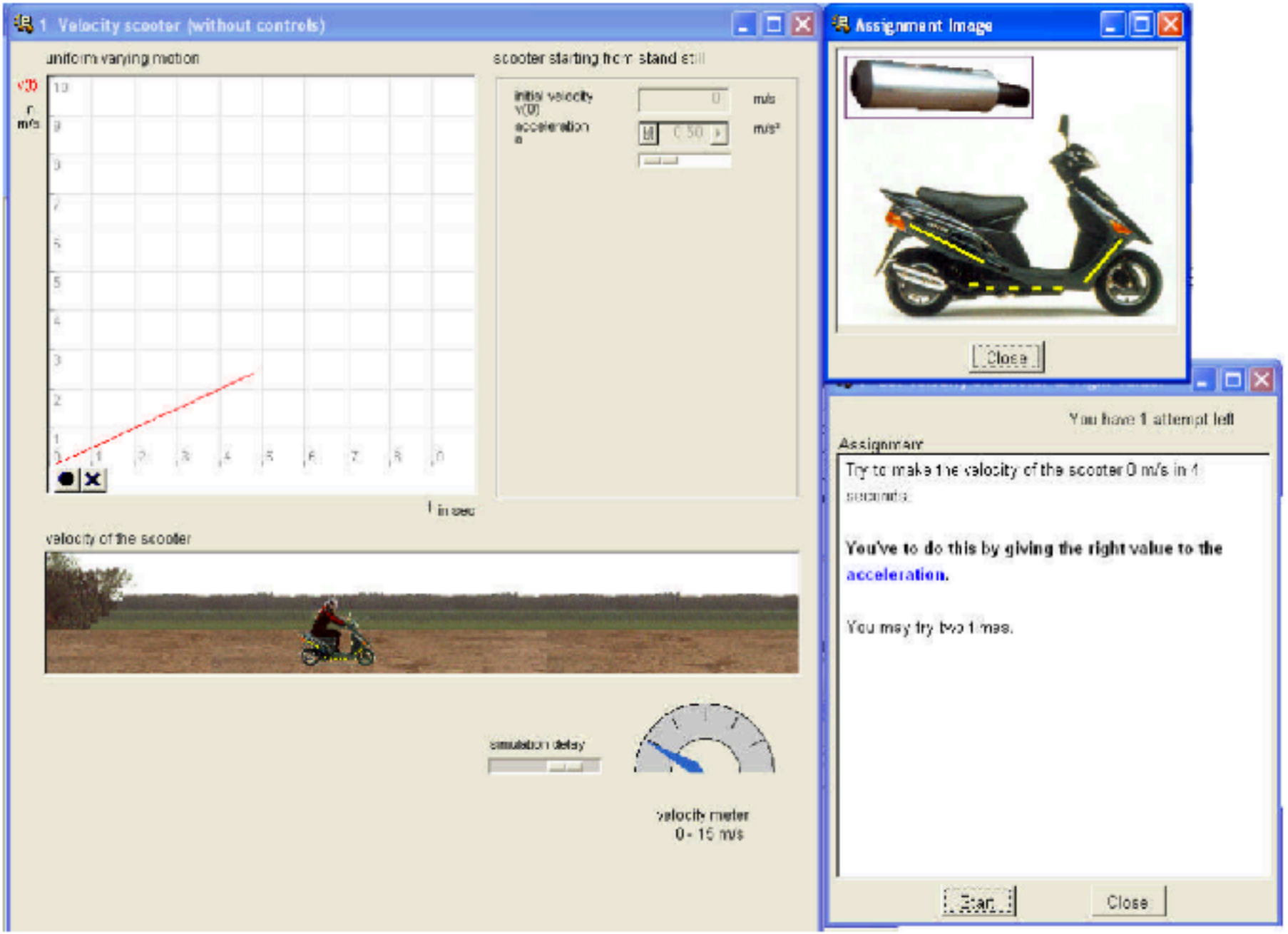
a_2 represents contents differently from a_1

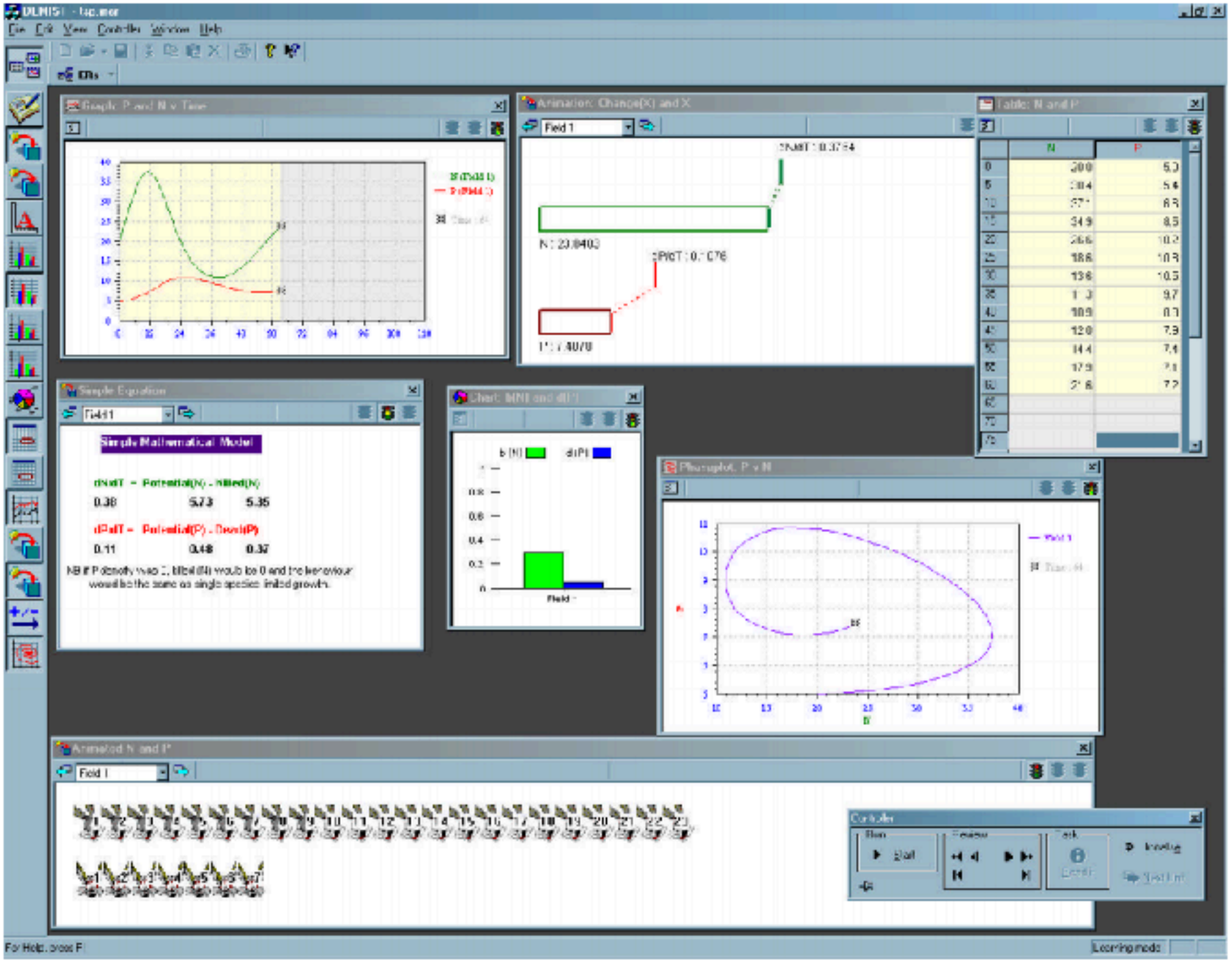


There is a large body of empirical studies that show that is beneficial for learners to switch between multiple representations.



http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.422.8795&rep=rep1&type=pdf





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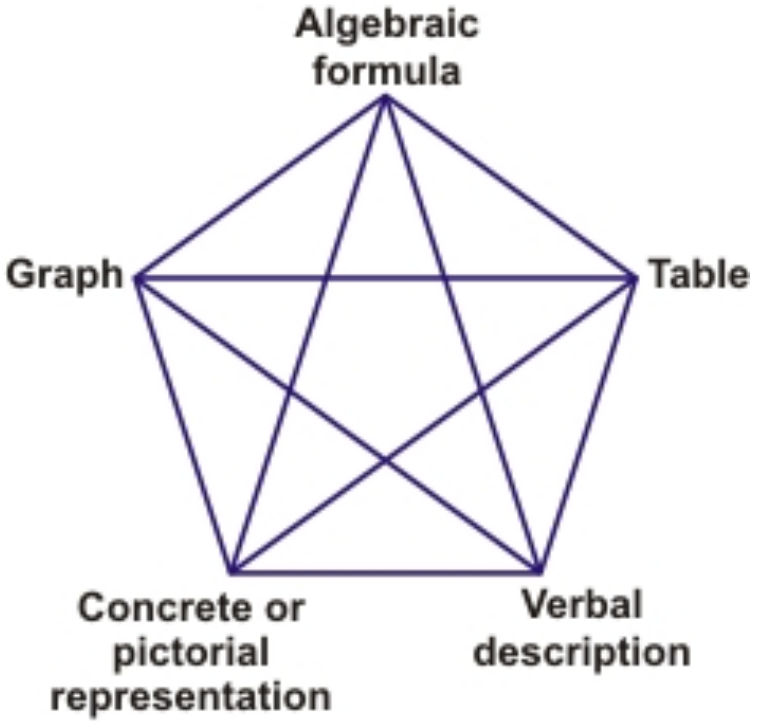
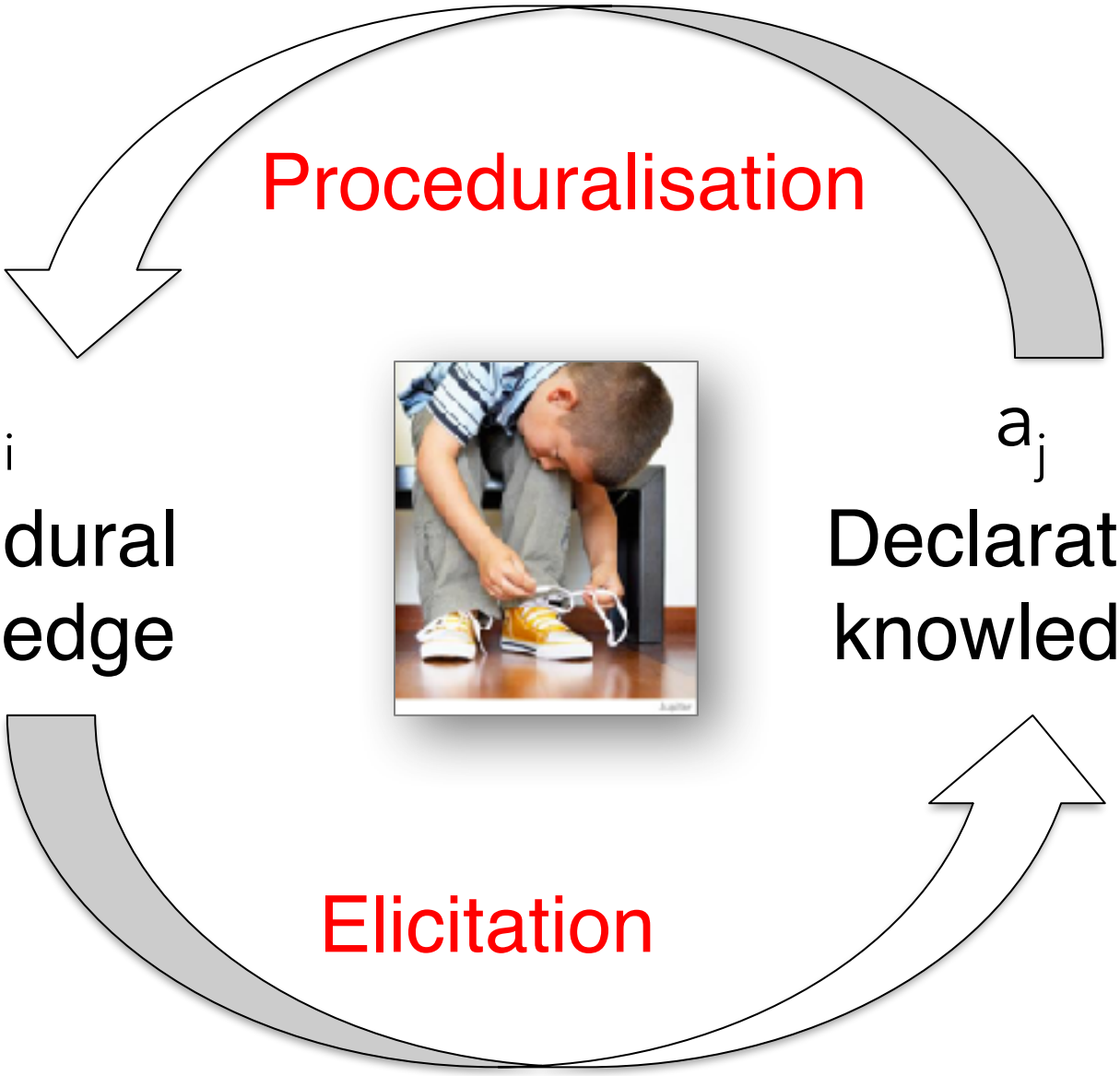


http://www.nctm.org/classroom-resources/lessons/Graphical-Representations-for-the-Number-of-Hits/

Why is an activity a_1 useful for an activity a_2?



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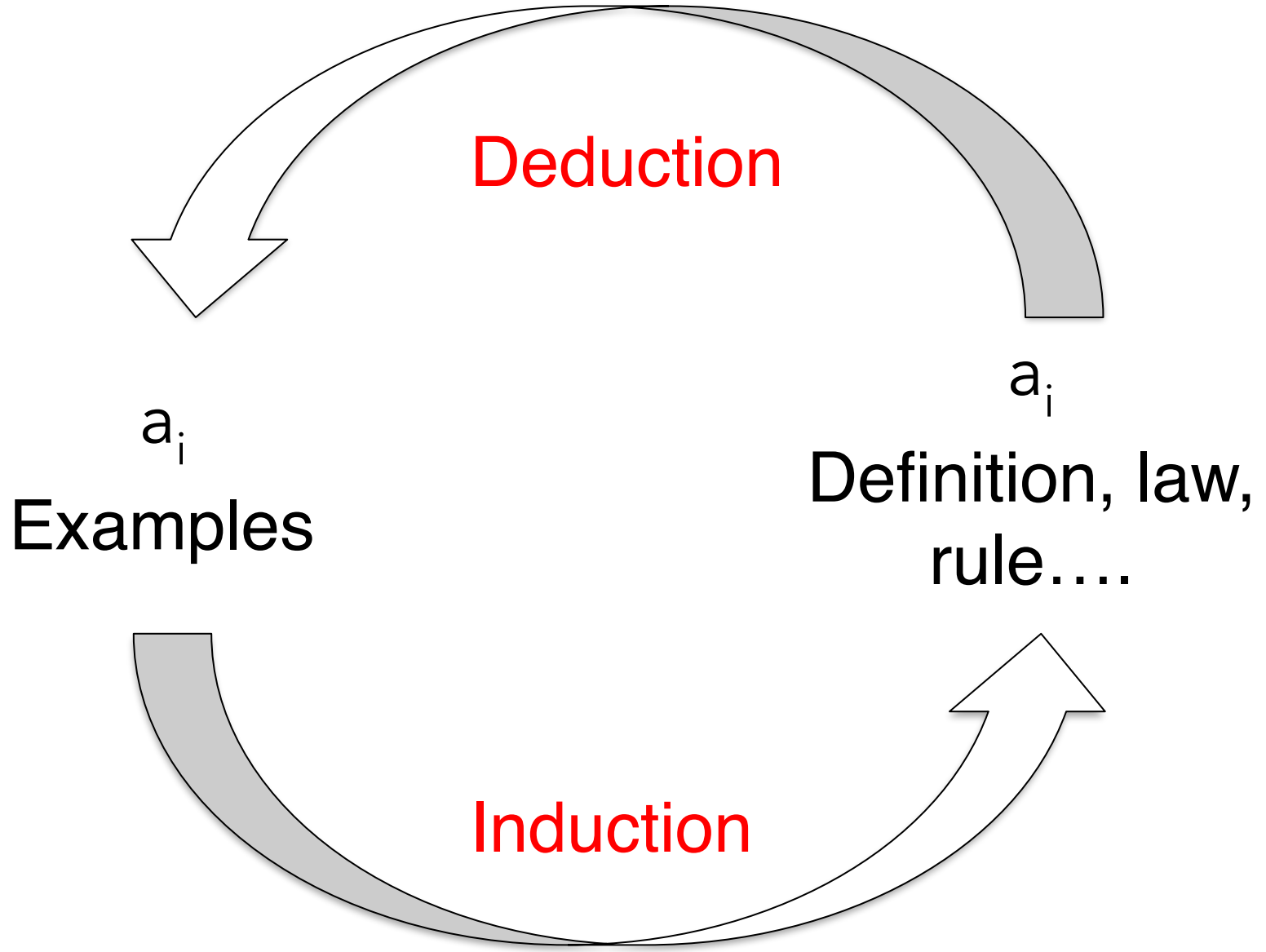


Why is an activity a_1 useful for an activity a_2?

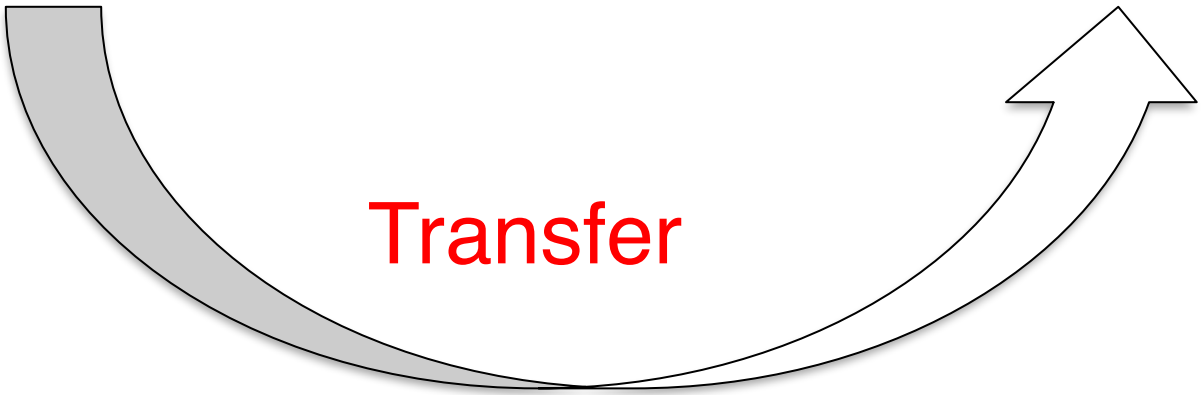
$$5\ X < 27$$

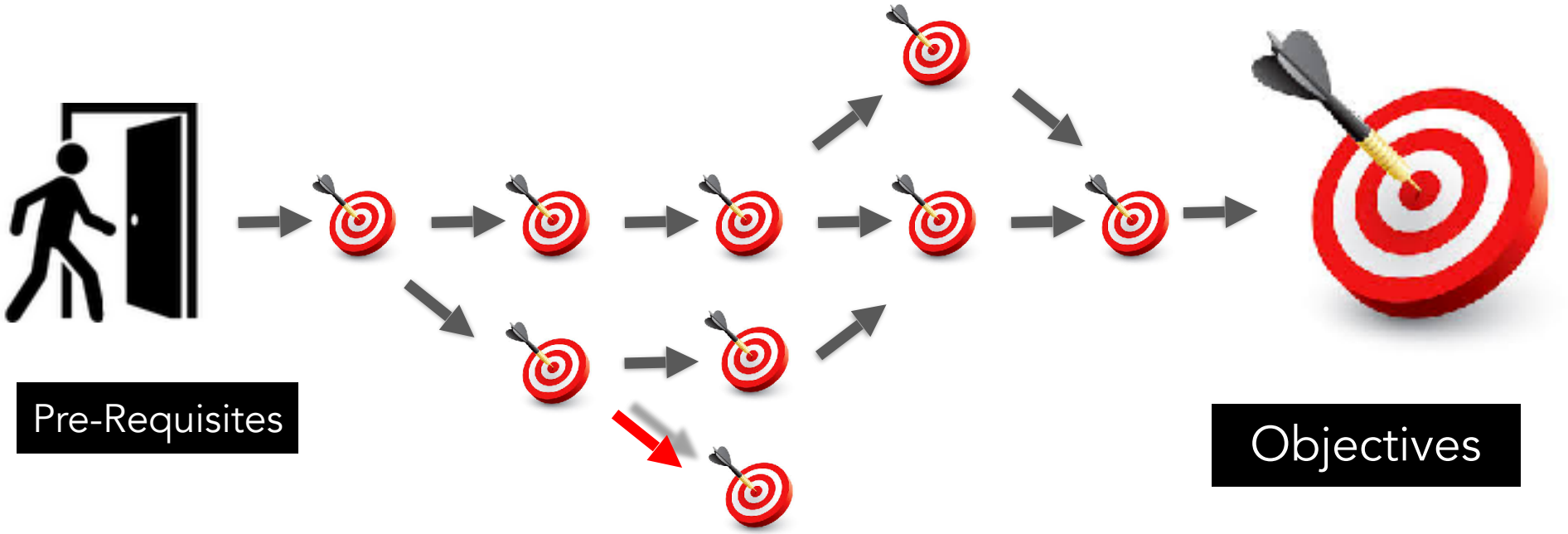
a_i

A chocolate bar costs 5 CHF.
How many bars can you buy for 27 CHF

a_i

A man walks 1 km in 5 min.
How many km can he walk in 27 min





- Pre-prequisite
- Advance Organiser
- Shift representations
- Intrinsic/Extrinsic Representations
- Induction/Deduction
- Proceduralisation/Elicitation
- Transfer

Examples of exam questions

① In which ways does this learning technology correspond to a behaviorist approach ?

② For which kind of learners is it relevant to choose inverted progressivity ?