Chapter 3: Mastery learning
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
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
How do people learn?
Yvan Pavlov, 1849-1936

Classical **Conditioning**


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

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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 Conditioning

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
FIG. II. 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

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.
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.

<table>
<thead>
<tr>
<th>SENTENCE TO BE COMPLETED</th>
<th>WORD TO BE SUPPLIED</th>
</tr>
</thead>
<tbody>
<tr>
<td>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 _______</td>
<td>bulb</td>
</tr>
<tr>
<td>2. When we turn on a flashlight, an electric current flows through the fine wire in the _______ and causes it to grow hot.</td>
<td>bulb</td>
</tr>
<tr>
<td>3. When the hot wire glows brightly, we say that it gives off or sends out heat and _______</td>
<td>light</td>
</tr>
<tr>
<td>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.</td>
<td>electric</td>
</tr>
<tr>
<td>5. When a weak battery produces little current, the fine wire, or _______, does not get very hot.</td>
<td>filament</td>
</tr>
<tr>
<td>6. A filament which is less hot sends out or gives off _______ light.</td>
<td>less</td>
</tr>
<tr>
<td>7. “Emit” means “send out.” The amount of light sent out, or “emitted,” by a filament depends on how _______ the filament is.</td>
<td>hot</td>
</tr>
</tbody>
</table>
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

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

Module 1

Module 2

Module 3

Module 4

Test
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: Did the learner reach the objectives of this module?

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

Adaptive Testing
Aptitude-Treatment Interactions:

The effect of a pedagogical method varies for different learners' profiles.

The effect of a pedagogical method varies for different learners' profiles.

- 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: $d=0.65$


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

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:** $\{\text{skills-}a_1\}$ is a subset of $\{\text{skills-}a_2\}$

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?

What should learners be able to do at the end?

(which they could not do at the beginning)

Pre-Requisites

Objectives
Prior Knowledge can be wrong

2 ice cubes at midnight, $t = 20^\circ C$

Which ice cube will melt faster?
Instructional design works backwards:

What should learners be able to do at the end?

What are they able to do at the beginning?

Pre-Requisites

Pre-Representations

Objectives

(which they could not do at the beginning)
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 $a_2$
« Let me show you an example of what you will be able to do at the end of this course »
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
- 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.
Diagrammatic representation

Numerical representation

Context representation

Graph

Graph
Assignmen

Try to make the velocity of the scooter 0 m/s in 1 sec.

You've to do this by giving the right value to the acceleration.

You may try two times.
Why is an activity $a_1$ useful for an activity $a_2$?

Shift Representation:

$a_2$ represents contents differently from $a_1$.

http://www.nctm.org/classroom-resources/lessons/Graphical-Representations-for-the-Number-of-Hits/
Why is an activity $a_i$ useful for an activity $a_j$?
Why is an activity $a_1$ useful for an activity $a_2$?

Examples

Definition, law, rule....

Deduction

Induction
Why is an activity $a_1$ useful for an activity $a_2$?

5 $X < 27$

$\text{a}_i$

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

$\text{a}_i$

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

Transfer
Pre-Requisites

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

Objectives
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?