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Teaching the Control of Variables Strategy: A Research-synthesis

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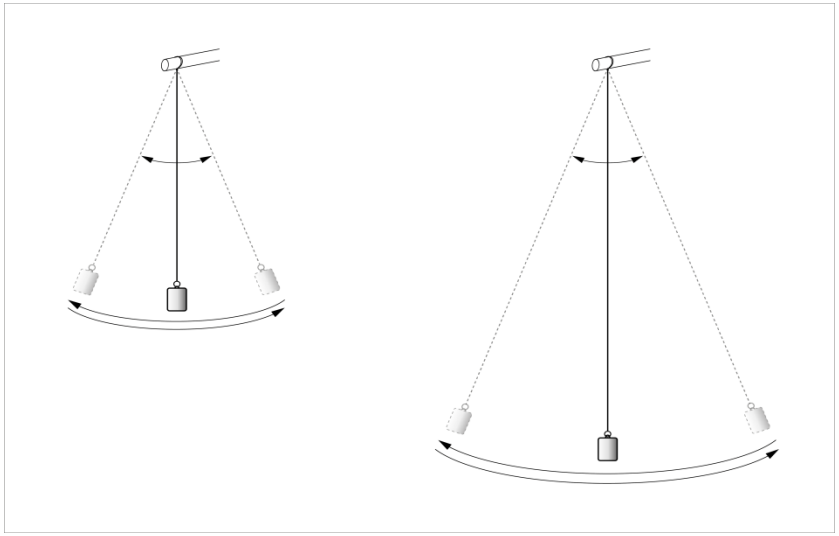
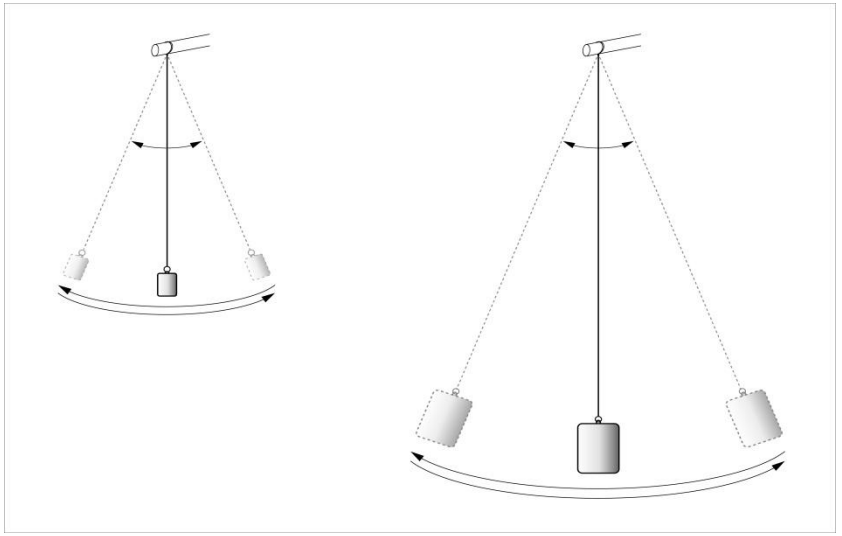
Controlling Variables





“Good experiment”

“Weak experiment”

(Inhelder & Piaget, 1958 p.68)

Students' understanding

- **CVS and Science Education**
  1) Important inquiry skill (Dewey, 2002; Popper, 1966)
  2) Curricula and standards (NGSS, 2013; NRC, 2000; KMK, 2005)
  3) Linked to general educational goals (Kuhn, 2005; Klafki, 1979)

- **Investigative studies:**
  - Students use the CVS in some circumstances but not in all

    (Tschirgi, 1980, Croker & Buchanan, 2011)
  - Students have no general understanding of the CVS without instruction

    (Morris et al, 2012)

➔ **CVS-Instruction**

CVS Instruction

- **Intervention studies:**
  - Direct instruction versus discovery learning

    (Chen & Klahr 1999; Klahr & Nigam 2004; Dean & Kuhn 2007)
  - Influence of age on learning the CVS

    (Grygier, 2008; Padilla, et al 1984; Case and Fry, 1973)

- **First meta-analysis** (Ross, 1988)
  - CVS-focused instructions
  - Feedback related to CVS
  - Origin of test instrument
  - …

CVS Instruction

A new meta-analysis is required because:

- Numerous new studies (n = 41)
- Changes in the methods & standards of meta-analysis

  (e.g. exclusion of outliers; depended effect sizes)

➔**Validity of older findings**

- Using different theoretical frameworks
- Using online materials
- Elementary students

➔**Potential additional study features**

Methods – Study search & inclusion

Literature search (**key words:** e.g. *control of variables strategy, inquiry, cognitive development*)

➔**450 studies**

Inclusion criteria:

1. Intervention study concerning the CVS
2. Contrasting of a treatment and a control group
3. Intervention context related to science
4. Reporting of data for calculating effect sizes
5. …

➔ **76 studies**

Methods – Study coding

Study features

Instructions

- Focus on CVS
- Explicit CVS rule
- Feedback
- Training on performance tasks
- Inducing cognitive conflicts
- CVS rule demonstrations

Test instruments

- Number of variables
- Similarity of test & training content
- Test format

Students

- Age
- Achievement level

Methods – Study coding

Study features

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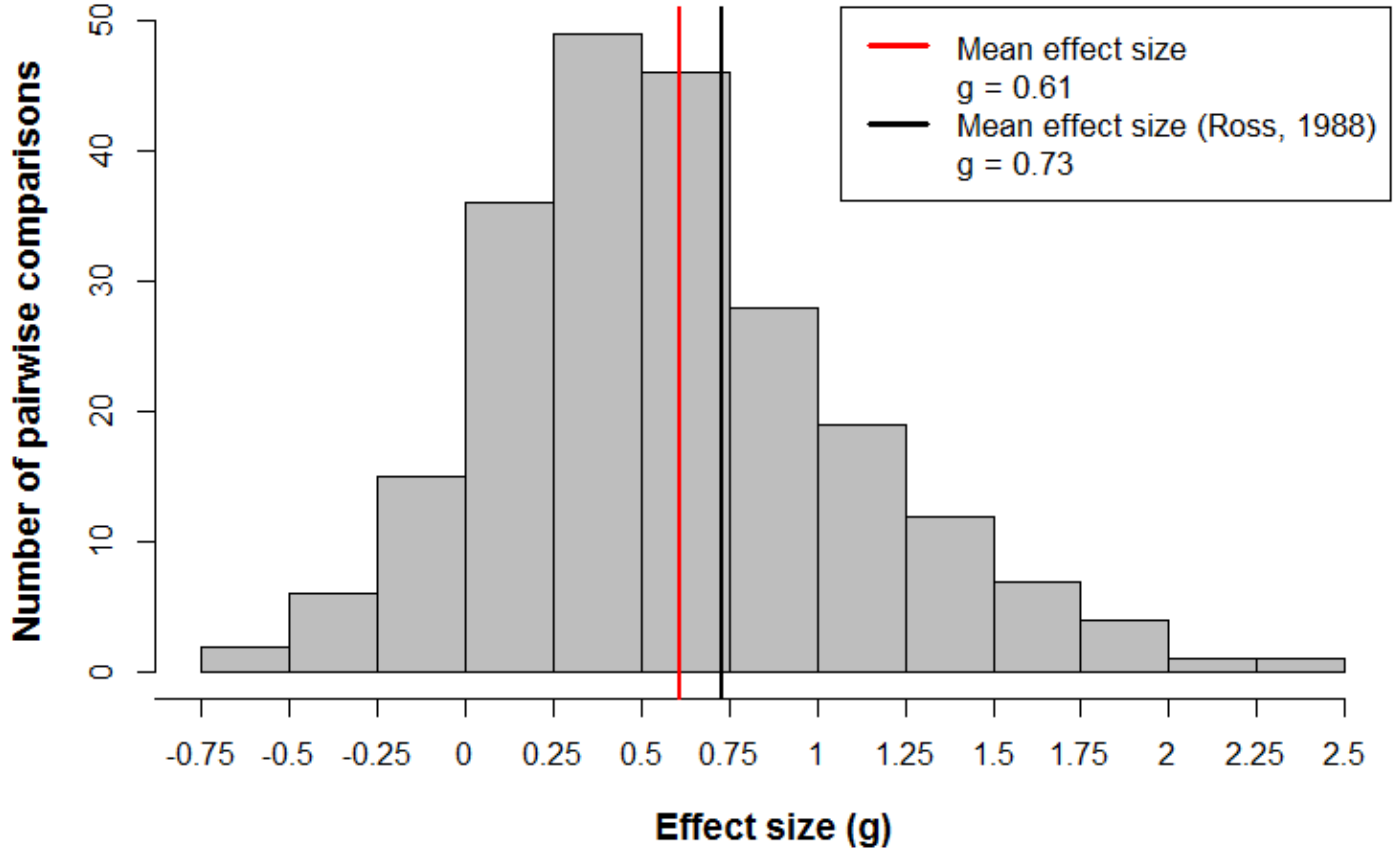
- Achievement level

➔237 pairwise comparisons from 76 studies

➔Robust meta-regression (Hedges, Tipton & Johnson 2010)

Results – Overall effect Size

Distribution of effect sizes after elimination of outliers



Results – Instruction features

Study features	g	SE	m	k
Focus on CVS	0.63	0.06	43	166
Additional (non-CVS) content	0.58	0.07	30	60
Teaching explicit CVS rule	0.58	0.06	44	137
No explicit rule	0.65	0.07	32	84
Use of feedback	0.66	0.09	33	91
No use of feedback	0.58	0.05	46	135

Results – Instruction features

Study features	g	SE	m	k
Training on real or virtual tasks	0.59	0.05	66	183
No training	0.74	0.08	14	43
Use of cognitive conflict	0.8	0.09	22	51_a
No use of cognitive conflict	0.53	0.05	54	175_b
Use of rule demonstrations	0.69	0.06	44	133_a
No use of rule demonstrations	0.48	0.08	24	69_b

Correlation

Results – Test features

Study features	g	SE	m	k
Four or more variables	0.68	0.09	36	103
Three or fewer variables	0.75	0.16	11	19
Identical content to training	0.61	0.09	23	59
Different content to training	0.57	0.05	51	139
Test-format				
Multiple-choice	0.52	0.05	20	42_{a}
Open-response	0.65	0.06	27	46_{a}
Performance tests (virtual)	0.42	0.05	11	25_{a}
Performance tests (real)	0.74	0.05	32	98_{b}

Discussion – CVS Instruction

1) Teaching CVS is effective but …
2) We know only two features of effective instructions
3) Explanation and physical experiences are non-effective

➔ Not learning but transfer of CVS

4) CVS is a cognitive strategy

➔ Hands-on hinder CVS learning

5) CVS is a complex construct

➔ More research on CVS sub-skills

Discussion – CVS Instruction

Features of direct instruction (Hattie, 2008)		**Our findings**
1) Engagement of students	➔	Cognitive conflicts
2) Presentation of information	➔	Rule demonstrations
3) Guided practice	➔	Training tasks
4) Feedback	➔	Feedback
5) Independent practice	➔	Training tasks

Discussion – CVS Instruction

Features of direct instruction (Hattie, 2008)		**Our findings**	
1) Engagement of students	➔	Cognitive conflicts	√
2) Presentation of information	➔	Rule demonstrations	√
3) Guided practice	➔	Training tasks	X
4) Feedback	➔	Feedback	X
5) Independent practice	➔	Training tasks	X

Discussion – CVS Instruction

Features of direct instruction (Hattie, 2008)		**Our findings**	
1) Engagement of students	➔	Cognitive conflicts	√
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3) Guided practice	➔	Training tasks	X
4) Feedback	➔	Feedback	X
5) Independent practice	➔	Training tasks	X

1) Which features make direct instruction effective?
2) What is direct in direct instruction?

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Thank You!

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Impact of outlier

Tab. 4
Comparison of different meta-analytical methods

	Ross (1988) with outliers	New analysis with outliers	Ross (1988) without outliers	New analysis without outliers
Studies	62	76	44	72
Percentage of Studies included in Ross´ analysis	100%	38%	100%	35%
Effect size (g)	0.73	0.77	0.61	0.61

Note. Datasets are not identical due to differing inclusion criteria

Impact of outlier

Methodological approach

Differences to Ross (1988) analysis:

a) Inclusion criteria

b) Estimation of effect sizes

c) Calculation of mean and moderator effect sizes

d) Exclusion of outliers

➔ Need for outlier analysis in meta-analysis