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Out-of-school learning opportunities/offers (OSLOs) Science Outreach Labs (SOLs): Research evidence

I.

I. Introduction
II. Affective factors: emotions, motivation, interest, …
III. Understanding and learning
IV. Success factors
V. Summary, perspectives

A. Müller, University of Geneva, Switzerland (andreas.mueller@unige.ch)
Faculty of Sciences / Physics Section and Institute of Teacher Education

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Außerschulische Lernangebote Out-of-School Learning Offers (OSLOs)

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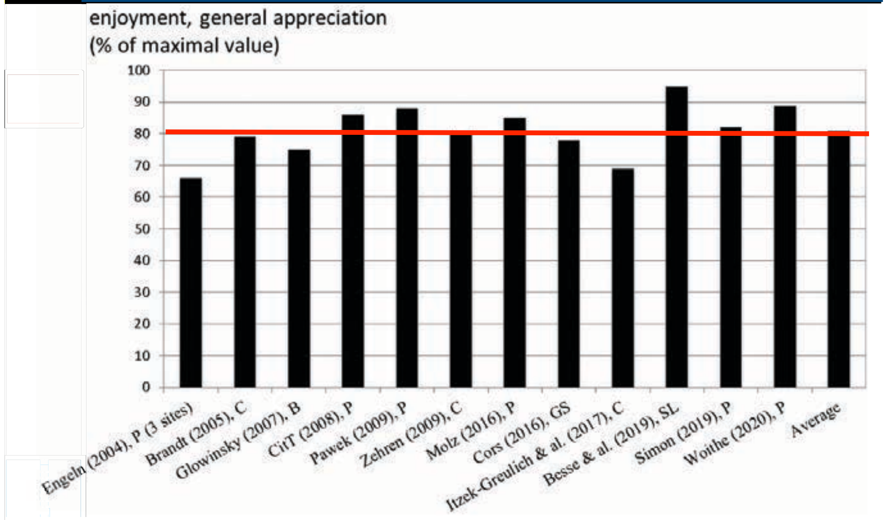
Science Outreach Labs: Fun factor (enjoyment, general appreciation)



Molz, A., Kuhn, J., AM. (2022). Effectiveness of science outreach labs …. Phys. Rev. Physics Education Research, 18(2), 020144.

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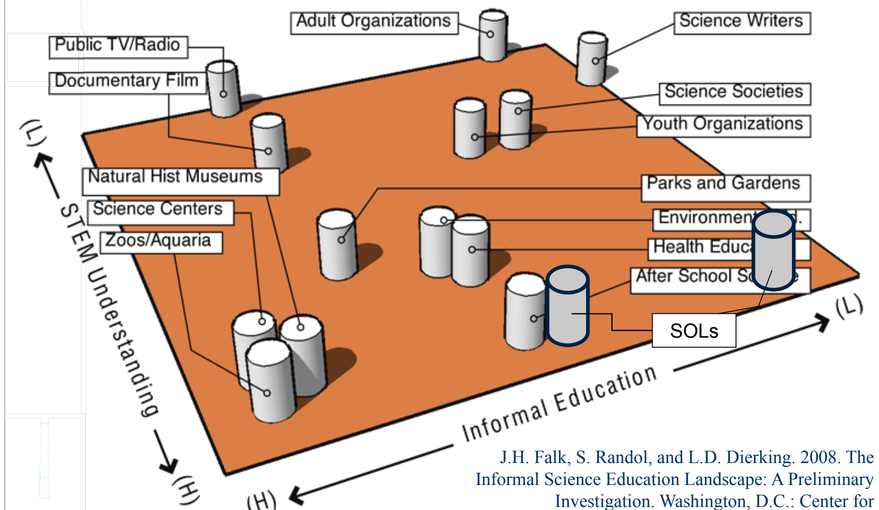
Some conceptual / terminological structure: Informal STEM landscape

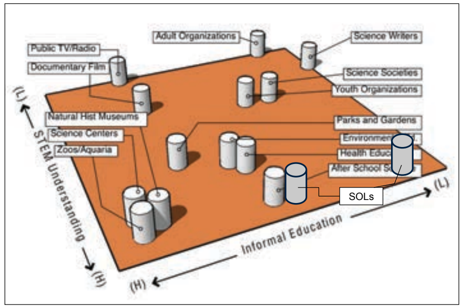


J.H. Falk, S. Randol, and L.D. Dierking. 2008. The Informal Science Education Landscape: A Preliminary Investigation. Washington, D.C.: Center for Advancement of Informal Science Education

Informal STEM landscape: some terminology / conceptualisation

I.

- Out-of-School Learning Offers / Opportunities (OSLO) Molz & al, 2022
  - can be closely connected to formal learning at school
  - thus differentiated from "informal learning"
- Science Outreach Labs (SOL) Thomas, 2012: Itzek-Greulich et al., 2015)
  - specific form of OSLOs, based on experimental hands-on activities and active lab work by the participants
  - usually within workshops lasting a few hours to a full day
  - provided by a wide range of host institutions



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Why Science Outreach Labs?

I.

- *Towards a More Authentic Science Curriculum : The contribution of out-of-school learning**
- How? Five major ways:
  - Extended and authentic practical work
  - Access to rare material and to "big" science
  - Improved development and integration of concepts
  - Attitudes to school science: stimulating further learning
  - Social outcomes: collaborative work and responsibility for learning

*Braund, M., & Reiss, M. (2006) International Journal of Science Education, 28(12), 1373

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A word on method: effect sizes

I.

$$d = \frac{M_T - M_C}{S}$$

M = averages
T/C: treatment/control group
S = standard deviation

- interpretation: signal (M_T - M_C) : noise (S) ratio
- conventional levels (Cohen):

small (0.2 ≤ *d* < 0.5) / medium (0.5 ≤ *d* < 0.8) / large (0.8 ≤ *d*)
established by "scale" of very many studies (education, medicine, other)

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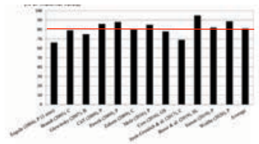
Science Outreach Labs: some research results on affective factors:

III.

- 1) "**fun factor**" (enjoyment)
  good to very good!



- 2) **"gender gap":** immediate positive effect for girls > boys
  - science interest difference (girls vs. boys) decreasing from d (long term) = −0,85 to d (after visit) = −0,51 (Pawek, 2009)

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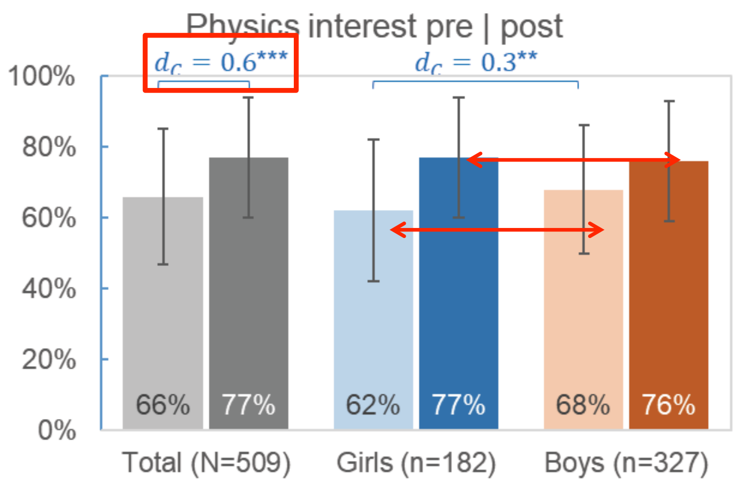
III.

Closing the “gender gap”



Woithe, AM, Schmeling, Kuhn (2022). Motivational outcomes of the science outreach lab S'Cool LAB…, Journal of Research in Science Teaching,

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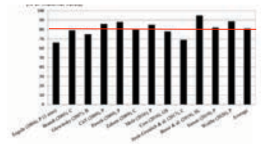
III.

Science Outreach Labs: some research results on affective factors:

- 1) “**fun factor**” (enjoyment) good to very good!



- 2) **“gender gap”:** immediate positive effect for girls > boys
  - science interest difference (girls vs. boys) decreasing from
    d (long term) = −0,85 to d (after visit) = −0,51(Pawek, 2009)
    d (physics) = −0,30, n.s. after visit = −0,51 (Woithe et al., 2022)
- 3) **“interest gap”:** similarly immediate positive effect for low interest group > high interest group
  - science interest difference (initial low vs. high interest group) decreasing for
    d (long term) = −2,33 to d (after visit) = −0,49 [Paw09, p. 122]

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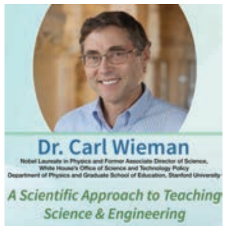
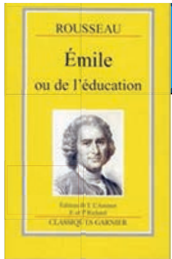
III.

Research on educational effects of SOLs/OSLOs

- Motivation, learning (affective and cognitive effects)
  - interest, curiosity, …
  - conceptual understanding, nature of science
- 3 kinds of research (at least)
  - measurement
  - effects, efficiency
  - influences, relations



Nobel prize 2001



Measurement: For example, ‘Curiosity’

Rendez votre élève attentif aux phénomènes de la nature, bientôt vous le rendrez curieux ; mais, pour nourrir sa curiosité, ne vous pressez jamais de la satisfaire. Mettez les questions à sa portée, et laissez-les lui résoudre. (J-J. Rousseau)
Macht euren Schüler auf die Naturerscheinungen aufmerksam, dann wird er neugierig. Stellt ihm Fragen, die seiner Fassungskraft ent-sprechen; laßt sie ihn selbst lösen.

Curiosity as „moving force“ of research

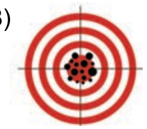
The Hungry Mind: Intellectual Curiosity Is the Third Pillar of Academic Performance

Perspectives on Psychological Science 6(6) 574–588 © The Author(s) 2011 Reprints and permission: sagepub.com/journalsPermissions.nav DOI: 10.1177/1745691611421204

The sober work on the detail...

Test for curiosity in OSLOs (Hirth, Hochberg, Molz, Cors, Woithe, ...)

- research-based, 9 items, duration ≈ 3min
- good test characteristics, eg reliability α_C = 0.8)
- further differenciation (discipline/topic/experiments; trait vs state)



Measurement: typical variable sets for affective and cognitive variables

Table 20: Variable Operationalization Matrix (Cors, 2018)

Variables	Keyword	# items	Variable Type	Definitions and Scales (Source) Pu=pupil; ML= mobiLLab; O=Ordinal; D=Dichotomous; I=Interval.	Surveys PRE	AT	POST
Independent Variables					Est. time (sec)*		
1) Tink NIF	Perceived technological capability	6	O	Whether Pu tinkers, or seeks direction, to interact with technology (Luckay & Collier-Reed,	120	0	0
2) V_NS NIF	Frequency science OSLeP visits	11	O	How often Pu visits natural science-related OSLePs (Falk et al., 2012a)	100	0	0
3) V_Tech NIF	Frequency technology OSLeP visits	11	O	How often Pu visits technology-related OSLePs (Falk et al., 2012a)	100	0	0
4) CurT	Curiosity trait	6	O	Pu dispositional curiosity (trait) (Litman & Spielberger, 2003; Naylor, 2007)	0	0	120
5) GrS NIF	Science grade	1	I	Pu grade in science (Natur und Technik) course.	20	0	0
6) GrM NIF	Match grade	1	I	Pu grade in math course.	20	0	0
7) ExpB NEF	Exploratory behavior	5	O	How much Pu explores equipment at ML visit (Luckay & Collier-Reed, 2011a)	0	10	0
8) OF NEF	Oriented feeling	3	O	How oriented Pu feels at ML visit (Orion et al., 1997b)	0	60	0
9) CurS NEF	Curiosity state	5	O	How curious Pu feels at ML visit (Litman & Spielberger, 2003; Naylor, 2007)	0	80	0
10) CL NEF	Cognitive load	4	O	How much workload Pu experiences at ML visit (Hart & Staveland, 1988)	0	80	0
11) VidNo	Intervention strength	6	N	Number of novelty-reducing videos Pu watched before ML visit	0	0	20
12) Know NEF	Knowledge	4/2/5	N	Pu pre-visit score on test about electromagnetic concepts (Schütz 2009; Barder 2007)	40	0	40
13) RA	Reality/ authenticity	6	O	How closely Pu thought their ML experience related to everyday life (Jochen Kuhn et al., 2008)	0	0	120
Dependent Variables							
14) Tint	Interest in technology	7	O	Pu dispositional interest in technology, from Pawek (2009)	120	0	120
15) Sint	Interest in natural science	7	O	Pu dispositional interest in natural science, from Pawek (2009)	120	0	120
16) Tatt	Attitude to technology	5	O	Pu attitude towards technology, from PISA (2006)	100	0	100
17) Satt	Attitude to natural science	5	O	Pu attitude towards natural science, from PISA (2006)	100	0	100
18) Tsc	Self-concept to technology	8	O	Pu self-concept to high-technology, from Pawek (2009)	160	0	160
19) Ssc	Self-concept to. natural science	8	O	Pu self-concept to natural science, from Pawek (2009)	160	0	160
20) CA	Career aspiration	1	O	Pu career aspiration with respect to S&T (Güdel, 2014, p. 306)	20	0	20
21) PSat	Program satisfaction	3	O	Pu satisfaction with ML visit, from Rennie (1994, p. 266)	0	0	60
Control Variables					0	0	0
22) Gen	Gender	1	N	Pu Gender	10	0	0
23) SY	School year	1	N	Pu school year	20	0	0
24) ST	School track	1	N	Pu school track (General versus Vocational)	20	0	0
25) HT_IC	Internet technology at home	4	O	Information & communication technologies at pupil's home, from OECD (2006)	60	0	0
26) HT_Mech	Mechanical technology at home	2	O	Mechanical technologies at pupil's home, from OECD (2006)	60	0	0
27) HL	Home language	1	N	Language spoken most often by pupil at home, from OECD (2006)	20	0	0
28) EXP_G	Experiment in small groups	1	O	How often pupil experiments in small groups in their classroom, from Engel (2004)	20	0	0
29) EXP_T	Observe teacher experiments	1	O	How often pupil observes experiments conducted by their teacher, from Engel (2004)	20	0	0

NIF = Novelty Influence Factor; NEF= Novelty Experience Factor.

Influences and (co-)relations

A test kit for science education / outreach: a collaborative R&D project

III.

- affective and cognitive dimensions
- two realms of application and collaboration:
  - science education, schools
  - science outreach, SOLs
- growing set of tests (eng/fr/ger)
  contact: Florian.Stern@unige.ch

Liste | Trier par sujet

type	Thématique	mots-clé	Nom original
compréhension	Mécanique - forces	mécanique forces cinématique	Force concept inventc
compréhension	Mécanique - concepts de base (I)	mécanique forces cinématique	Inventory of Basic Cor
compréhension	Mécanique - concepts de base (II)	mécanique forces moment énergie	Mechanics Baseline Te
compréhension	Cinématique - graphes	cinématique graphes	Test of Understanding
compréhension	Cinématique rotationnelle	cinématique	Rotational Kinematics
compréhension	Électricité - concepts de base	électricité magnétisme	Inventory of Basic Cor
attitudes / croyances	Attitudes envers la science	attitudes sciences	Colorado Learning Att
attitudes / croyances	Attitudes envers la résolution de	attitudes résolution de problème	Attitudes and Approa

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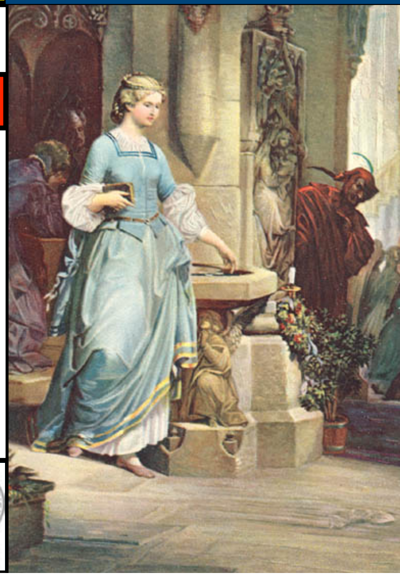
Die Gretchenfrage

III.



Sag mir, was bringt es für das Lernen?
(Tell me, what about learning?)

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SOL Learning effects

- iPhysics Lab, Kaiserslautern (A. Molz, 2016)
  - Sec I: hydrostatic pressure; ≈ 180 min, n = 190
    conceptual learning: very large gain pre-post (*d* = 2.3)
  - Sec II: radioactivity; n = 80
  - conceptual learning: very large gain pre-post (*d* = 2.2) and pre-follow up (*d* = 1.7)
- S'Cool LAB, CERN (J. Woithe, 2020)
  - Sec II: fields, particles, radiation; ≈ 180 min n = 453
  - conceptual learning: medium – large effect (*d* =.74)
- Learning in SOLs:
  - measurement is possible!
  - very encouraging effects!

Conceptual difficulty

Drinking straw: "sucking vacuum" vs. atmospheric pressure difference
Forces on a stone (or similar object) in water
Archimedes principle and difficulties related to it
Connection of buoyancy and hydrostatic pressure

After a sports accident the foot of a patient is X-rayed to check whether there are bone fractures. Is it dangerous for the patient's family to be in the vicinity of her immediately after the X-ray scan?

Molz, Kuhn, AM (2022). Effectiveness of science outreach labs ….
Phys. Rev. Physics Education Research, 18(2), 020144
Woithe, AM, Schmeling, Kuhn (2022). Motivational outcomes of the science outreach lab S'Cool LAB…
Journal of Research in Science Teaching, https://doi.org/10.1002/tea.21748

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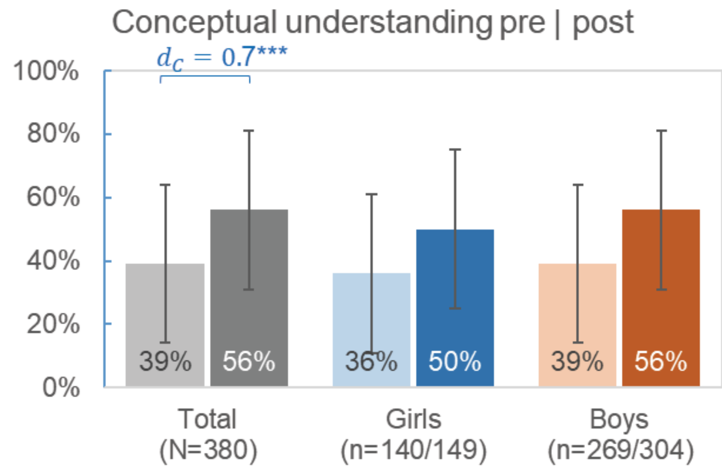
(Conceptual) learning

III.



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Woithe, AM, Schmeling, Kuhn (2022). Motivational outcomes of the science outreach lab S'Cool LAB…, Journal of Research in Science Teaching,

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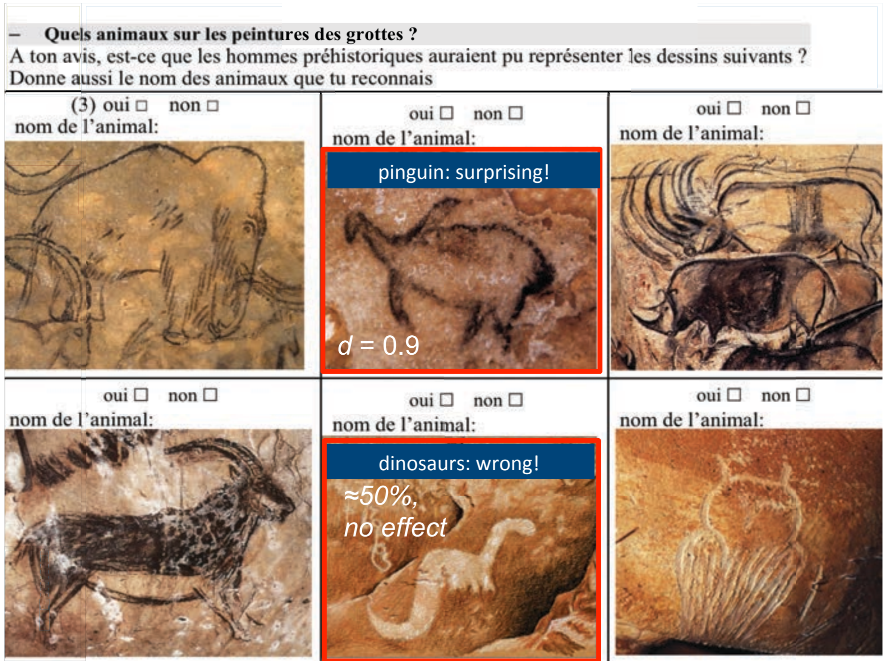
SOL Learning effects: two complementary examples

- Valentina & Léo (SNF Agora, PI M. Besse, 2013 - 2015)
  - primary school: archaeology/prehistory; ≈ 90-120 min, n = 441
  - ***science & humanities***



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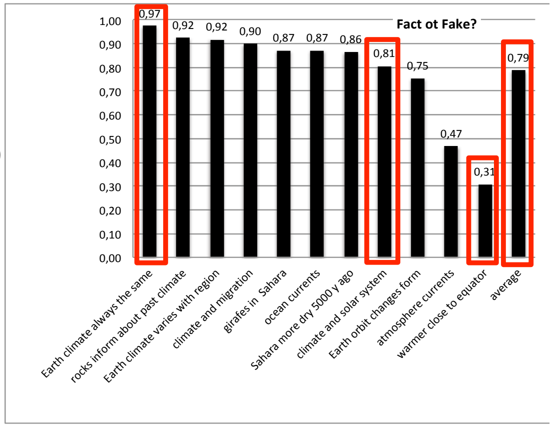
SOL Learning effects: two complementary examples

- Valentina & Léo (SNF Agora, PI M. Besse, 2013 - 2015)
  - primary school: archaeology/prehistory; ≈ 90-120 min, n = 441
  - ***science & humanities***
  - conceptual learning & basic knowledge: medium – large gains pre-post (d = 0.5 – 0.9)

Besse, Fragnière, AM, … (2019). Learning About Archaeology and Prehistoric Life. Science & Education, 28(6-7), 759-795.

- ClimatiZENs (SNF Agora, PI S. Castelltort, 2019-2024)
  - sec I: ***sustainability,*** n= 119
  - conceptual learning (climate change, climate research, …)
  - short questionnaire on key issues
  - Earth climate invariable, astronomic influences,…



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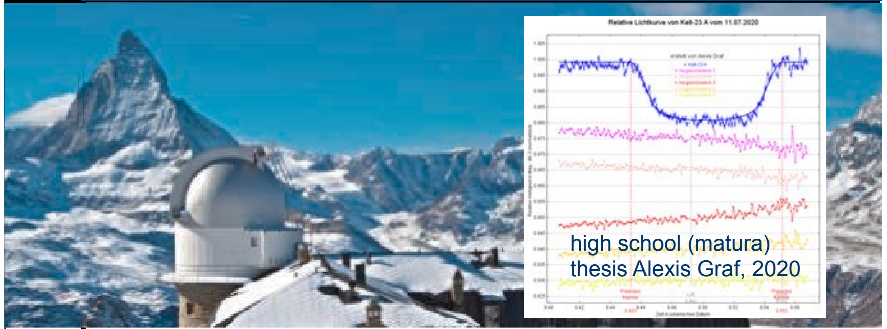
Stellarium Gornergrat A remote / open access SOL



- A remote controlled observatory for educational purposes
- open access, ready-made learning modules
- five instruments, unprecedented opportunities
- https://stellarium-gornergrat.ch/?lang=fr
  Jean-David.Picon@unige.ch

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Influences and (co-)relations, success factors

IV.

I. Introduction
II. Emotions, Motivation, Interest
III. Understanding and Learning
IV. Influences and (co-)relations, success factors
  - gender: closing the gender gap
  - tutors
  - curriculum links
  - cognitive load,
  - differentiation, heterogenity
  - novelty space theory
  - …
V. summary and Outlook

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Influences and (co-)relations: Tutors

IV.

- situational interest (given SOL event)
  - S'Cool LAB / CERN (J. Woithe, 2020)
  - N = 535, 13 countries
- strongest factor: perceived support by tutors
- what exactly does the support consist in?
  - Delta X (F. Simon, 2019)
  - N = 1466

- strongest positive tutor influences:
  - support for experience of competence
  - cognitive activation*
  - clarity
  - even effects on physics interest (rather stable trait)

  … publication in preparation

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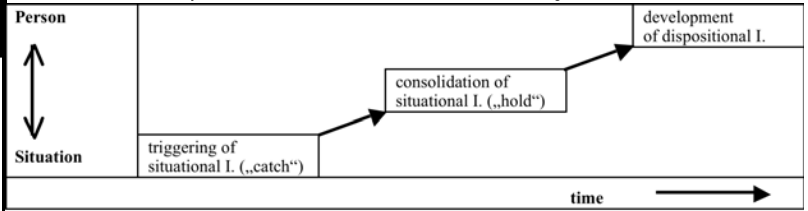
Person-Object (Situation) Theory of Interest Development

IV.

2 dimensions: time, locus of process
(a „coordinate system“ for the development of long-term interest)



- **situational**
  - „catch“ factors: fun, curiosity, surprise, fascination
  - „hold“ factors: meaningful, relevant for current aims and values
- **dispositional (personal)**
  - cognitive factors (see above)
  - affective factors (“basic needs”, Deci & Ryan); feeling of
  1) competence (self-confidence)
  2) autonomy (self-determination)
  3) social relatedness (families, peer groups)

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Importance of classroom links (preparation / follow-up work)

IV.

strong vs. weak (no) links

- **interest for experiments** (“catch”):
  d = 0.65 (medium effect, Glowinsky (2007), bio)
- **interest, div. facets**, in particular emotional components
  d = 0.79 (medium-large effect; Streller (2015), phy)
- **self concept** (“hold”):
  d = 0.47 (small/medium effect, [Paw09, phy])
- **learning**:
  - *d* = 0.57 (medium effect, [WB06, bio], in particular for open questions
  - *d* = 0.82 (large effect, Molz (2016), Sec I : atmospheric pressure)
  - *d* = 1.06 (großer Effekt, Molz (2016), Sec II: radioactivity)

  note: does NOT prevent positive effects on motivational variables
- **importance for teachers**

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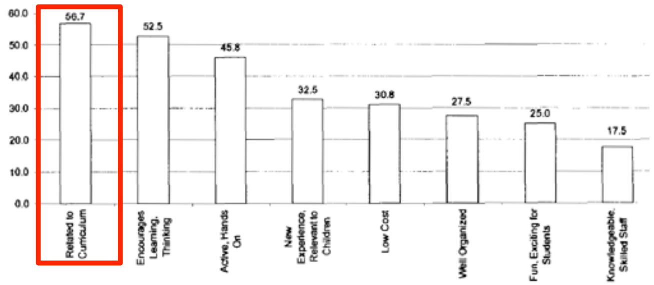
Importance of curriculum links: The voice of the field experts

IV.

- “field trips” in general [Har05; characteristics of an ideal field trip]
  frequency of factors stated by teachers
  1st : related to curriculum, 2nd: encourages learning & thinking, 3rd: hands on



- science in particular (frequencies):
  curriculum links: 90% [Kie05], companion material: 90% [Eul09]

“[…] teachers’ perceptions about curriculum fit and pre- and post-visit activities emerge as the most frequently cited factors to impact the development of disciplinary specific knowledge from field trips.”
[ES05; National Academies of Sciences’ Committee on Science Learning]

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Importance of curriculum links

IV.

An obvious field of action !

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Influences, Relations

RESEARCH ARTICLE

JRST | WILEY

Motivational outcomes of the science outreach lab S'Cool LAB at CERN: A multilevel analysis

Julia Woithe[1] | Andreas Müller[2] | Sascha Schmeling[1] |

- broad sample: 509 high-school students from 13 countries
- dependent variables: situational interest and self-concept
- systematic study of 13 predictors based on prior research
- only significant:
  - prior values,
  - perceived quality of support (tutor, “tinkering”)
- almost 60% of variance explained!

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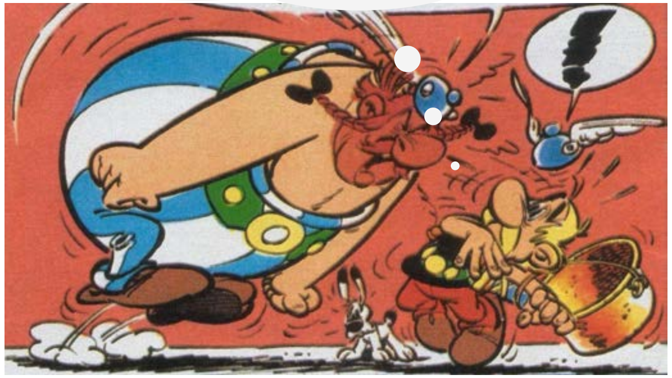
IV. Summary and Outlook

V.

And the message?
What´s the message, hä ??!



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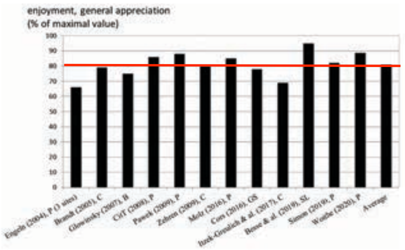
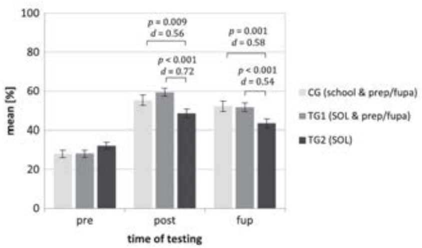
Hello to some good news: Why OSLEOs ?

considerable effects on motivation
\+ in particular for girls and less interested pupils
\+ content learning as in (very) good regular teaching
\+ learning *about* science
\+ contact with scientists / research institutions
\+ widening the horizon
\+ research-based improvement and further development
= large potential for science education





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Goodbye to some Illusions

III.

emotional effects
↓ *no automatic link*
→ important: tutor support!
motivational effects
↓ *weak link (r = 0.3 – 0.4)*
→ important: connection to school!
learning effects

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Recommendations, perspectives

- dare to evaluate your SOL!
  - consider also learning, no „Science Disney“
  - evidence based justification and improvement
- close collaboration science outreach – science education
  - evaluation methods (instruments, analysis, …)
  - research-based design of SOL offers
  - classroom / curriculum links
- interdisciplinary topics
  - sustainability goals
  - STEAM: aesthetical and cultural aspects
- Astro, Nano, …

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Acknowledgments: co-operations, projects, theses

- AGORA/SNF funding scheme, other funding agencies
  - Stellarium Gornergat I, II, III: A remote-controlled observatory for educational purposes (2012 -)
  - Valentina & Leo:Learning about archaeology and prehistoric life (2013 - 2015)
  - Green Breath Box: Insights into biogeochemical cycles, environment, and sustainability (2019 -)
  - Climatizens: Past climates for future citizens (2020 - 2024)
- PhD theses
  - Alexander Molz, iPhyscisLab, TU Kaiserslautern (2016)
  - Rebecca Cors, MobiLLab, PH St. Gallen (2016)
  - Florian Simon, DeltaX, HZDR (2019)
  - Julia Woithe, ScoolLAB, CERN (2020)

FNSNF Fonds national suisse Schweizerischer Nationalfonds Fondo nazionale svizzero Swiss National Science Foundation

swissuniversities

Stifterverband Bildung. Wissenschaft. Innovation.

Wilfried-und-Ingrid-Kuhn-Stiftung für Physikdidaktik

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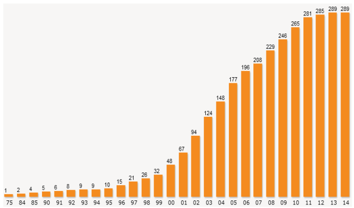
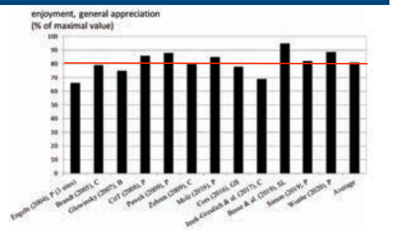
III.

Out-of-school learning opportunities/offers (OSLOs) Science Outreach Labs (SOLs): Scientific evidence





Looking forward to the discussion

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