LEARNING, TEACHING AND THE MEASUREMENT OF CHANGE

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A long time ago, the German educator Willmann (1889) defined "teaching as the making of learning,"

Skinner (1954) distinguished between "***the science of learning and the art of teaching***."

… when you want to teach people you must know how they learn (cf. Bransford et al., 2004).

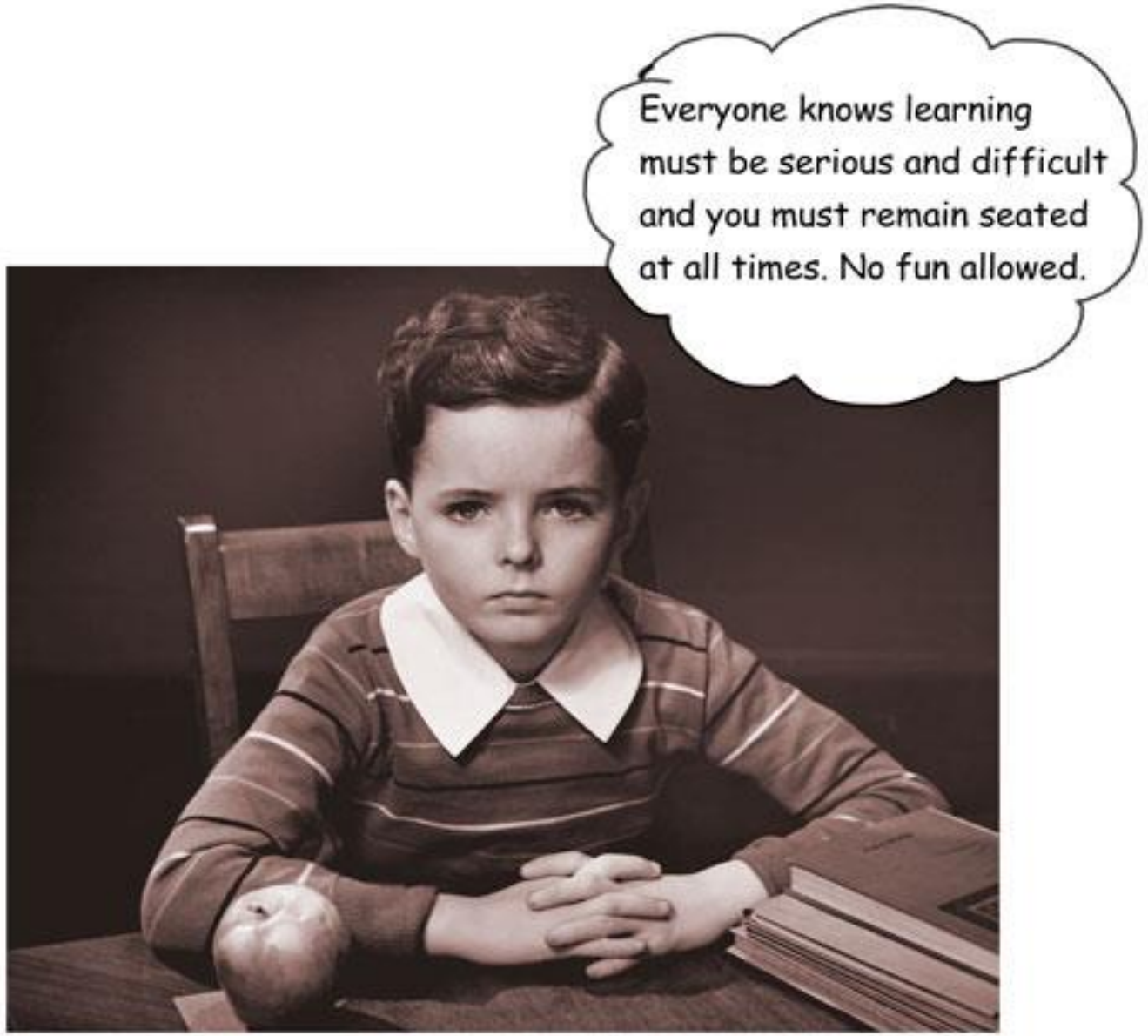
It's all very well to say that ….

Learning is an extremely broad concept and there are many things to be learned.

Even the practical understanding of learning as "knowing or being able to do something better than before" encompasses a multitude of processes –
from changes in behavior and knowledge brought about by everyday experiences up to changes in value positions and ideologies mediated by media.

Teaching is an extremely broad concept … it gets more complex the more we know.
It presupposes pedagogical expert knowledge about

- conditions of leraning,
- task-specific conditions of situations, and
- available resources, such as media and organizational constraints.


Everyone knows learning must be serious and difficult and you must remain seated at all times. No fun allowed.

Variants of human learning (Roth, 1963):

1. Learning in which the **emergence of an ability** is the main goal as well as the automation of abilities to form motor and mental skills.
2. Learning centers on ***problem solving*** (thinking, understanding,"insight").
3. Learning which aims at ***construction, retention and remembrance of knowledge***.
4. Learning in which the main goal is **to *learn a procedure*** (learning to learn, learning to work, learning to do research, learning to look things up, etc.).
5. Learning in which ***transferal to other domains*** is the main point, i.e. the heightening of abilities and efforts (learning Latin as an aid for learning other Romanic languages).
6. Learning in which the main goal is to *develop one's* ***social positions, value positions, and attitudes***.
7. Learning in which the main goal is to *gain an* ***increasing and heightened interest*** *in a topic* (differentiation of motives and interests).
8. Learning in which the goal is a ***change in behavior***.

Contemporary research on learning is diverse, but it always has been.

Learning is existential, and so its study must be complex and interdisciplinary. Over the past centuries, many theories have been posited in various disciplines to explain how humans and other animals learn.

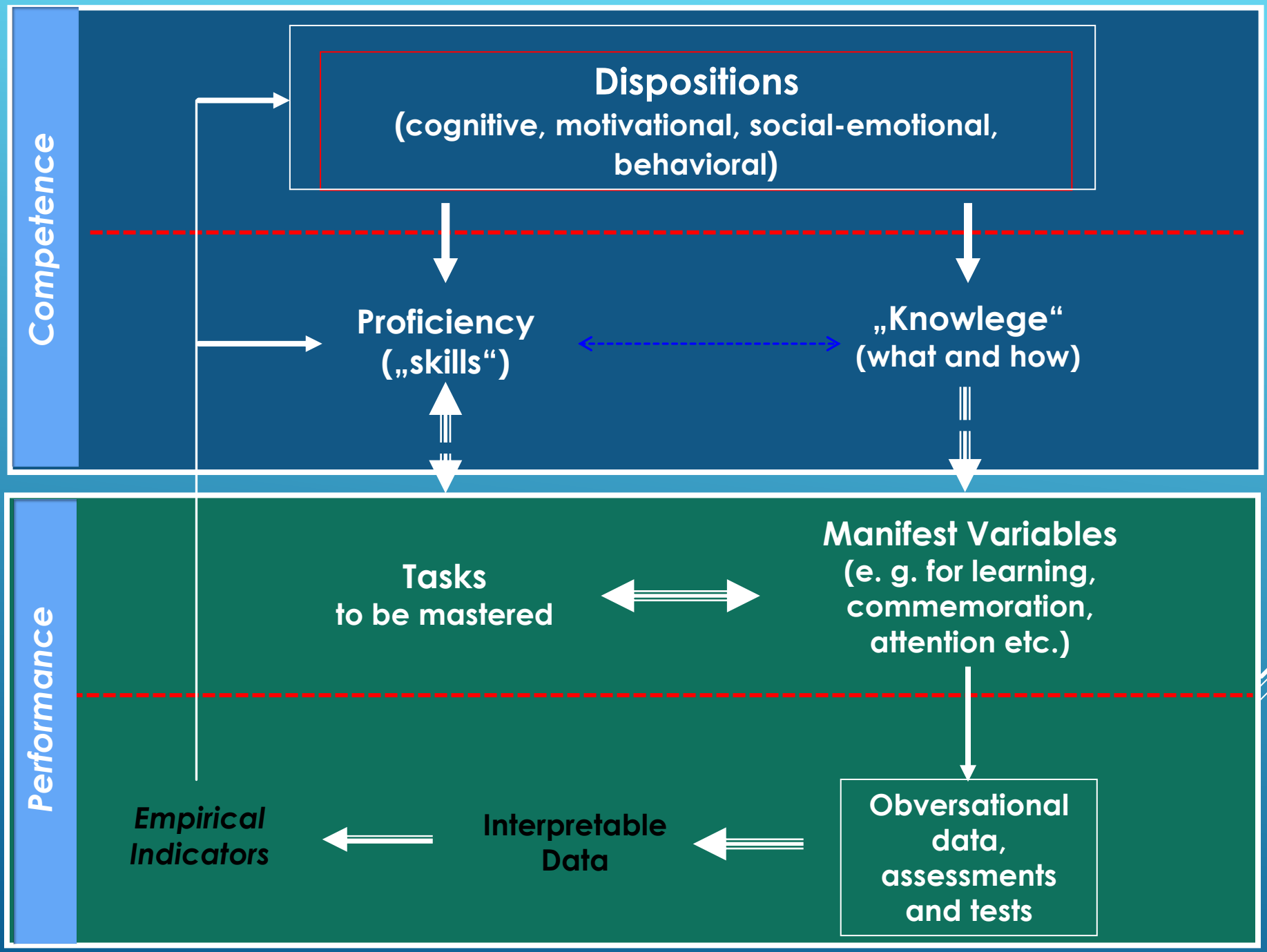
In its long history, there has never been a time when all scientists agreed on a single paradigm.

Learning is a theoretical construct … such as motivation, attitudes, and teaching.

Learning is a theoretical construct … such as motivation, emotion, attitudes, and teaching.

Two levels of consideration must be distinguished:

1. *The level of competence and*
2. *The level of performance.*


Competence
Dispositions
(cognitive, motivational, social-emotional, behavioral)
Proficiency
(„skills“)
„Knowlege“
(what and how)
Performance
Tasks
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Manifest Variables
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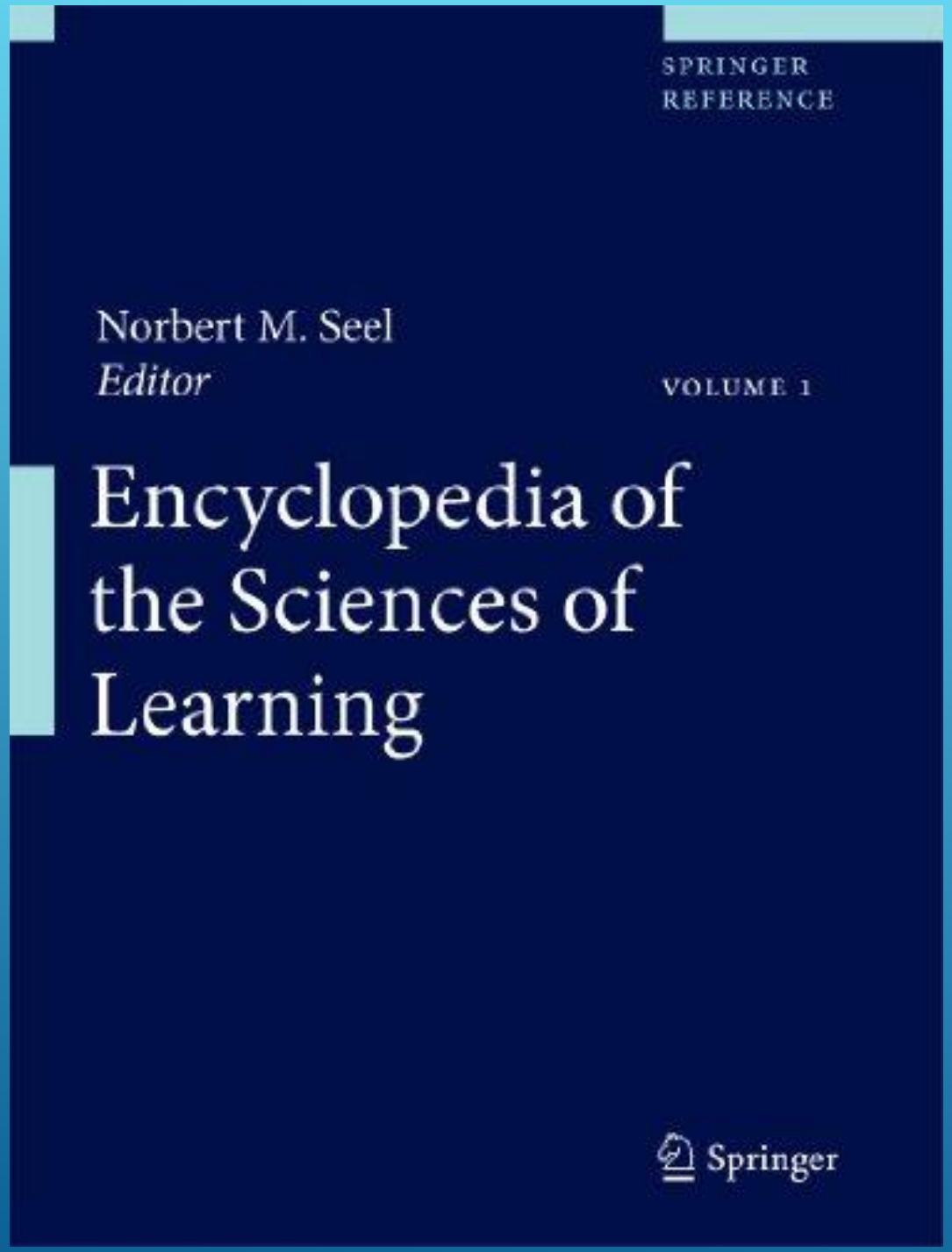
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Human Learning – Cognitive approach

Humans and other animals have three essential abilities for processing information and acting successfully in various environments.

1. **They are very good at *pattern matching* in order to quickly settle on an interpretation of an input pattern.**

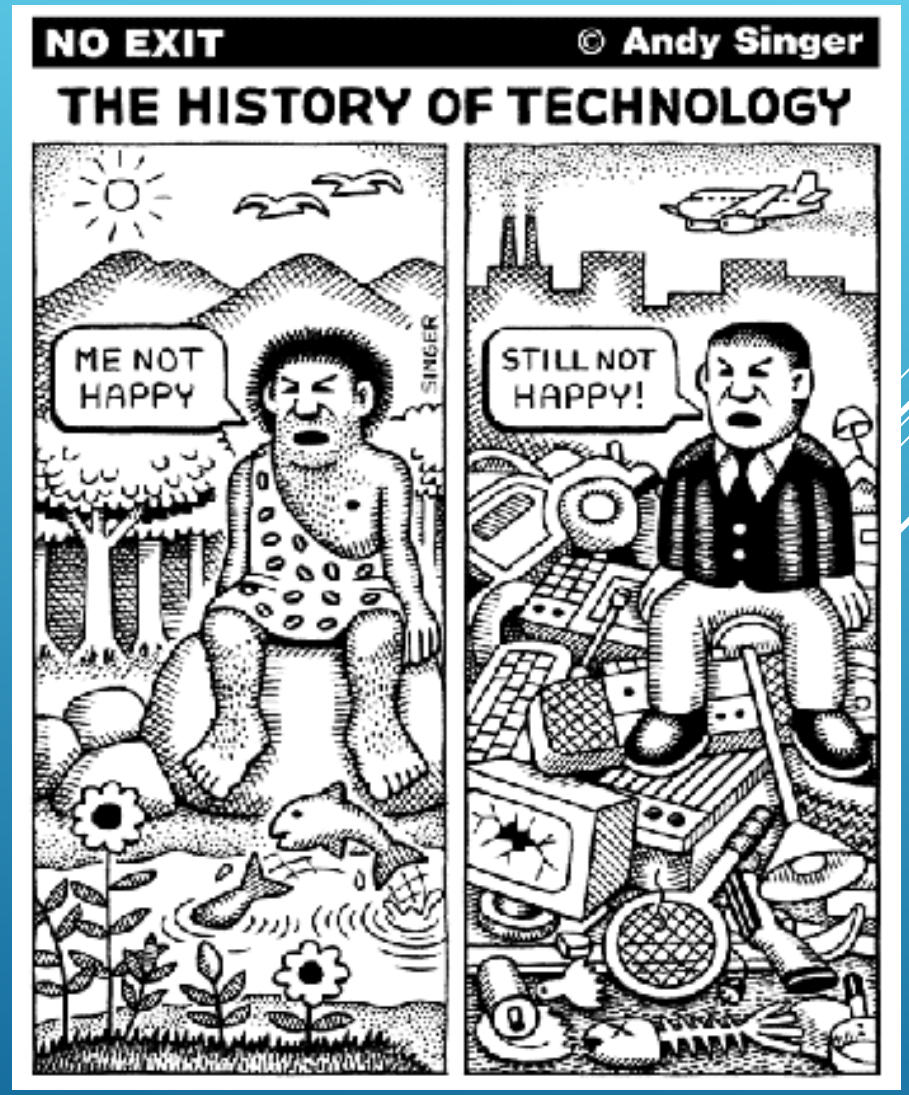
Times for object recognition, counting, and selection tasks vary from 25 to 170 msec (with 70 msec as th eaverage).

The accuracy of visual recognition improves as display times increase from 125 msec (16% accuracy) to 1000 msec (80% accuracy).

2. Humans are very good at ***modeling their worlds*** with the aim to anticipate new states of affairs.

3. Humans are good at ***manipulating their environments*** with the aim to create external representations.

   A version of (hu)man-the-tool-user.



These basic capabilities presuppose a cognitive system with two modules or sets of units (Rumelhart et al., 1986):

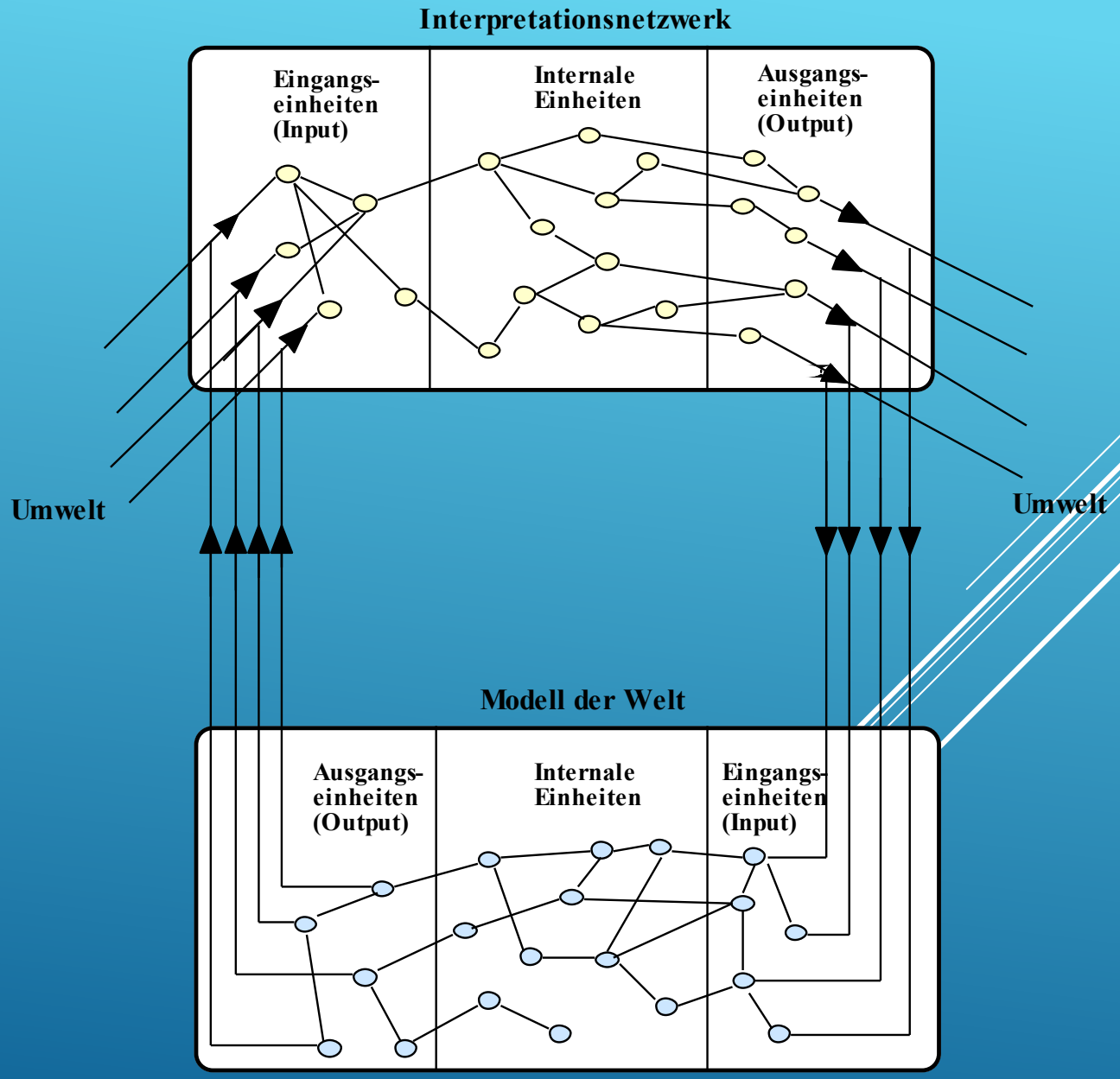
- an ***interpretation network*** –

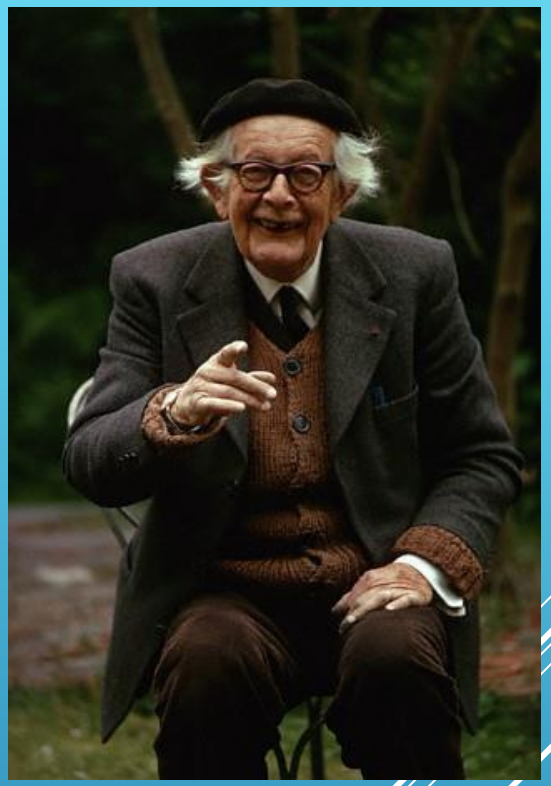
  which is concerned with producing appropriate responses to any input from the external world.

  The interpretation network receives input from the world and reaches a relaxed mental state by producing relevant cognitive responses.

- an ***model of the world*** –

  which is concerned with producing an interpretation of ***what would happen if we did that*** with a particular external representation.





This cognitive architecture corresponds to Piaget's epistemology that cognition is regulated by the continuous interaction between ***assimilation*** and ***accommodation***, which aims at adjusting the mind to meet the necessities of the external world **.**

Assimilation is dependent on the activation of schemas, which allow new information to be integrated into existing cognitive structures.

Schemas are slot-filler structures that serve central cognitive functions, such as integrating information into cognitive structures, regulating attention, making inferences in the process of acquiring knowledge, and reconstructing it from memory

"Without a schema to which an event can be assimilated, learning is slow and uncertain" (Anderson, 1984, p, 5).

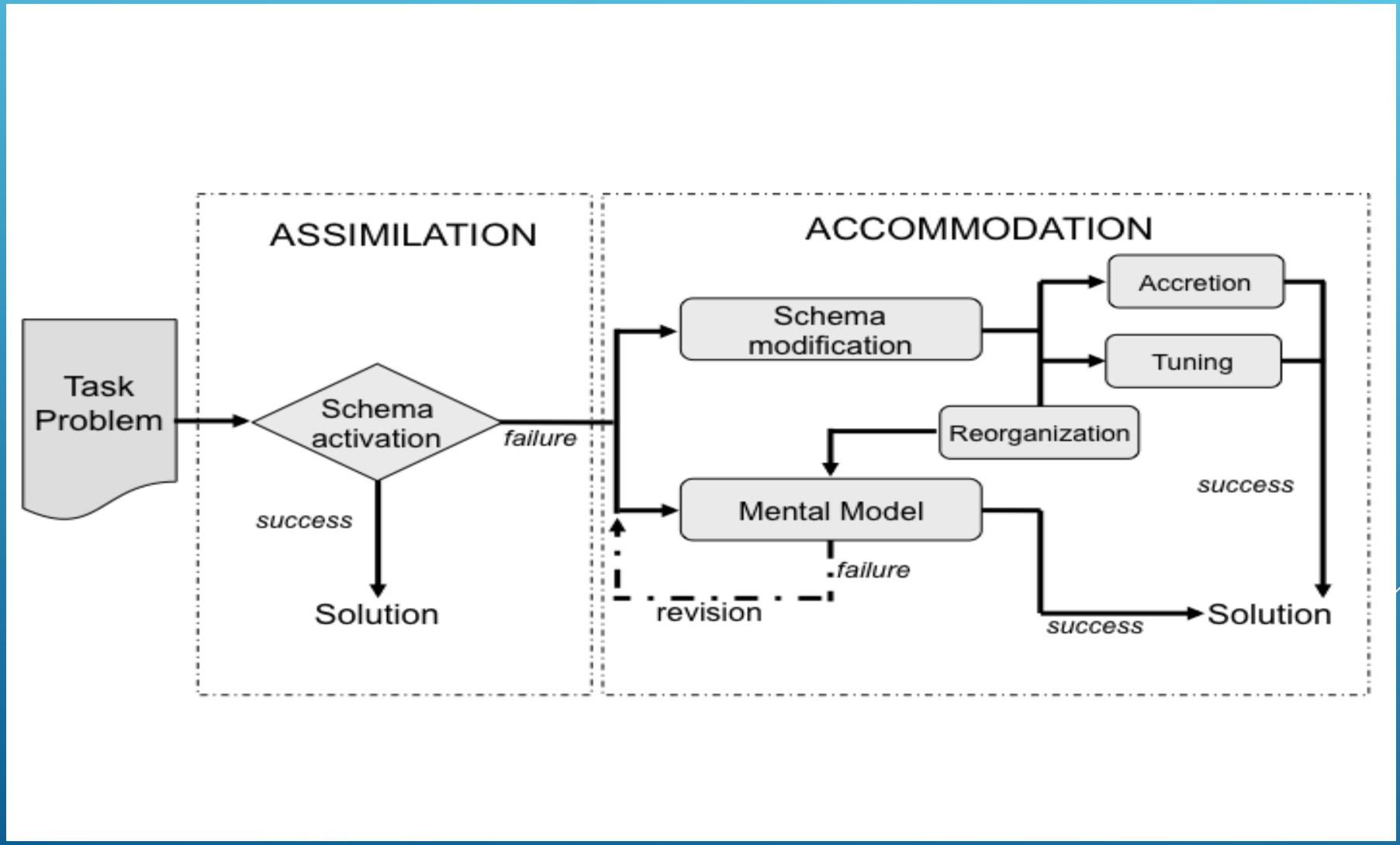
Accommodation aims at restructuring knowledge ...

.... by means of accretion, tuning, or the reorganization of schemas and their content (Norman & Rumelhart, 1978). .

If an adjustment of a schema is not possible, i.e., if the accretion, tuning, and/or reorganization of a schema fails – or if no schema can be activated at all – the learner either can abandon the cognitive processing or must invest some mental effort to develop a mental model.

"mental models play a central and unifying role in representing objects, states of affairs, sequences of events, the way the world is. … They enable individuals to make inferences and predictions, to understand phenomena, to decide what action to take and to control its execution, and, above all, to experience events by proxy" (Johnson-Laird, 1983, p. 397).

As long as the information being processed can be assimilated promptly into cognitive structures and as long as schemas can be modified by means of accretion, tuning, and reorganization, there is no need to construct a mental model.



Examples of schema-based learning (and instruction):

Meaningful verbal learning and the impact of advance organizers (Ausubel)

Generative learning and teaching (Witrock)

Cognitive Load (Sweller)

Examples of model-based learning (and instruction):

Learning by Design (e.g. Kolodner)

Model-based learning and teaching (e.g. Seel)

Model of model-based instruction: MOMBI (Hanke)

Learning of humans and other animals is cumulative by nature.

Learning systems, human or artificial, **accumulate** knowledge and abilities that serve as building blocks for subsequent cognitive development.

Cumulative learning deals with the gradual development of knowledge and skills that improve over time.

In both psychology and artificial intelligence, such layered or ***sequential learning*** is considered to be an essential cognitive capacity ...

... in acquiring useful aggregations and abstractions that are conducive to intelligent behavior and in producing foundations for further cognitive development.

“There has been remarkably little study of learning -- real learning, the learning of complex topics, the learning that takes months, even years to accomplish.

I have estimated that experts at a task may spend 5,000 hours acquiring their skills: that is not such a long time; it is 2 1/2 years of full-time study, 40 hours a week, 50 weeks a year. Not much time to become a professional tennis player, or computer programmer, or linguist.

What goes on during that time?

Whatever it is, it is slow, continuous.

No magic dose of knowledge in form of pill or lecture. Just a lot of slow, continual exposure to the topic, probably accompanied by several bouts of restructuring of the underlying mental representations, reconceptualizations of the concepts, plus many hours of accumulation of large quantities of facts [...]

Very little effort gets spent at studying what it would take to accomplish this, perhaps because there is the implicit realization that the task is harder than it might seem. [...]

And so the study and understanding of the learning process remains at a miniscule level.

Pity"

(Norman, 1981, p. 284).

In 2000, PISA shocked the world (i. e. Germany)....

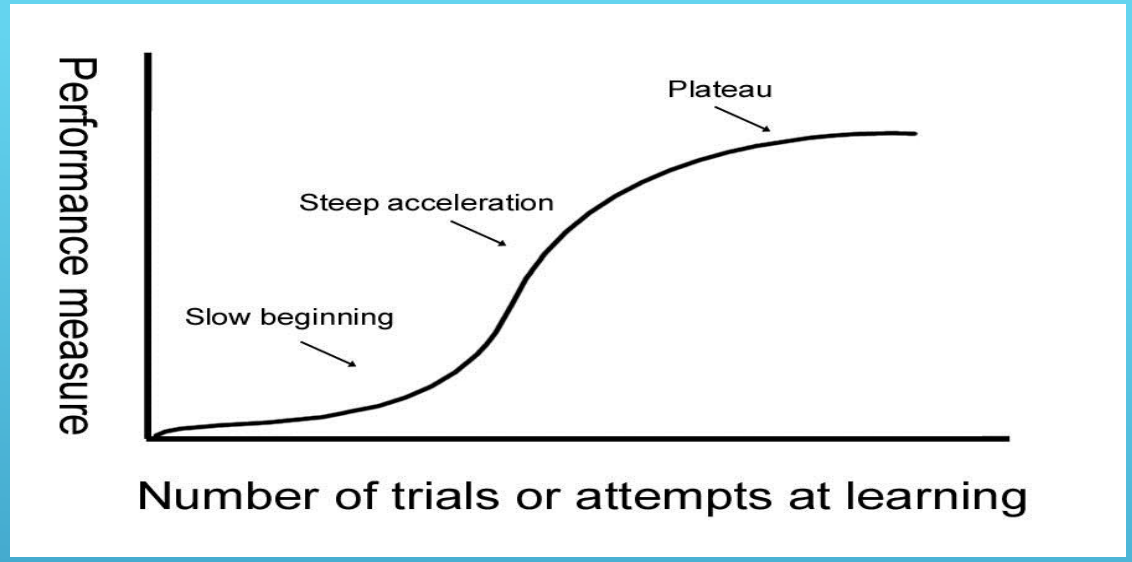
In one of the follow-up PISA-studies, *PISA-I-Plus,* the longitudinal change of learning results was measured across two grades (at two measurement points).

In mathematics, the students (15 and years old) had improve their learning with 60 %, in science only with 44 % .... but 20 % had forgotten what they had learned before.

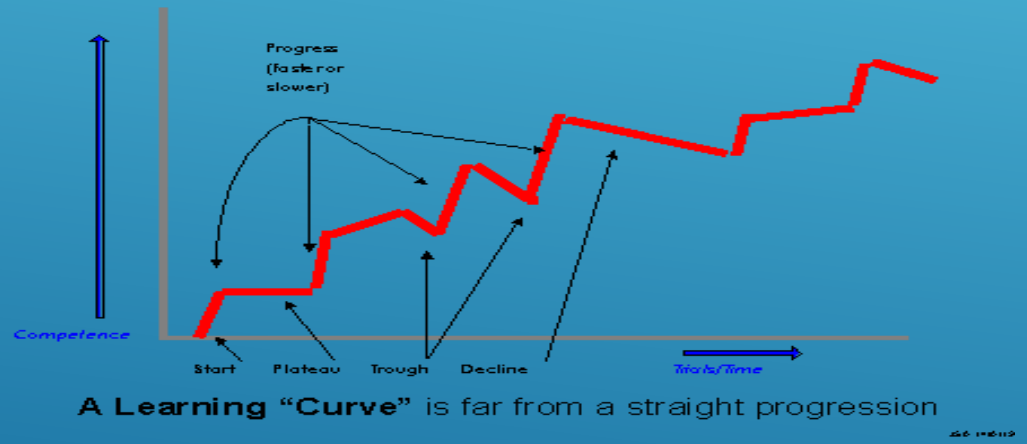
Contrarily, an extensive meta-analysis by Semb & Ellis (1994) shows that ***students retain much of what they have learned*** in the classroom and, amazingly, they retain in over a really long time.

Of course, a loss of retrieval would be observable after some time but forgetting was evidently not comparable with the forgetting curves in psychological learning experiments.

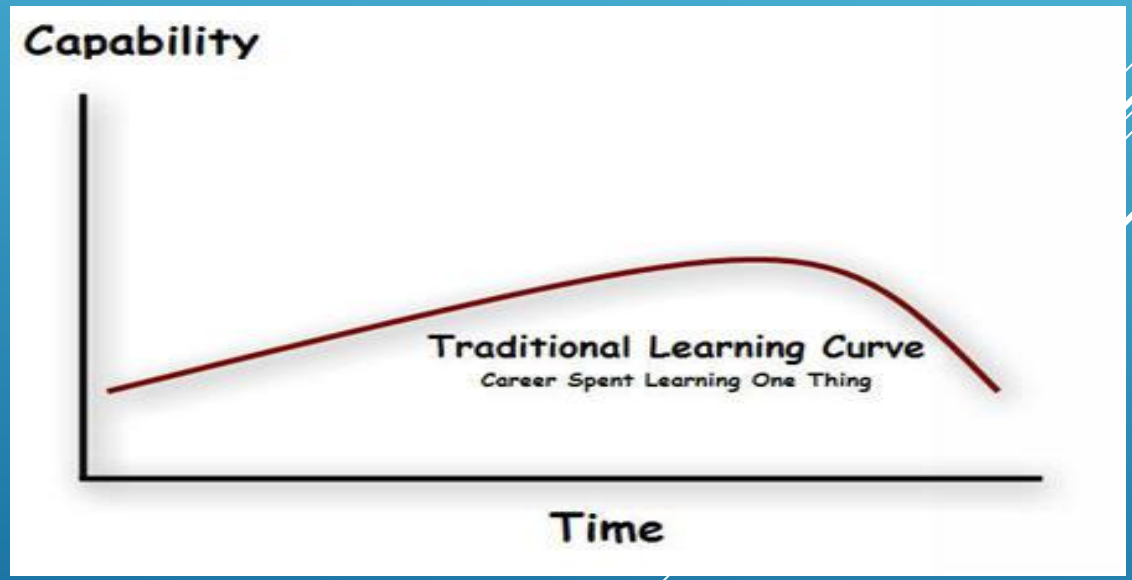
That‘s the curve expected by most people (and by PISA):

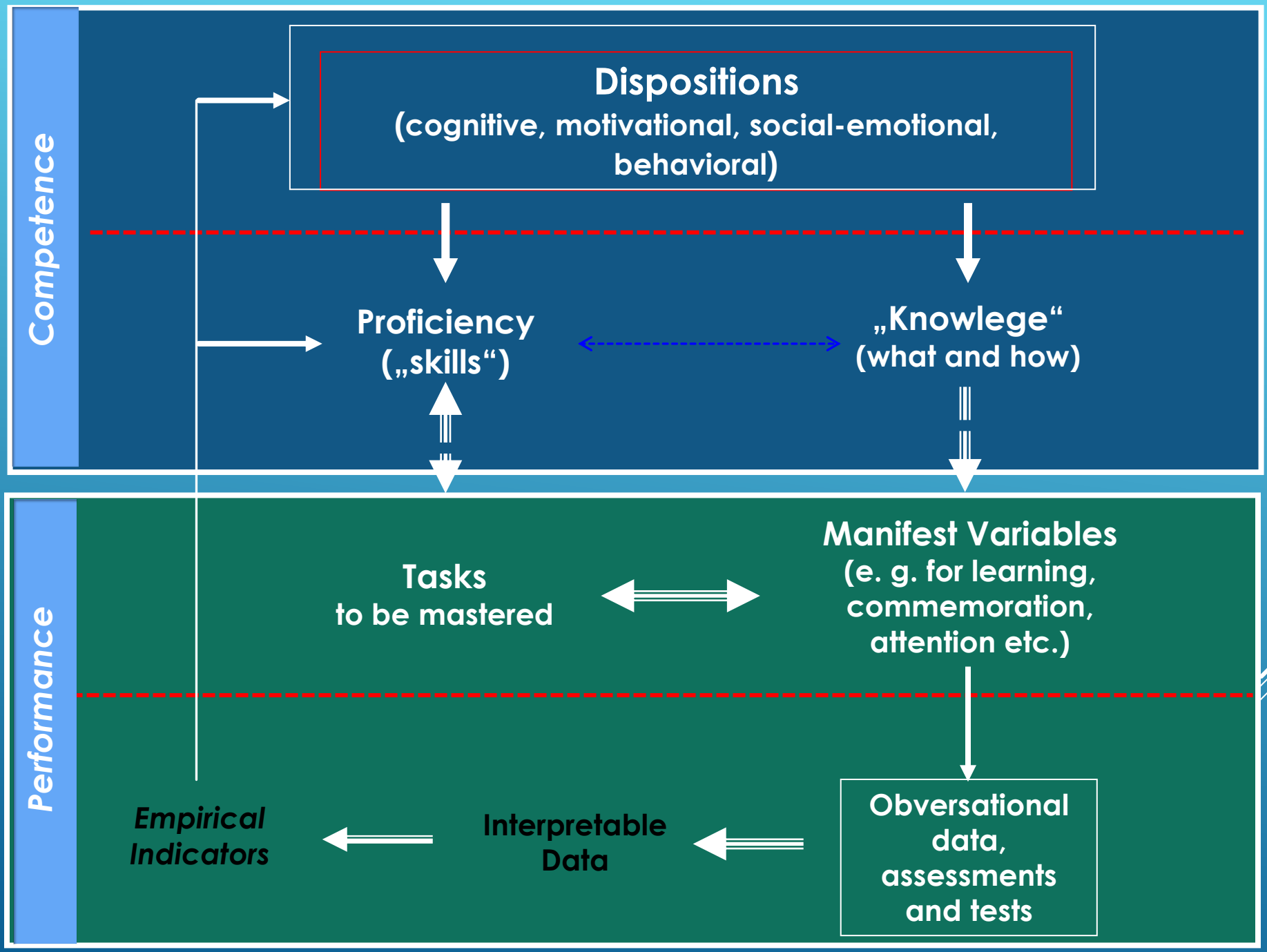


But a learning „curve“ is far from a straight progression:



What we should expect in general:

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Mental models in education -

"What is at issue is how such models develop as an individual progresses from novice to expert, and whether there is any pedagogical advantage in providing people with models of tasks they are trying to learn" (Johnson-Laird, 1989, p. 485)

"we have to assess carefully the learner's preconceptions as well as their transitions to more appropriate mental models at any stage of the learning process" (Seel, 1999, p. 159)

A simple pre- and post-test measurement does not provide any detailed insight into the progression of an individual's learning process over time!

Standard methods of assessment within the realm of mental model research are

(a) Experimental methods

(b) Protocol analysis

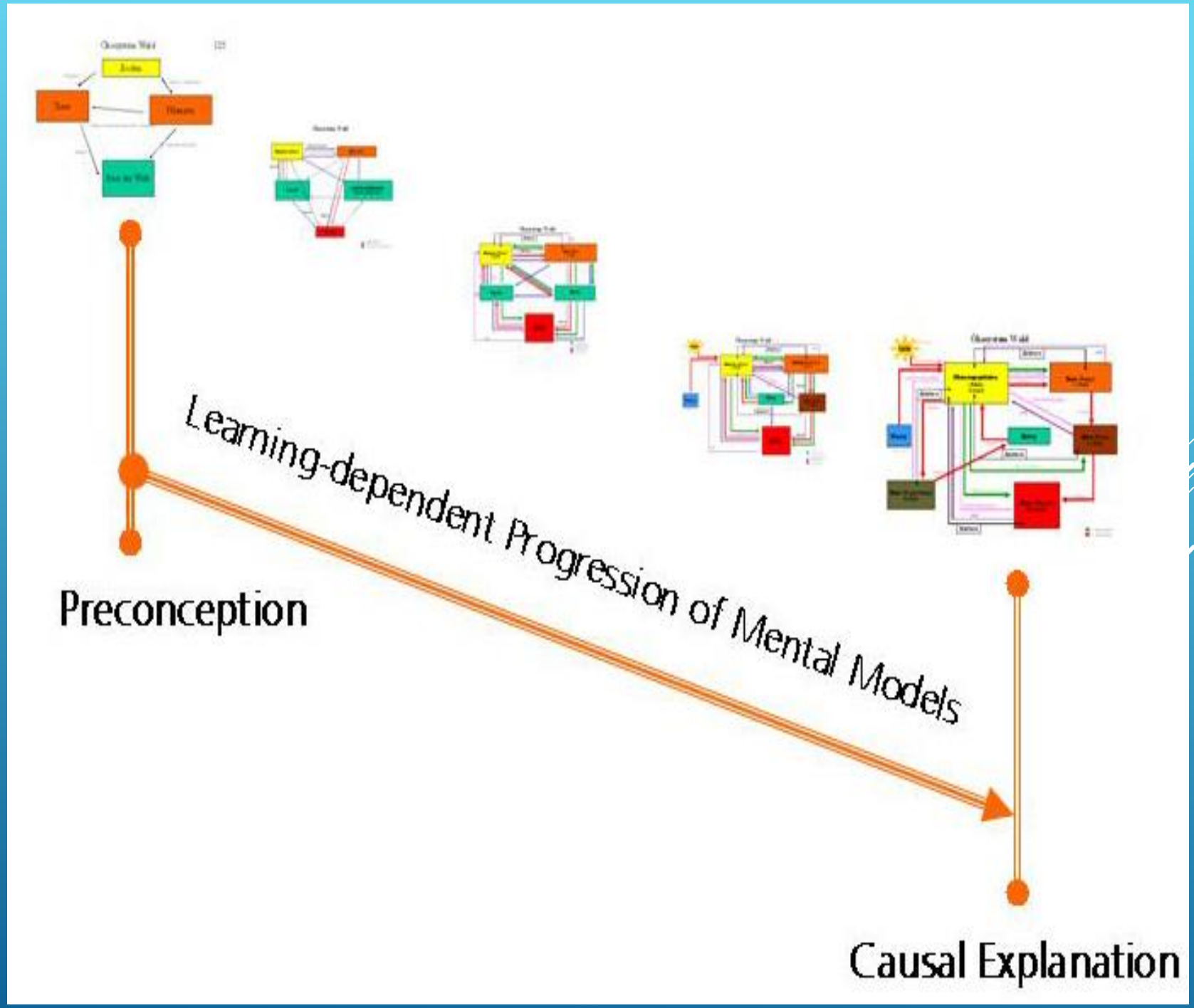
(c) Computer modeling and simulation (e.g. Model it)

(d) Causal diagrams

(e) ….

Based on causal diagrams Seel et al. developed a stochastic model to assess similarities and dissimilarities of learner' causal diagrams (i.e. externalizations of mental models) on the basis o transition probabilities.

This measurement of change is helpful to calculate the pro-babability of a learning-dependentprogression of mental models
(i.e. their externalizations by means of causal diagrams) constructed in the course of learning.



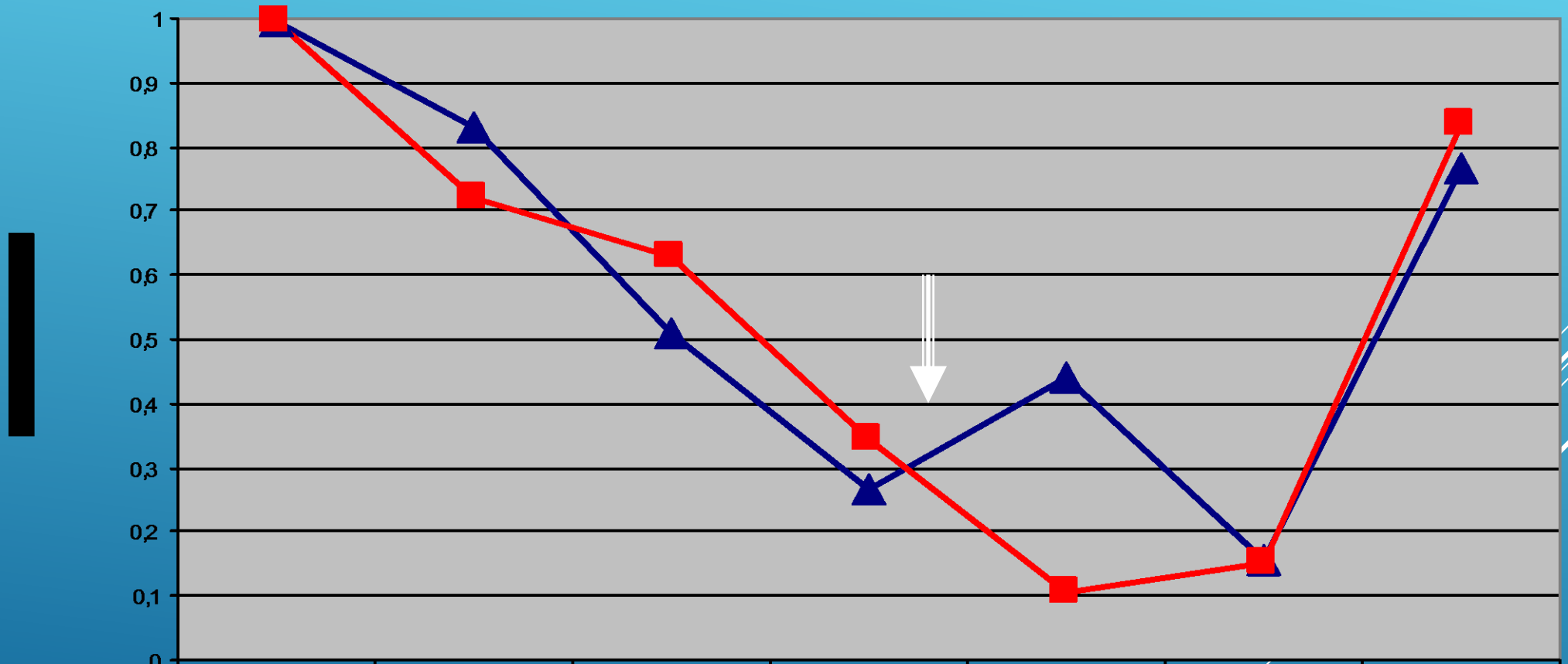
Results of two independent studies show

1. That the instrument is highly reliable,

2. There is a high probability of change from preconceptions to subsequent models.

3. There is a decrease in the probability of change in the course of continuous learning → stabilization of mental models.

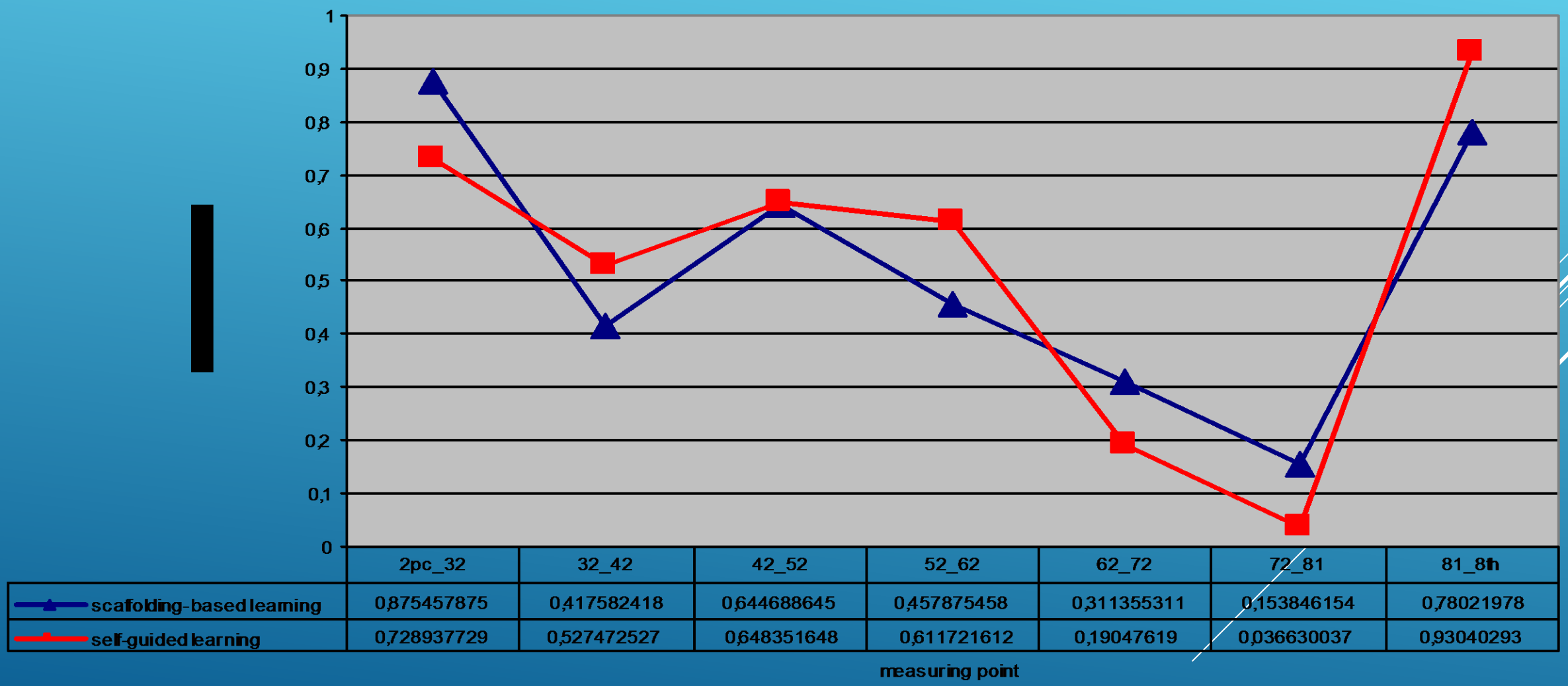
Measurement of change for *explanation models of study 1*



	2pc_32	32_42	42_52	52_62	62_72	72_81	81_8th
scaffolding-based learning	0,995475113	0,828054299	0,511312217	0,266968326	0,438914027	0,153846154	0,764705882
self-guided learning	0,995475113	0,719457014	0,628959276	0,343891403	0,104072398	0,149321267	0,837104072

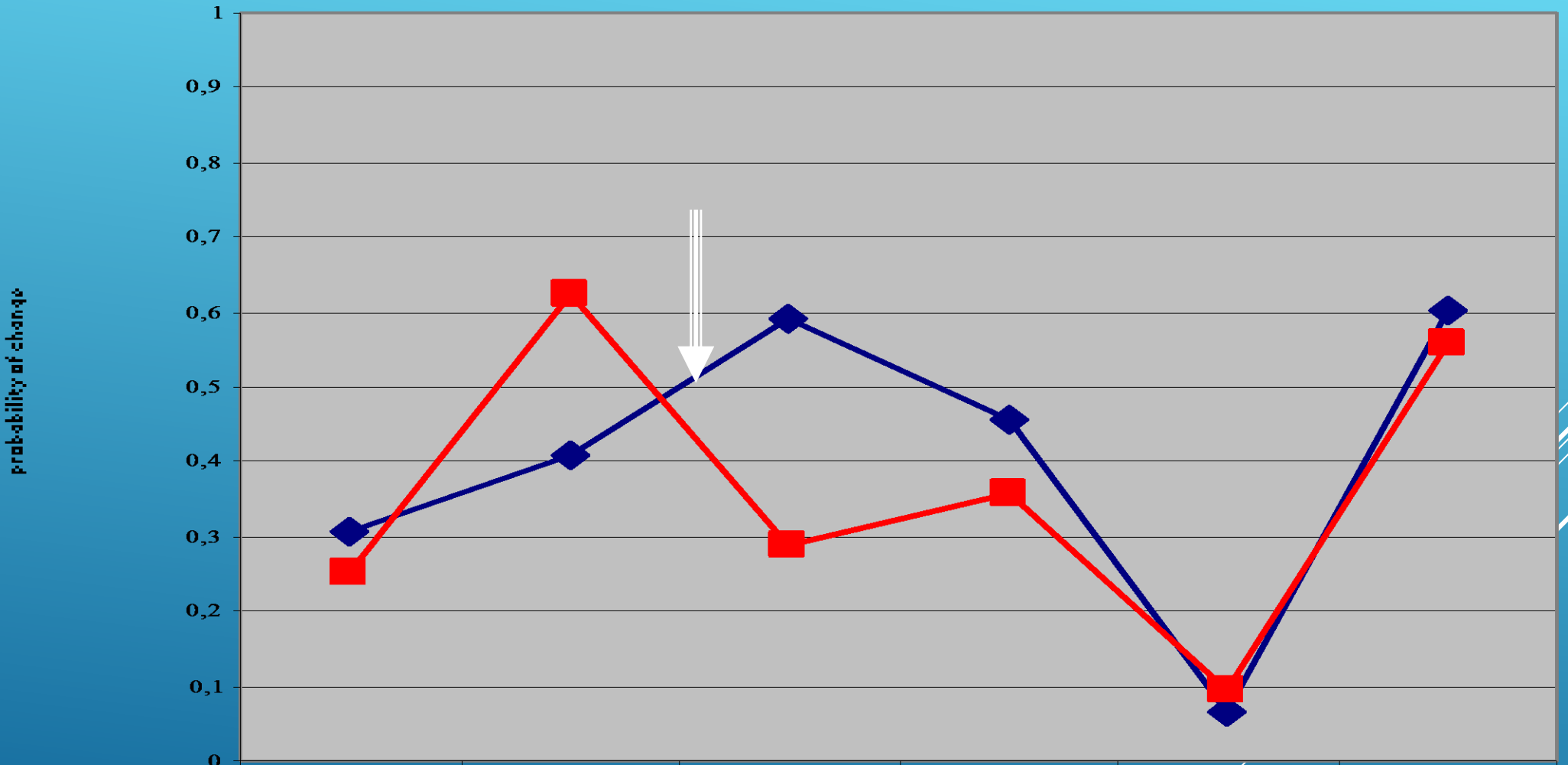
measuring point

Measurement of change for *analogy models of study 1*



	2pc_32	32_42	42_52	52_62	62_72	72_81	81_8th
scafolding-based learning	0,875457875	0,417582418	0,644688645	0,457875458	0,311355311	0,153846154	0,78021978
self-guided learning	0,728937729	0,527472527	0,648351648	0,611721612	0,19047619	0,036630037	0,93040293

Measurement of change for the *analogy models of study 2*



	2pc_31	31_32	32_41	41_42	42_51	51_5th
scaffolding-based learning	0,306905371	0,409207161	0,590792839	0,457800512	0,063938619	0,601023018
self-guided learning	0,252717391	0,625	0,288043478	0,355978261	0,095108696	0,559782609

The results of both studies demonstrate that this measurement of change can be considered a suitable method of assessing the learning-dependent progression of mental models
(both the *explanation models* and the *analogy models)*.