

Knowledge restructuring as a powerful mechanism of learning

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High memory capacity?

Good strategies?

Intelligence?

Knowledge!!!!!!

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Impact of domain-specific knowledge on achievement differences

- Transfer research: formal training of little value (e.g., studies on learning Latin from Haag & Stern)
- Expert-Novice-Paradigms
- Developmental Perspective

Origin of knowledge in science and mathematics: fast-track learning enabled by special start-up mechanisms (primary abilities)

- Mathematics

- Cardinal number
- Principles of counting
- Quantitative change

- Science

- Features of objects
- Animate and inanimate movement

Here are 5 birds and here are 3 worms.

Suppose the birds all race over and each tries to get a worm.

How many birds won't get a worm? **96%**

How many more birds than worms are there? **25%**

Privileged and non-privileged knowledge (primary and secondary abilities)

Privileged

- Counting
- Change
- Perceiving single features of objects
- Perceiving movement and speed

Non-privileged

- Numbers for other purposes than counting
- Integrating features, e.g., density
- Analytical approach of speed: $\text{distance}/\text{time}$

Years ago some fundamental steps were made in Human intellectual development

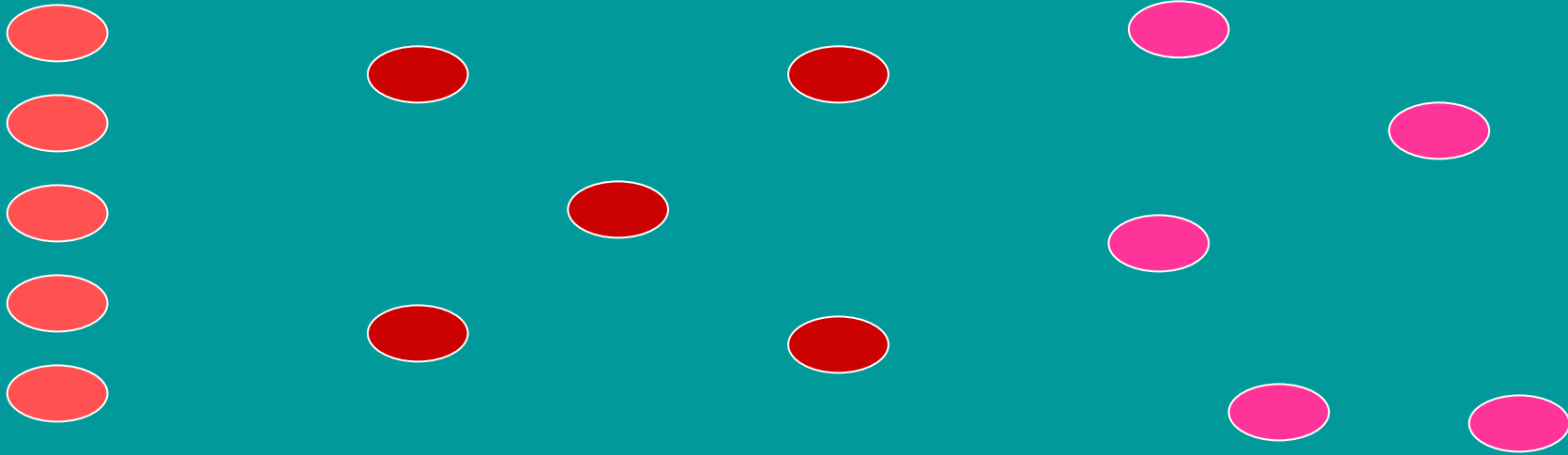
- 40.000: Last fundamental changes in the genes of human beings
- 5.000: Use of script
- 3000: Use of number symbols
- 2200: Concept of density (Archimedes)
- 800: Arabic number system common in Europe
- 400: Analytic geometry (Descartes)
- 300: Laws of mechanics (Newton)
- 50: Structure of DNA

Symbols as reasoning tools

$$\text{CIV} : \text{XXVI} =$$

$$104 : 26 =$$

Representations of „5“



relational number

relational number



cardinal number

ordinal number

Equalization:

Peter has 8 marbles.

John has 5 marbles.

How many marbles must John get in order to have the same amount of marbles as Peter?

95%

Comparison:

Peter has 8 marbles.

John has 5 marbles.

How many marbles does Peter have more than John?

20%

Why do we need early education?

Young brains absorb information like a sponge?

- True only for privileged knowledge
- Only few windows of opportunity are known
- But: Children carefully filter information, they only let in what can be further processed

Why do we need early education?

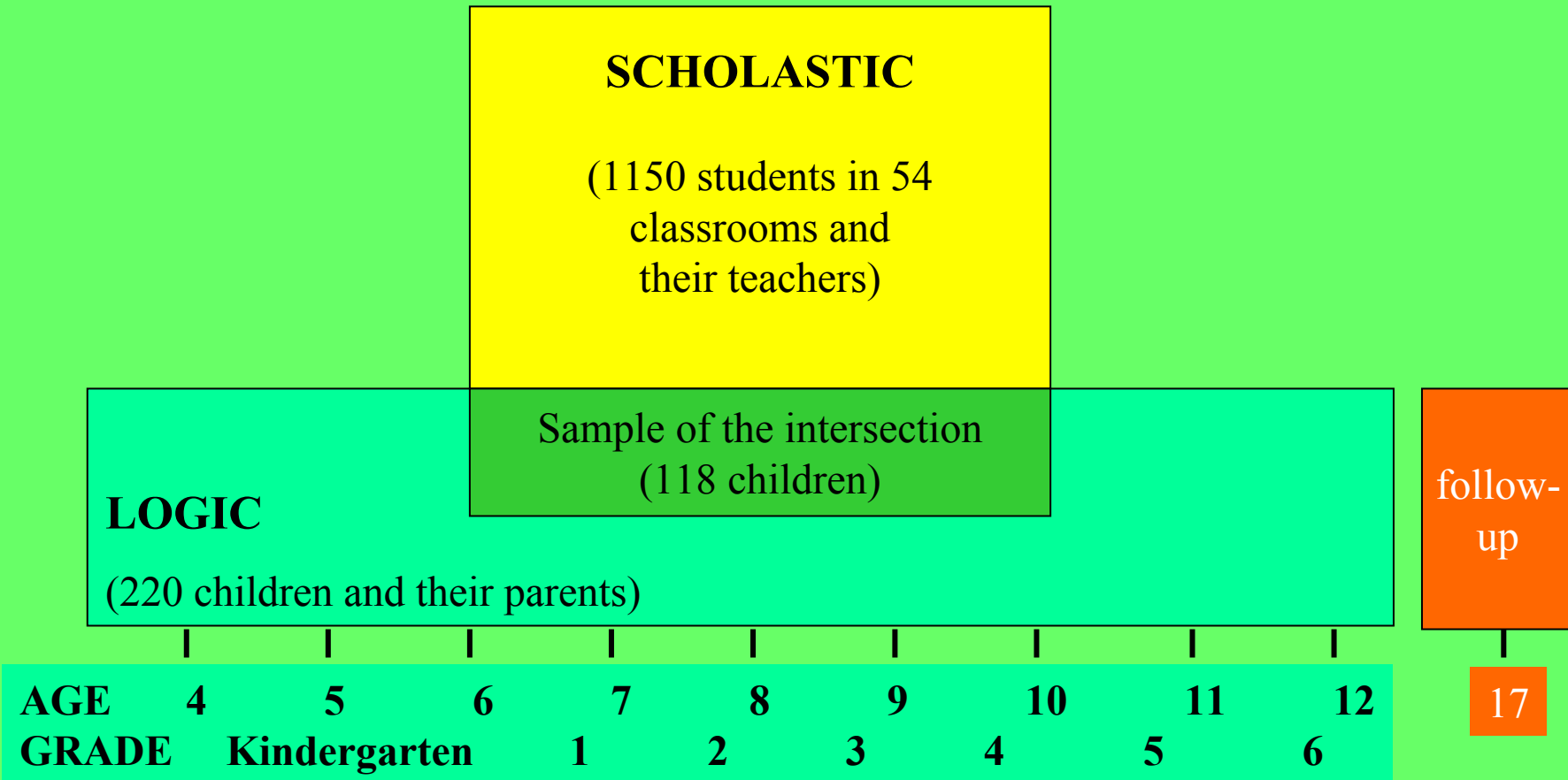
- Laying the foundations for non-privileged learning (secondary skills *sensu* Geary) which support mental leaps
- We are equipped with simple heuristics that make us smart
- We have to acquire complex competencies that make us cultured

Key competencies (e.g. Metacognition)

- **Source of metacognition: Theory of mind**
- **Metacognitive competencies can be learned, but hardly be taught**
- **Isolated training of learning- and thinking strategies is without benefit**
- **Learning- and thinking strategies are a useful byproduct of challenging content specific activities**

The case of mathematics:
Extending the function of
numbers

The Munich Longitudinal Studies headed by Franz Weinert



Which x-value fulfills the equation $x^2 - 14x + 49 = 0$

- A) 7 and 0
- B) 7
- C) -14
- D) 7 and -7
- E) 14 and 0

2nd grade:

Peter has 5 marbles.

Susan has 3 more marbles than Peter.

How many marbles do Susan and Peter have altogether?

4th grade:

There are 3 ways from A to B and 4 ways from B to C.

How many ways are there from A to C over B?

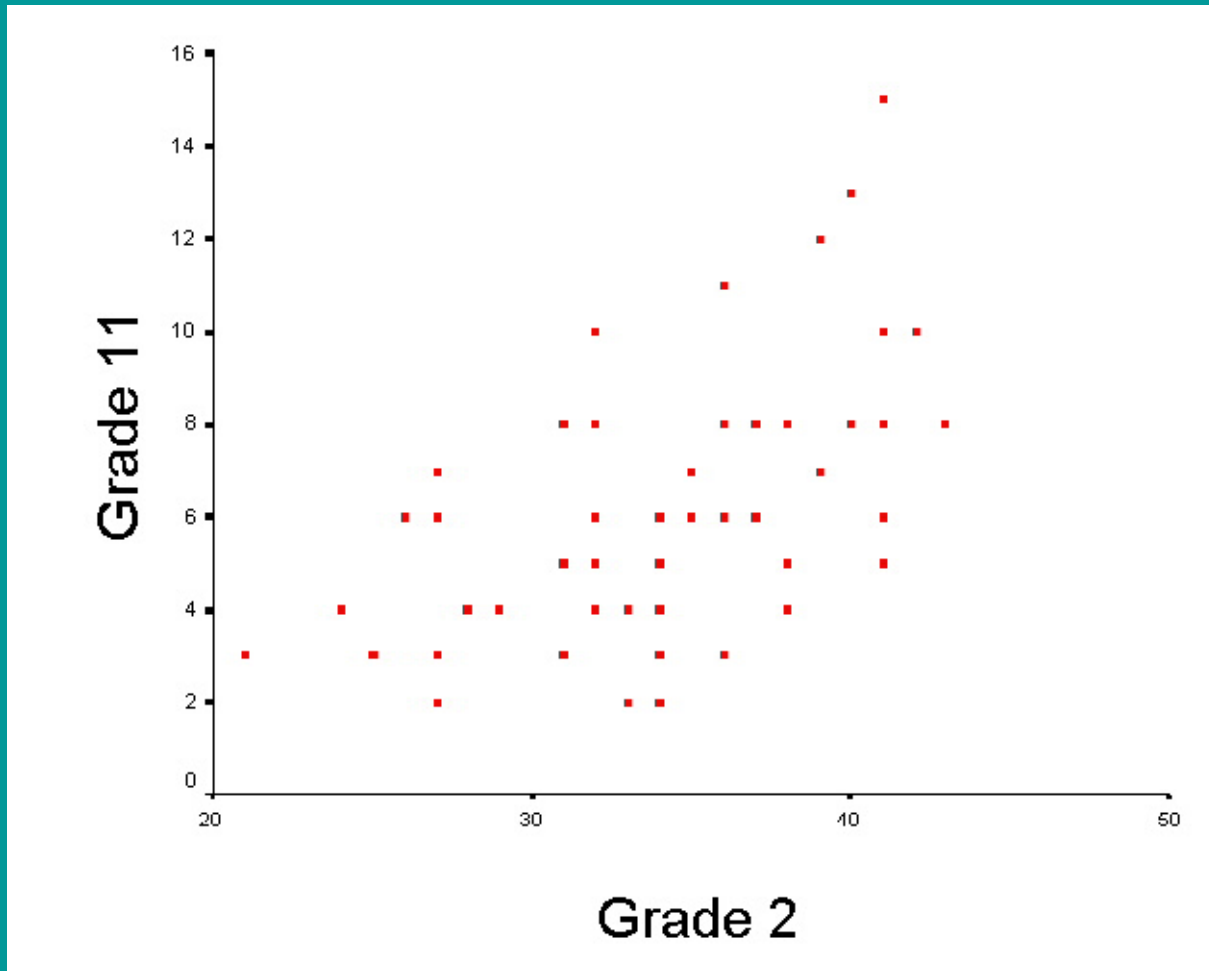
Correlation between math achievement in 11th grade and other measures in earlier grades.

Grade	Mathematical Reasoning	Computing	Intelligence
2 nd	.58	.22	.04 (ns)
3 rd	.45	.21	.45
4 th	.42	.25	.44
5 th	.46		
6 th	.49		.42
11 th			.41

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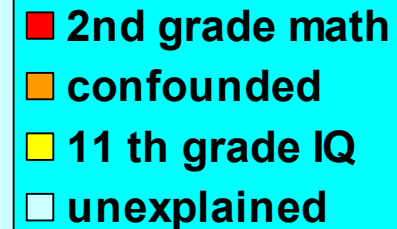
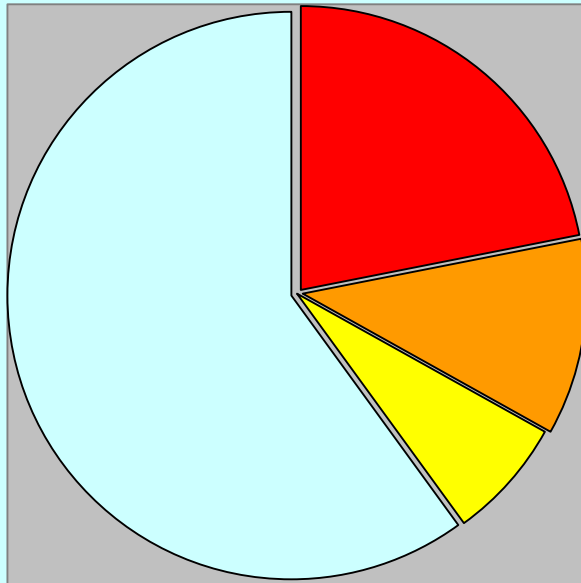
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Stability of Mathematical Reasoning



$r = .58$

Communality analysis: Explained Variance in 11th grade mathematics achievement by (1) IQ grade 11 and (2) Mathematics grade 2



Percentage of Comparison Problems in Textbooks:

John and Peter have 12 marbles altogether.

John has 2 marbles less than Peter.

How many marbles does Peter have?

- Former Soviet Union: 45%
- Slovak Republic: 40%
- Former GDR (DDR): 30%
- Western Germany: 3%

Summary: How to design learning environments

- Think from the end: define usable knowledge students should have acquired when they finish school.**
- Find out the basic elements of this knowledge and design scaffolded curricula.**
- To foster non-privileged learning, student's focus should be directed to aspects which would not have spontaneously attracted their attention.**

It is intelligent content knowledge,
stupid

What makes knowledge intelligent?

- Knowledge is usable: solving challenging problems, answering complex questions,
- Concept based: facts and routines are integrated
- Broadness of applicability