Computing Before Computers

A Look at the History of Educational Technology

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Yikes!

Media Overload

Need for a Comprehensive Theory of Instruction
Can we make better use of educational technology by studying its past?
Predicting the Future

Anyone who tries to draw the future in hard lines and vivid hues is a fool. The future will not sit for a portrait. It will come around a corner we never noticed, take us by surprise.

– George Leonard, 1968

*Education and Ecstasy*
Educational Device Wish List

- **Easy-To-Use** – no training needed
- **Easy-To-Read** – typeset-quality text
- **Flexible** – graphics and images
- **Small** – carry in a pocket
- **Portable** – doesn’t need to be plugged in, doesn’t even need batteries
- **Reliable** – never breaks down
- **Durable** – different students can share it and it can be reused year after year
- **Inexpensive** – under $5/student
The Bible of 42 Lines

printed 1456
Quod eis audisset dævid: descendit in presidiis. Philisthiæ autem venientes diffusit fune in valle raphaim. Et co-suluit dævid dum dicens: Si ascendat ad philisthiæ et si dabis eos in manu mea: Et dixit eos ad dævid. Ascende:

1398-1468
Monitorial School 1839

Joseph Lancaster, 1778-1838
St. Louis Museum
1905

Bring the World to the Child
Cleveland Museum

VISUAL AIDS
MATERIAL USED IN CLEVELAND PUBLIC SCHOOLS

1909
Maria Montessori

1870-1952
Montessori Method 1911

- Respect for the learner’s individuality
- Encouragement of the learner’s freedom
Stimulus and response are not fully independent events, they are organically related.

Learning involves two-way interaction between learners and their environment.

Learners’ experiences within their environments are the basis of the meanings they deduce and the goals and actions they pursue.
Edward L. Thorndike

1874-1949
Thorndike Laws

- **Law of Exercise**
  - The more often a stimulus-induced response is repeated, the longer it will be retained.

- **Law of Effect**
  - A response is strengthened if followed by pleasure and weakened if followed by displeasure.

- **Law of Readiness**
  - In any given situation, certain “units” are more predisposed to conduct than others due to the structure of the nervous system.
Thorndike Principles 1913

- Self-activity
- Interest (motivation)
- Preparation and mental set
- Individualization
- Socialization
Jean Piaget

1896-1980
### Tests of Various Types of Conservation

<table>
<thead>
<tr>
<th>CONSERVATION OF LIQUIDS</th>
<th>Start with: Two equal glasses of liquid.</th>
<th>Then: Pour one into a taller, thinner glass.</th>
<th>Ask the child: Which glass contains more?</th>
<th>Preoperational children usually answer: The taller one.</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONSERVATION OF NUMBER</td>
<td>Two equal lines of checkers.</td>
<td>Lengthen the spaces between one line.</td>
<td>Which line has more checkers?</td>
<td>The longer one.</td>
</tr>
<tr>
<td>CONSERVATION OF MATTER</td>
<td>Two equal balls of clay.</td>
<td>Squeeze one ball into a long, thin shape.</td>
<td>Which piece has more clay?</td>
<td>The long one.</td>
</tr>
<tr>
<td>Tests of Various Types of Conservation</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>----------------------------------------</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>CONSERVATION OF LENGTH</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Start with: Two sticks of equal length.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Then: Move one stick.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ask the child: Which stick is longer?</td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Preoperational children usually answer: The one that is farther to the right.</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

| **CONSERVATION OF VOLUME**            |
| Start with: Two glasses of water with equal balls of clay inside.|
| Then: Change the shape of one ball.   |
| Ask the child: Which piece of clay will displace more water? |
| Preoperational children usually answer: The long one. |

| **CONSERVATION OF AREA**              |
| Start with: Two identical pieces of cardboard on which are placed the same number of equally-sized blocks.|
| Then: Rearrange blocks on one piece of cardboard. |
| Ask the child: Which has more cardboard covered up? |
| Preoperational children usually answer: The one with the blocks not touching. |
If, by a miracle of mechanical ingenuity, a book could be so arranged that only to him who had done what was directed on page one would page two become visible, and so on, much that now requires personal instruction could be managed by print.

— *Education*, 1912
A self-scoring multiple-choice apparatus that gives tests and scores – and teaches
A multiple-choice device that omits items from further presentation once the student can consistently answer them correctly.
Pressey Variant by Skinner

1958
Rheem-Califone Variant

1959
Pressey Punch-board

1950
FIG. II. Scores made of two midterms by three groups of students, those who had taken (a) no practice tests, (b) practice tests simply as tests, and (c) practice tests using the punchboard.
Skinner Questions 1953

- What behavior is to be established?
- What reinforcers are available?
- What responses are available?
- How can reinforcements be most efficiently scheduled?
Programmed Instruction

The whole process of becoming competent in any field must be divided into a very large number of very small steps, and reinforcement must be contingent upon the accomplishment of each step... By making each successive step as small as possible, the frequency of reinforcement can be raised to a maximum, while the possible aversive consequences of being wrong are reduced to a minimum.

– *Science and Human Behavior*, 1953
Table 1. A SET OF FRAMES DESIGNED TO TEACH A THIRD- OR FOURTH-GRADE PUPIL TO SPELL THE WORD “MANUFACTURE”

1. Manufacture means to make or build. Chair factories manufacture chairs. Copy the word here:

☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐ ☐

2. Part of the word is like part of the word factory. Both parts come from an old word meaning make or build.

man u ☐ ☐ ☐ ☐ u r e

3. Part of the word is like part of the word manual. Both parts come from an old word for hand. Many things used to be made by hand.

☐ ☐ ☐ ☐ f a c t u r e

4. The same letter goes in both spaces:

m ☐ n u f ☐ c t u r e
Student at work in a self-instruction room. Material appears in the left-hand window. Student writes his response on a strip of paper exposed at the right.
Skinner Disk 1958
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>
</tbody>
</table>
Skinner Variant by Porter

1958
Holland Discrimination Task
“A Teaching Machine...

...for Lower Organisms”

Holland, 1960
There is a simple job to be done. The task can be stated in concrete terms. The necessary techniques are known. The equipment needed can easily be provided. Nothing stands in the way but cultural inertia.

– B.F. Skinner, 1954
Teaching Rats and Humans

There is, to the best of my knowledge, no science of maze running to be taught. ... The only reason a rat should turn to the right rather than the left at a certain point is that it is that turn which leads to reinforcement. No better reason can be learned because there is none.

Students sometimes pass courses in logic and mathematics in the same way. ...

– John W. Blyth, 1960
Teaching Rats and Humans

A student who gives a particular response merely because that is the one the teacher reinforces has not learned a subject... The reason for giving some response must be more than the fact that it causes the teacher to say "correct."

Our experience has convinced us that the most effective method of presenting a program of questions and answers is a machine using microfilm and designed for individual use.

– Heines paraphrase of Blyth, 1960
Teacher Supervision
Porter, 1958
Briggs Subj.-Matter Trainer

1958
Enter the Computer

1959
“The program of materials presented can be arranged so that the presentation of new items depends upon the student’s own performance.”
Adaption to Failure

Flowchart:

1. Present Concept N
2. Present exercises/tests on Concept N
3. Assess student performance
   - Unsatisfactory
   - Satisfactory
4. Present remedial instruction on Concept N
5. Present Concept N+1
Adaption to Success

1. Present Concept N
2. Assess student performance
   - Very Good: Skip ahead to a much more difficult concept
   - Very Poor: Probe difficulty & loop back to problem concept
   - Poor: Present exercises/tests on Concept N
   - OK: Present remedial instruction on Concept N
3. Present Concept N+1
Intrinsic Programming

FIG. I. A simple program step

Norman A. Crowder, 1960
FIG. II. A simple subsequence
FIG. III. A wash-back program

Norman A. Crowder, 1960
Intrinsic Programming

FIG. IV. A wash-ahead program

Norman A. Crowder, 1960
FIG. V. A complex wash-back program

Norman A. Crowder, 1960
### Types of Test Error

<table>
<thead>
<tr>
<th></th>
<th>Student's Actual State</th>
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<tr>
<td><strong>MASTER</strong></td>
<td></td>
</tr>
<tr>
<td><strong>NON-MASTER</strong></td>
<td></td>
</tr>
<tr>
<td><strong>MASTER</strong></td>
<td>Type II error</td>
</tr>
<tr>
<td><strong>NON-MASTER</strong></td>
<td>Type I error</td>
</tr>
</tbody>
</table>

- **Type I Error**: Occurs when a student is not tested as a non-master when they are not actually a non-master.
- **Type II Error**: Occurs when a student is tested as a master when they are not actually a master.

**Student's Tested State**

- **MASTER**: No error
- **NON-MASTER**: No error
Type I: False Negative Error

- True master classified as a non-master
- Student *takes unneeded* instruction
- *Less* serious than a Type II error
Type II: False Positive Error

- True non-master classified as a master
- Student *skips needed* instruction
- *More* serious than a Type I error
Decision Model

To minimize the probability of an error, we use a decision model that takes these error conditions into account.
Decision Model

Standard Criterion-Referenced Decision Model

100% Correct

Mastery and Non-Mastery Criterion Score

0% Correct
Decision Model

Sequential Testing
Criterion-Referenced Decision Model
With Decision Certainty Factor Based on Test Length

0% Correct
100% Correct

Mastery Criterion Score
Variable Size Uncertainty Interval
Non-Mastery Criterion Score
Decision Model

Sequential Testing Criterion-Referenced Decision Model

For Tests 1-2 Items Long

All scores fall within the uncertainty interval.
Decision Model

Sequential Testing
Criterion-Referenced Decision Model
For Tests
4 Items
Long

Uncertainty interval

25%
Non-Mastery Classification
0%
Decision Model

Sequential Testing
Criterion-Referenced Decision Model
For Tests
6 Items
Long

Uncertainty interval

Non-Mastery Classification
33%
0%
Decision Model

Sequential Testing Criterion-Referenced Decision Model

For Tests 9 Items Long

Uncertainty interval

100% Mastery Classification

40% Non-Mastery Classification
Decision Model

Sequential Testing
Criterion-Referenced Decision Model
For Tests 15 Items Long

100%
90%
45%
0%

Mastery Classification
Uncertainty interval
Non-Mastery Classification
Influencing Factors

- Fixed
  - Mastery Criterion
  - Non-Mastery Criterion
  - Allowable Probability of a Type I Error
  - Allowable Probability of a Type II Error

- Variable
  - Test Length
For Pretests

We want to be very sure the student is a master before letting instruction be skipped.

- Mastery Criterion 90%
- Non-Mastery Criterion 65%
- Type I Error Probability 0.025
- Type II Error Probability 0.058

Note the low probability of a Type I (false positive) error.
The student has already gone through the material at least once, so the criteria can be loosened.

- Mastery Criterion: 85%
- Non-Mastery Criterion: 60%
- Type I Error Probability: 0.050
- Type II Error Probability: 0.104

Note that the probability of a Type I error is twice as high as before.
Pretest Decision Rules

Number of Items Answered Correctly

Number of Items Presented
Posttest Decision Rules

- Number of Items Answered Correctly
- Number of Items Presented

Graph showing decision rules with areas for Master, Best Possible Score, and Non-Master.
Decision Rules Compared

Pretest

Posttest
Technology’s Role

student
Technology’s Role

Knowing

student

Knowing

Knowing

Knowing
Technology’s Role
Technology’s Role

student → student → student

? → teacher → ?

KNOWLEDGE
Technology’s Role

Student → Teacher → Knowledge

Text → Personal Tutelage → Audio-Visuals

Books → Knowledge
The best teacher uses books and appliances as well as his own insight, sympathy, and magnetism.

– Edward L. Thorndike

*Education*, 1912
thank you

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Primary References


Some Secondary References


