# Testing is the mother of knowledge


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# My coauthors with Miro

# My coauthors without Miro

# Memory and learning

encoding

storing

recall

# Memory and learning

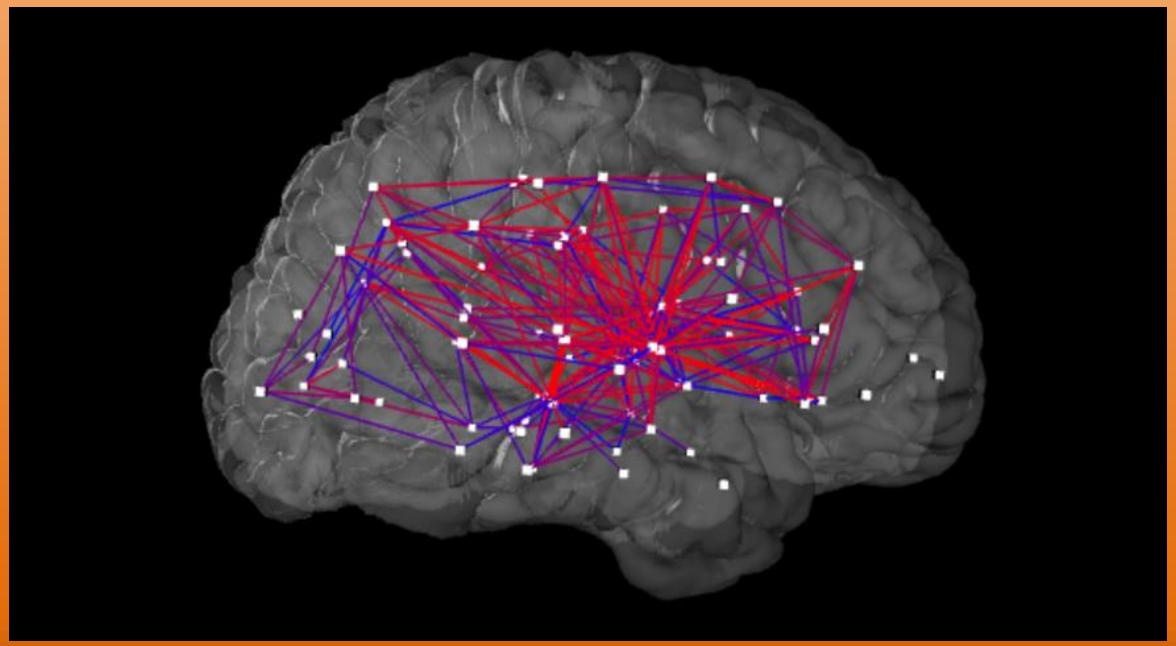
encoding

storing

recall


# Learning theories

Behaviorism, Gestaltism, Cognitivism, Constructivism, Connectivism, Trialog …



# Filling up storage

long term memory = storing

teaching = filling up storage

retrieval = test

Roediger, Karpicke 2006

# Retrieval effect

- Laboratory experiments:

| | 3x read | 1x read , 2x tested |
|---|---|---|
| 5 min later | 80% | 75% |
| 2 days later | 55% | 70% |
| 1 week later | 40% | 55% |

# Retrieval effect

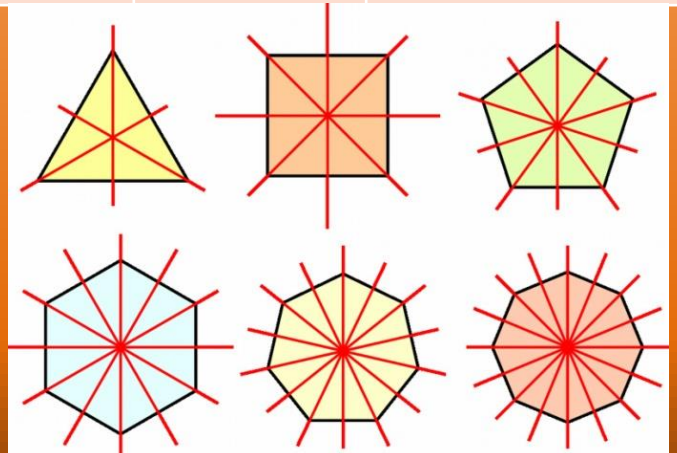
- Different variations of the experiment
- Retrieval $\subset$ Encoding
- Retrieving: chemical trace in brain

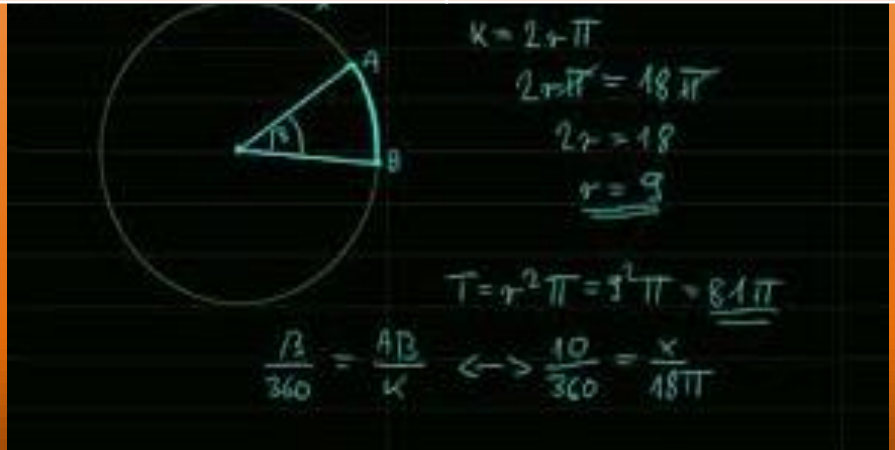
# Retrieval-enhanced learning

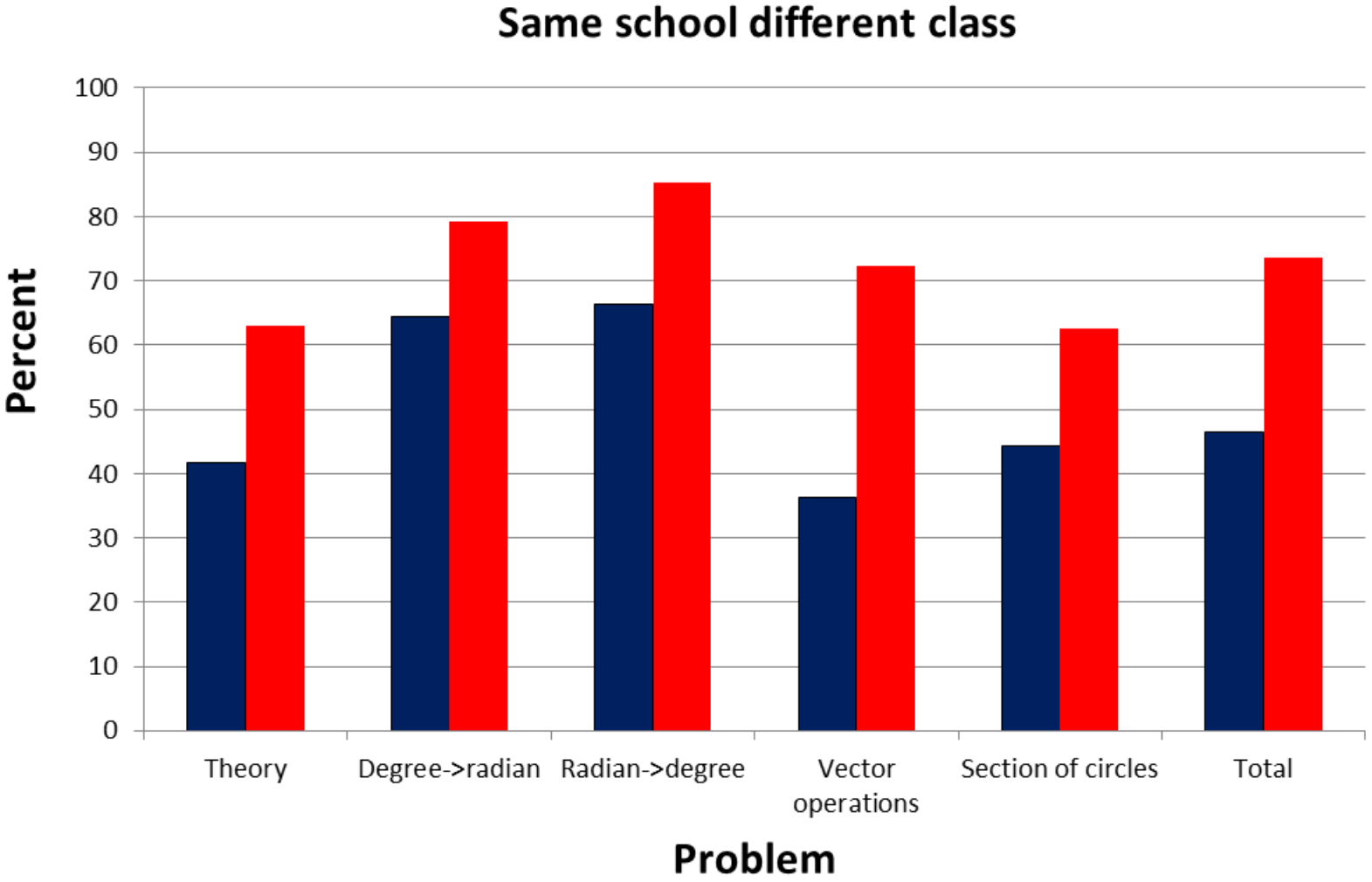
| Before: | Now: |
| --- | --- |
| • Laboratory<br>• Psychology students<br>• Text memorizing<br>• Memorizing foreign words | • Real life<br>• Grade 9 pupils (highschool)<br>• Mathematics lessons |

# Experiment 1

| Monday | Tuesday | Wednesday | Thursday | Friday | Saturday | Sunday |
|---|---|---|---|---|---|---|
| | | Short test at the end of each class<br>• 5 min<br>• 2 questions: 1 theoretical<br>1 practical | | | Hand-in homework<br>• By email<br>• Until Sunday<br>…or Monday… | |

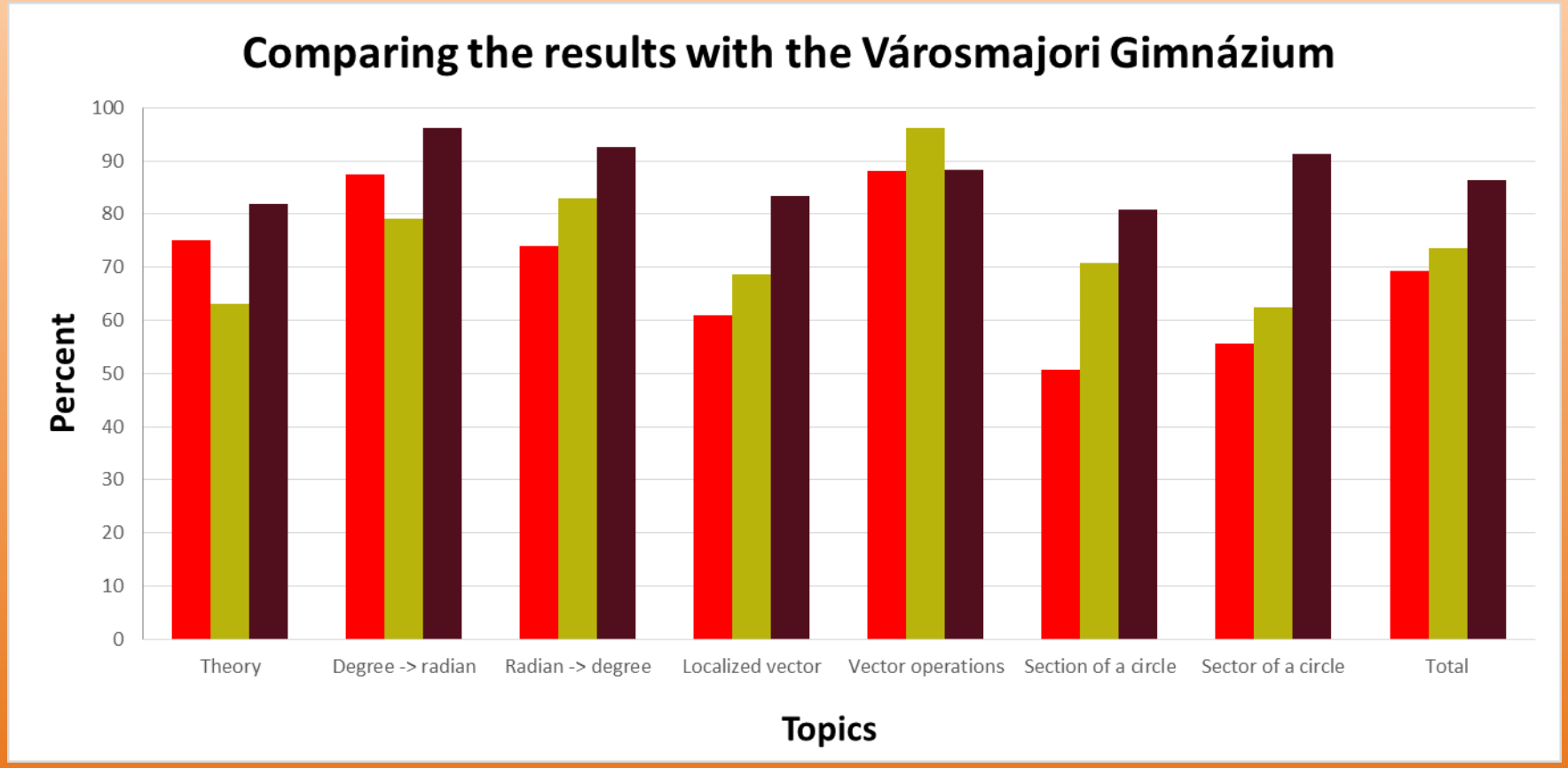





Same school different class
Percent
100
90
80
70
60
50
40
30
20
10
0
Theory
Degree->radian
Radian->degree
Vector operations
Section of circles
Total
Problem

# Experiment 1 – Városmajori Gimnázium

| Experimental group | Control groups |
| --- | --- |
| • One group from 9 b. | • 9.c and 9.e classes (1 teacher) |
| • 9 students | • 16, 18 students |
| • 3 lessons/week, 3-4 weeks | • 4 lessons/week, 4-5 weeks |
| • Total: 11 lessons | • Total: 19, 16 lessons |
| • Vocational school | • Grammar school |
| • Socially handicapped students (2016 National Survey of Competences) | • Elite (District 12 of Budapest, 6th in national ranking in 2017) |


Comparing the results with the Városmajori Gimnázium
Percent
100
90
80
70
60
50
40
30
20
10
0
Theory
Degree -> radian
Radian -> degree
Localized vector
Vector operations
Section of a circle
Sector of a circle
Total
Topics

# Our experiment at University

## Pre-service math teachers

- 125 students
- Number theory
- 2+2 hours/week
- 6 groups of problem sessions
- End of semester: final grade (1-5)

# The curriculum

- Division algorithm
- Fundamental theorem of arithmetic
- Arithmetic functions
- Congruences
- Order, primitive root
- Euler-Fermat theorem
- High degree Diophantine equations

# Our experiment at University

**Our experiment is based on the facts that the:**

- Students study.
- Students study regularly.
- Students study properly.

statements are all false!

# Timing

**3 experimental groups:**

- First retrieval within 24 hours
- Copying is not retrieval
- Controlled conditions

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- 5 minute test after every class
- 2 problems on the material of the class

# An example

**Piaget's research on 4 years old children**

# An example

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# An example

**Piaget's research on 4 years old children**

# An example

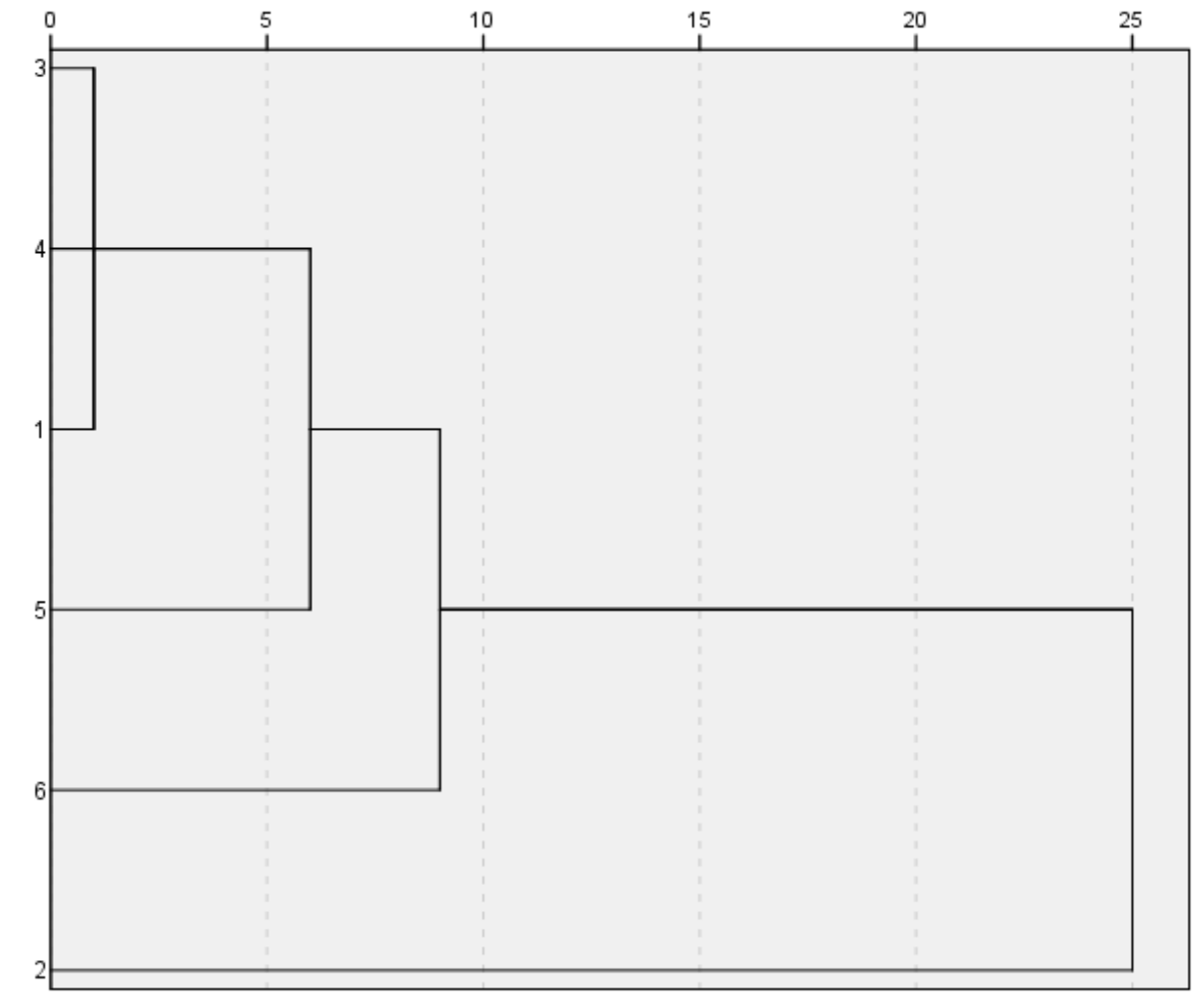
**Modified version of Piaget's experiment**

# Our experiment is LIVE

**2nd week: gossip in the tram**

***They haven't written any tests.***

# Among those studying the subject for first time



# Some results

- Experimental groups perform better statistically (on both midterms)
- The difference increased by time

| Score | Failure-barely passed | Not bad-very good | Excellent |
|---|---|---|---|
| Control | 37 | 7 | 4 |
| Experimental | 10 | 27 | 5 |

# Purpose of teaching

**Why do we teach? / Why do they learn?**

- To perform well on midterms?
- To understand the material?
- To know the material?
- **To know it long term?**

# Post - midterm

- 3 months later
- no preparation or revision
- 20 minutes,  4 problems
- analogue to midterm problems

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| experimental | equal | improved | 3.6/6 |
| control | | decayed | 1.2/6 |

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# The team

# Pre-tests

- pre-knowledge test
- spec/normal math class
- highschool final exam
  - type
  - score
  - when
  - where
- how many times have been registered for the subject
- other studied subject
- digit span test
- reverse digit span test
- visual memory test
- reverse visual memory test
- AMAS test
- number theory pre-test