The Effectiveness of Multimedia Materials in Science Education from a Cognitive Load Theory Perspective

Kimberley Leslie
Renae Low
John Sweller

THE UNIVERSITY OF NEW SOUTH WALES
SCIENTIA
MANU ET MENTE
SCHOOL OF EDUCATION

Decline in science students

- Over the past decade there has been a general worldwide decline in the number of students electing to study science at higher levels.

Australia :

- In 2008 less than 12% Year 12 students elected to study physics.

Butler, M. (2008)

Problems with discovery

- Don’t look at a textbook : avoid most of them as you would poison….the student of any branch of natural science must go to the bench and work hard there.

  Armstrong (1896)

- Students in discovery situations are more likely than those receiving direct instruction to encounter inconsistent or misleading feedback providing them with misinformation of the science concept being studied.

  Klahr (2004)

Multimedia Instruction

- Kalyuga, Chandler & Sweller, 1999 : trade apprentices
- Mayer, Heiser & Lonn, 2001: university psychology students,
- Kalyuga & Sweller, 2004 : Year 9 secondary students,
- Lee, Plass & Homer, 2006: middle school chemistry students,
- Gyselinck, Jamet & Dubois, 2008 : school of engineering students aged 19-23,

Purposes of Study

- Assess effectiveness of Science programs.
- Assess effectiveness of multimodal presentations.
- Use Cognitive Load Theory as a framework to inform conclusions.

Cognitive Load Theory

- Working Memory
- restricted in the amount of information that it can store and process at any one time.
- Long Term Memory
- Effectively limitless capacity. Oganised into hierarchical schemas.
- Schema
- Function under either controlled or automated processing. Schema construction should be major aim of learning.

Cognitive Load Theory Effects

- Modality Effect
  - Tindall-Ford, Chandler & Sweller, 1997
  - Moreno & Mayer, 2000
- Redundancy Effect
  - Leahy, Chandler & Sweller, 2003
- Expertise Reversal Effect
  - Kalyuga, Ayres, Chandler & Sweller, 2003

Experiment 1

AIM :

- to investigate the cognitive and instructional effects when learners view demonstrations of science experiments and hear the information and explanation of the demonstrations presented simultaneously.

Participants

Students of

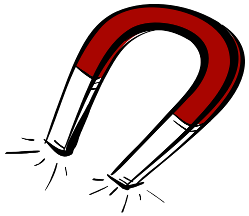
- Year 6 : 51
- Year 5 : 47
- Year 4 : 49

Total : 147 participants

Instructional groups

- Group A : auditory only
- Group B : auditory plus visual

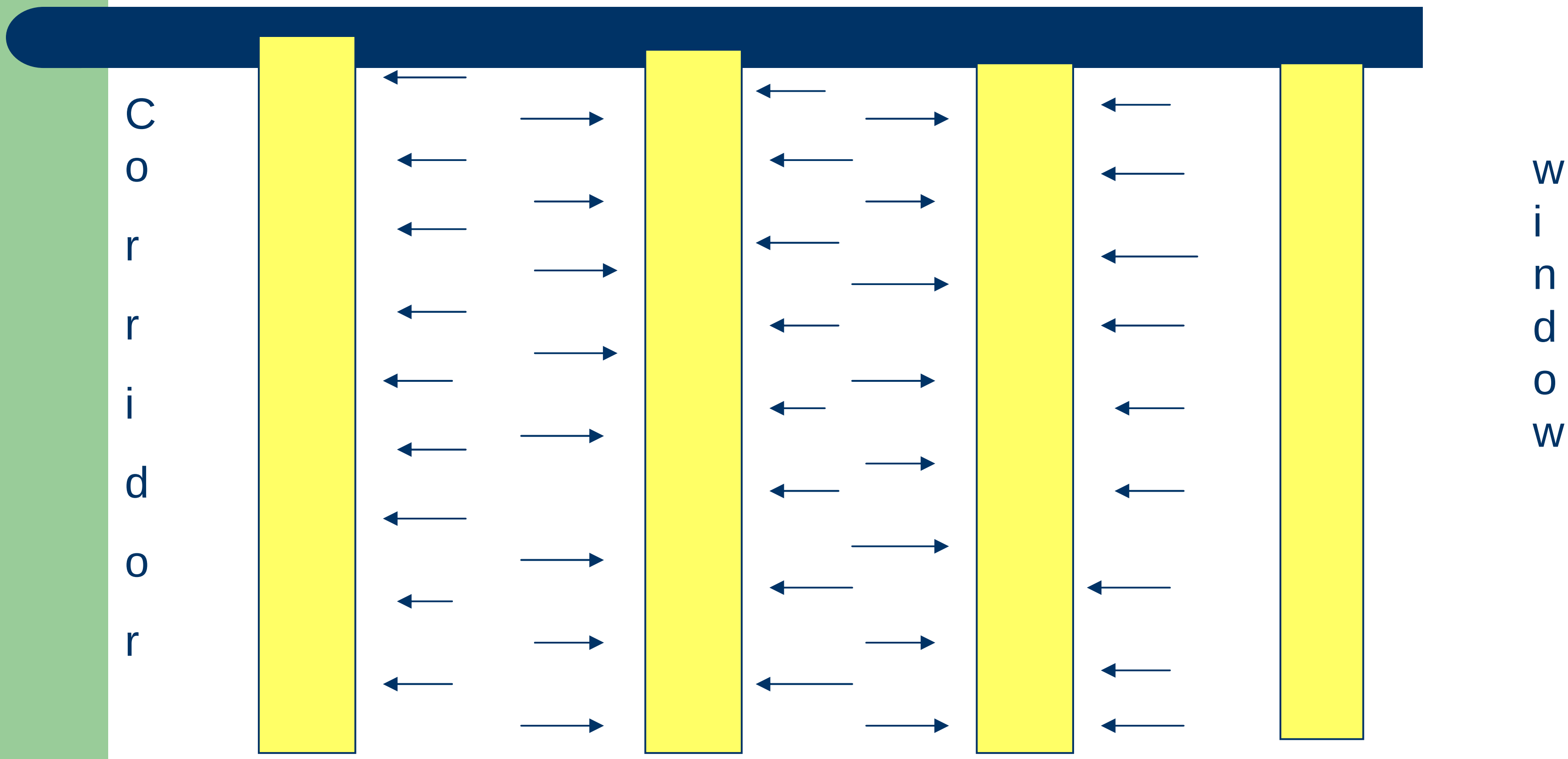
MAGNETISM



- Similar question :
- 6. One north pole will _______________ another north pole.

- Transfer question :
- 4. If a bar magnet is hung horizontally by one piece of string on the Harbour Bridge which direction would the south pole be pointing? _____________

Seating arrangement



YEARS 4, 5 & 6 - MAGNETISM

Descriptive Statistics

Dependent Variable:Score for transfer questions on postest

School Year group	Experimental group	Mean	Std. Deviation	N
Year 5	Experimental group A - auditory only presentation	8.83	3.270	23
	Experimental group B - auditory plus visual presentation	9.71	2.368	24
	Total	9.28	2.849	47
Year 6	Experimental group A - auditory only presentation	11.96	2.325	23
	Experimental group B - auditory plus visual presentation	10.07	2.666	28
	Total	10.92	2.667	51
Year 4	Experimental group A - auditory only presentation	8.72	3.311	25
	Experimental group B - auditory plus visual presentation	10.04	3.099	24
	Total	9.37	3.245	49

Magnetism

- S**imilar questions**,
- a **significant** advantage for Year 6 over Years 4 & 5, F(1, 141) = 11.79, MSe = 3.45, p = .000.
- no instructional effect F(1, 141) = .499, p = .481,
- no Year by Instruction interaction, F(1, 141) < 1.

- **Transfer questions**,
- **a significant effect** for the Year 6 students, F(1, 141) = 5.76, MSe = 8.22, p = .004,
- no difference between instructional conditions, F(1, 141) < 1, and
- **a significant interaction** for the Year by Instruction interaction, F(1, 141) = 4.57, p = .012.

Experiment 2

AIM :

- to investigate the cognitive and instructional effects when learners view demonstrations of science experiments and hear the information and explanation of the demonstrations presented simultaneously considering the prior knowledge of the participants.

Participants

Students of

Year 6 : 48

Year 5 : 50

Year 4 : 49

Total : 147 participants

LIGHT

- Similar question
  - 4. Light travels in ________ lines.
- Transfer question.
  - 12. Why are some shadows darker than others at the same time of the day?

YEARS 4, 5 & 6 - LIGHT

Descriptive Statistics

Dependent Variable:total score for transfer questions

Year group of student	experimental group	Mean	Std. Deviation	N
Year 5	Experimental group A - auditory only presentation	10.65	4.569	23
	Experimental group B - auditory plus visual presentation	11.26	3.448	27
	Total	10.98	3.972	50
Year 6	Experimental group A - auditory only presentation	13.57	3.906	23
	Experimental group B - auditory plus visual presentation	9.84	4.634	25
	Total	11.63	4.652	48
Year 4	Experimental group A - auditory only presentation	8.41	3.825	22
	Experimental group B - auditory plus visual presentation	9.44	3.468	27
	Total	8.98	3.631	49

Light

- **Similar questions**,
- a **significant** advantage for Year 6 over Years 4 & 5, $F(1, 141) = 11.79$, $MSe = 3.45$, $p = .000$.
- no instructional effect $F(1, 141) = .499$, $p = .229$,
- no Year by Instruction interaction, $F(1, 141) < 1$.

- **Transfer questions**,
- **a significant advantage** for the Year 6 students, $F(1, 141) = 6.28$, $MSe = 15.88$, $p = .002$,
- no difference between instructional conditions, $F(1, 141) < 1$, and
- **a significant interaction** for the Year by Instruction interaction, $F(1, 141) = 5.27$, $p = .006$.

Cognitive Load

- Cognitive load always relates to the cognitive processes of a specific person.

- As a consequence, formats that are effective for novices could be ineffective for more expert learners.

Kalyuga, 2007

Prior knowledge

- …learner knowledge base is a single most important cognitive characteristic that influences learning and performance.

Kalyuga, 2007

Albert Einstein: Connect

- “The relationship between two entities is more important than the entities themselves.”
- Learning is about seeking & securing connections.
- Schools are good at doing bits of information and not good at joins.

Cognitive Load Theory

- The basic premise of cognitive load theory is that the focus of an instructional module must be the instruction itself.
- the instruction must be designed to minimize cognitive load and enhance working memory.
- The mental resources of working memory can be overloaded. Any information that ignores cognitive load may interfere with the process of acquiring knowledge and skills.

Human Cognitive Architecture

- Working memory
- Long term memory
- Schema
- Element interactivity

Memory

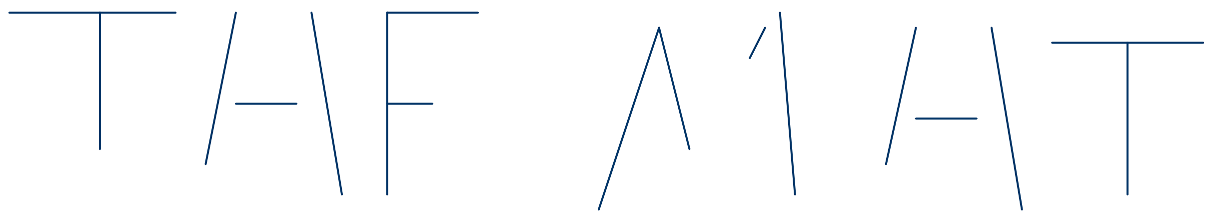
- Is about seeking and securing connections.
- Dewey : To remember a fact, an event or a situation is to see it in its relation to other things.
- Greenfield : “Understanding is the ability to relate to the association forged in your personal experience.”

Human Memory

- Working memory
  - Very limited in both capacity and duration
  - Processing capacity 7+or- 2(Miller, 1956)
  - If not rehearsed the information is lost within 30 secs.

- Long term memory
  - Effectively unlimited
  - Stores and organises information – schema
  - Skilled performance with increasing numbers of complex schemas.
  - The aim of all instruction is to alter long-term memory. (Kirschner & Sweller, 2006)

Context

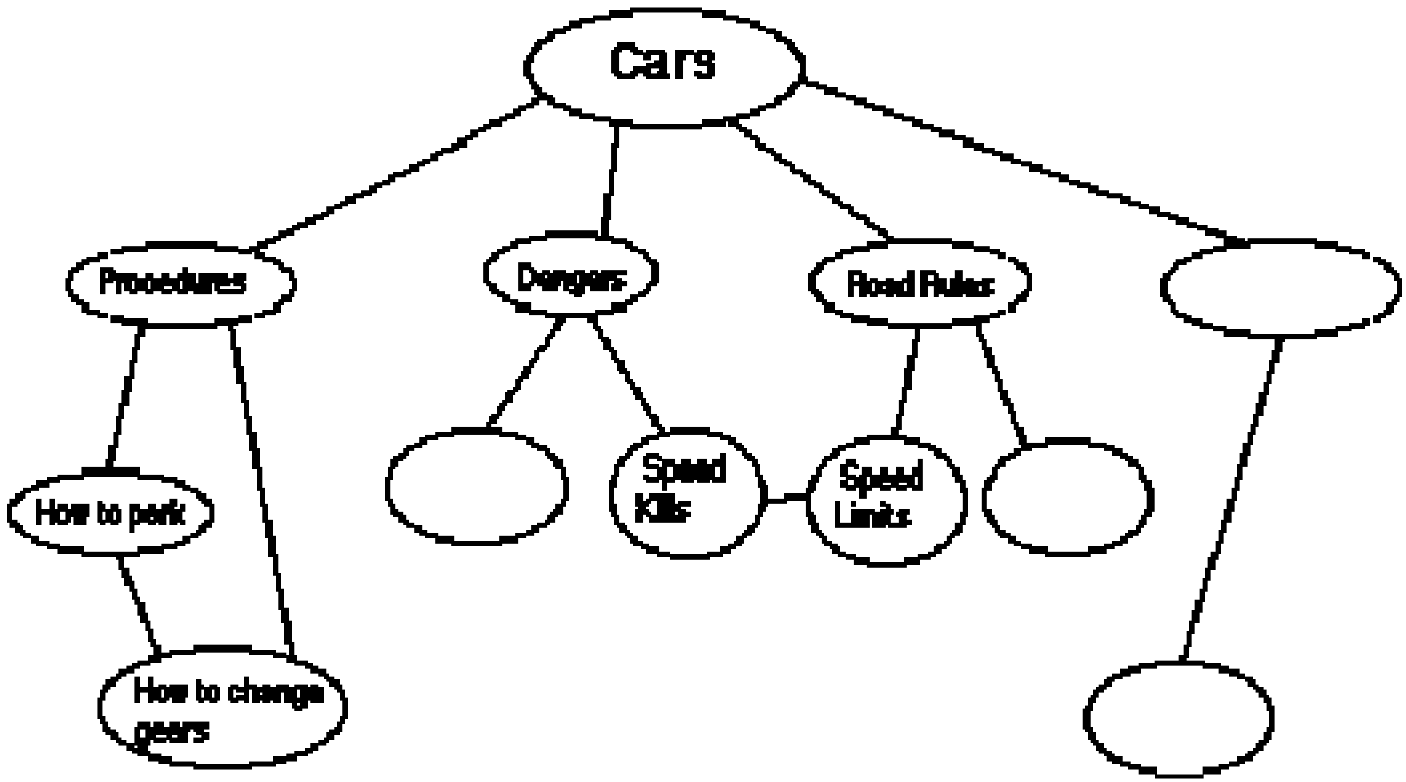


B B b B b B B b

Schema

- Connect
- Skill in any area is dependent on the acquisition of specific schemas stored in long-term memory.
- Depends on level of learner
- Automation
- Expertise Reversal Effect (Sweller, Kalyuga, Chandler & Ayers, 2003)

Schema for driving a car.



Puzzle

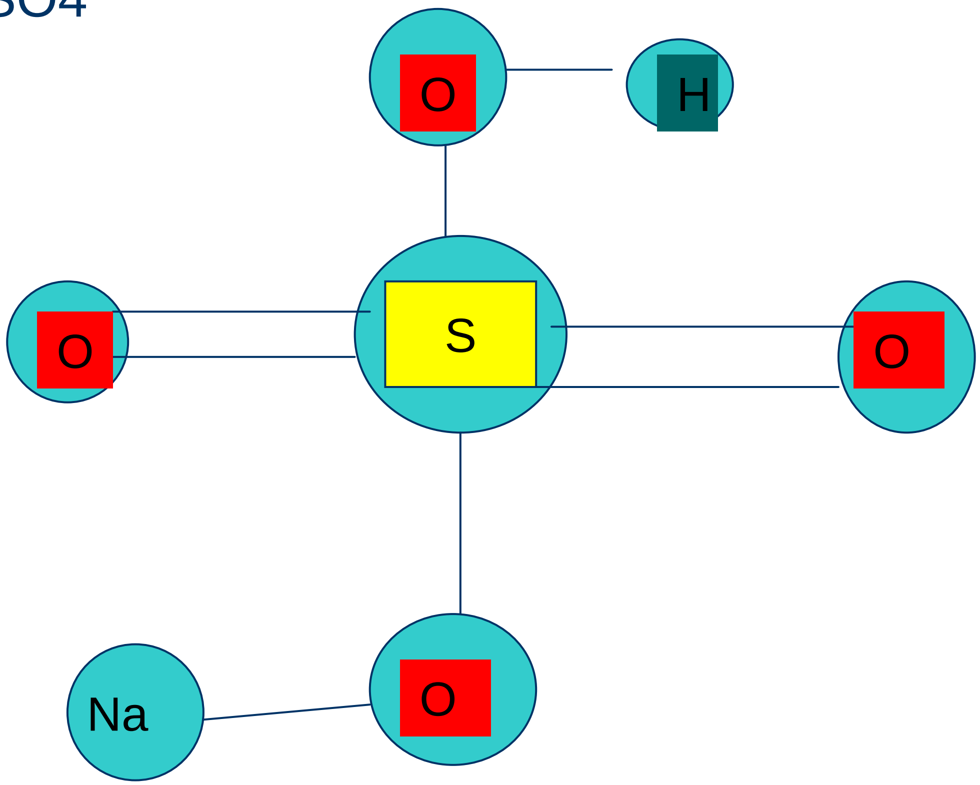
- Complete puzzle without first putting subject into context.
- Provide context for understanding.
- Complete puzzle.

Extraneous Cognitive Load

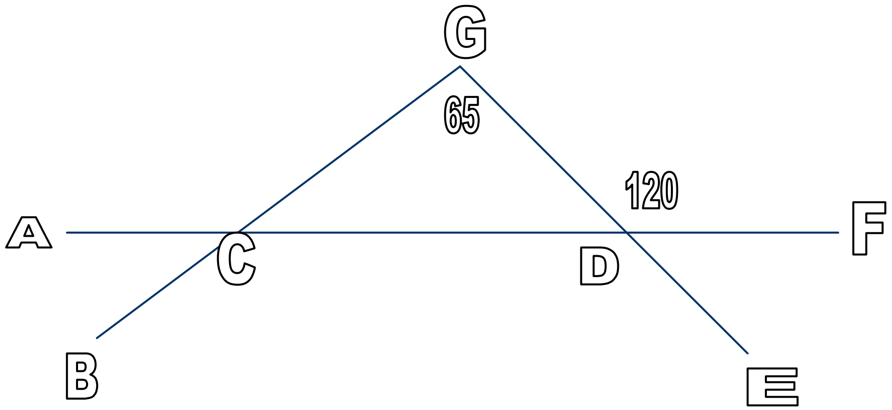
- Make a model of a Sodium Hydrogen Sulphate Molecule.
- Join a yellow sulphur and red oxygen ball with two grey flexi-links. Repeat this step with another oxygen ball on the opposite side of the yellow sulphur ball. Join the yellow sulphur ball to another oxygen ball with a single grey link. Repeat this step with another red oxygen ball. Now select one of the oxygen balls that has a single grey link to the sulphur ball, and join this oxygen ball to a white hydrogen ball with a single white link. Find the other oxygen ball that is connected to the sulphur ball by a single grey link and join this oxygen ball to a silver sodium ball using a single white link.

When a graphic can be understood by itself, adding explanatory verbal information is redundant. Chandler & Sweller, 1991.

- Make a model of a Sodium Hydrogen Sulphate Molecule: $NaHSO_4$



Conventional coordinate geometry worked example



Find Angle ACG.

Step 1: Angle GCF = Angle FDG – Angle EGB (external angles of a triangle equal the sum of the opposite internal angles)

Angle GCF = 120° - 65°

Angle GCF = 55°

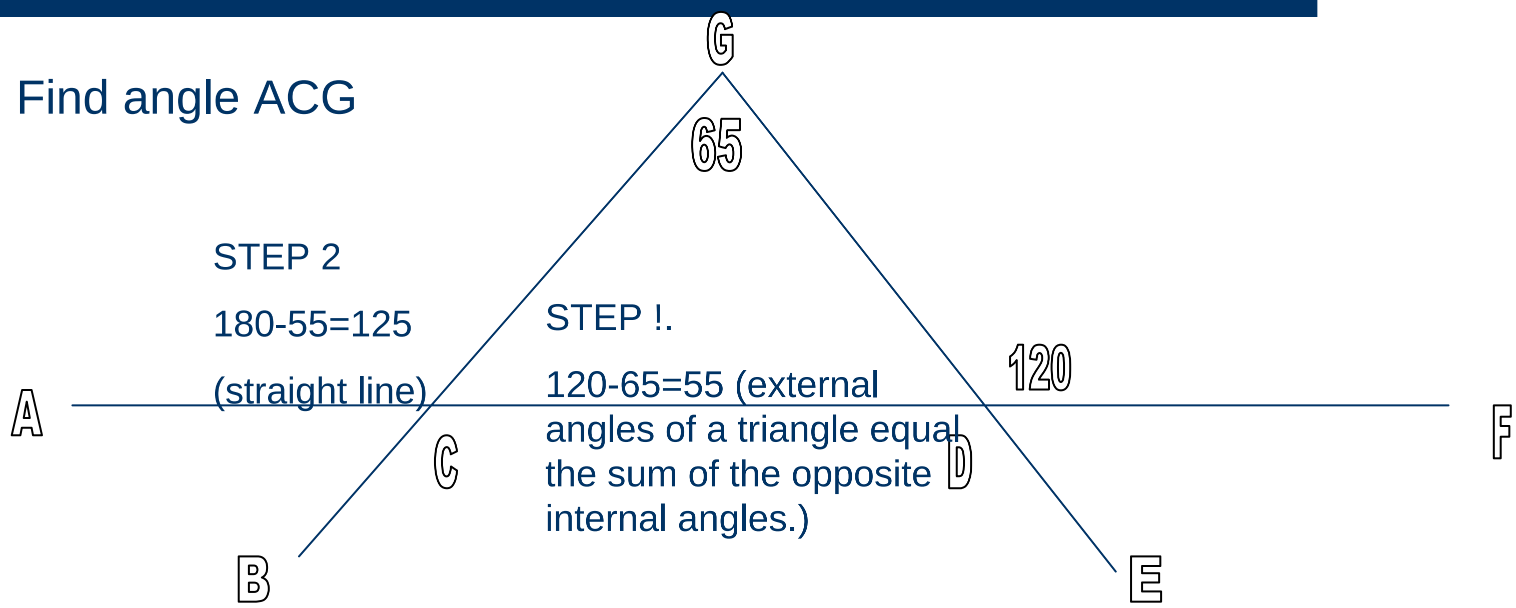
Step 2: Angle GCF + Angle ACG = 180° (straight line)

55° + Angle ACG = 180°

Angle ACG = 125°

Integrated coordinate geometry worked example

Find angle ACG



An integrated geometry worked example. The text has been integrated into the diagram.

Suggested readings

- Optimizing Cognitive Load for Learning From Computer-Based Science Simulations

  Hyunjeong Lee, Jan L. Plass, and Bruce D. Homer

  (2006)

- Why Minimal Guidance During Instruction Does Not Work: An analysis of the failure of constructivist, discovery, problem-based, experiential, and inquiry-based teaching

  Paul A. Kirschner, John Sweller, Richard E. Clark

  (2006)

- The Equivalence of Learning Paths in Early Science Instruction: Effects of direct instruction and discovery learning

  David Klahr & Milena Nigam

  (2004)