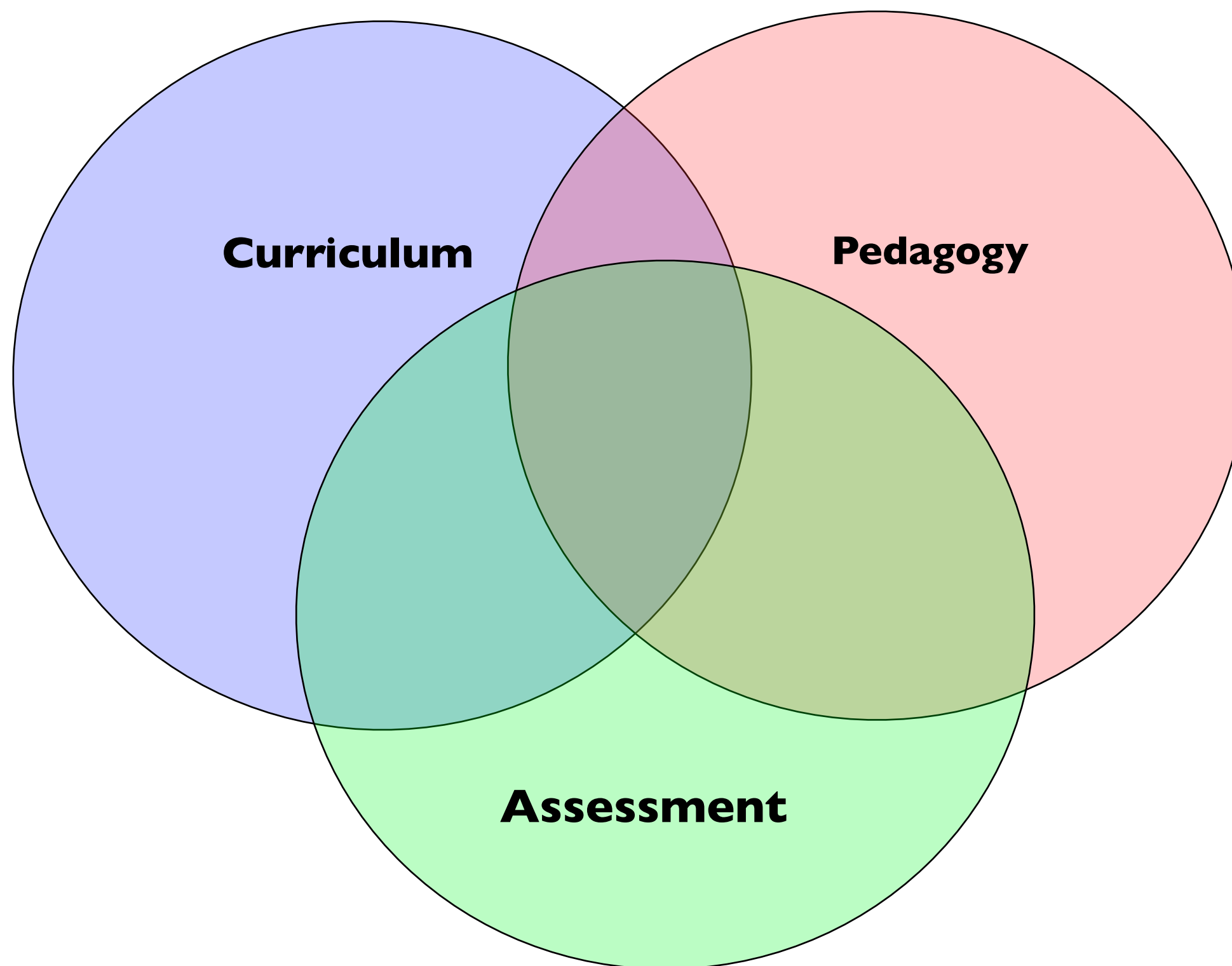




The Argument for Argument in Science and Math Education

Jonathan Osborne

Teaching and Learning

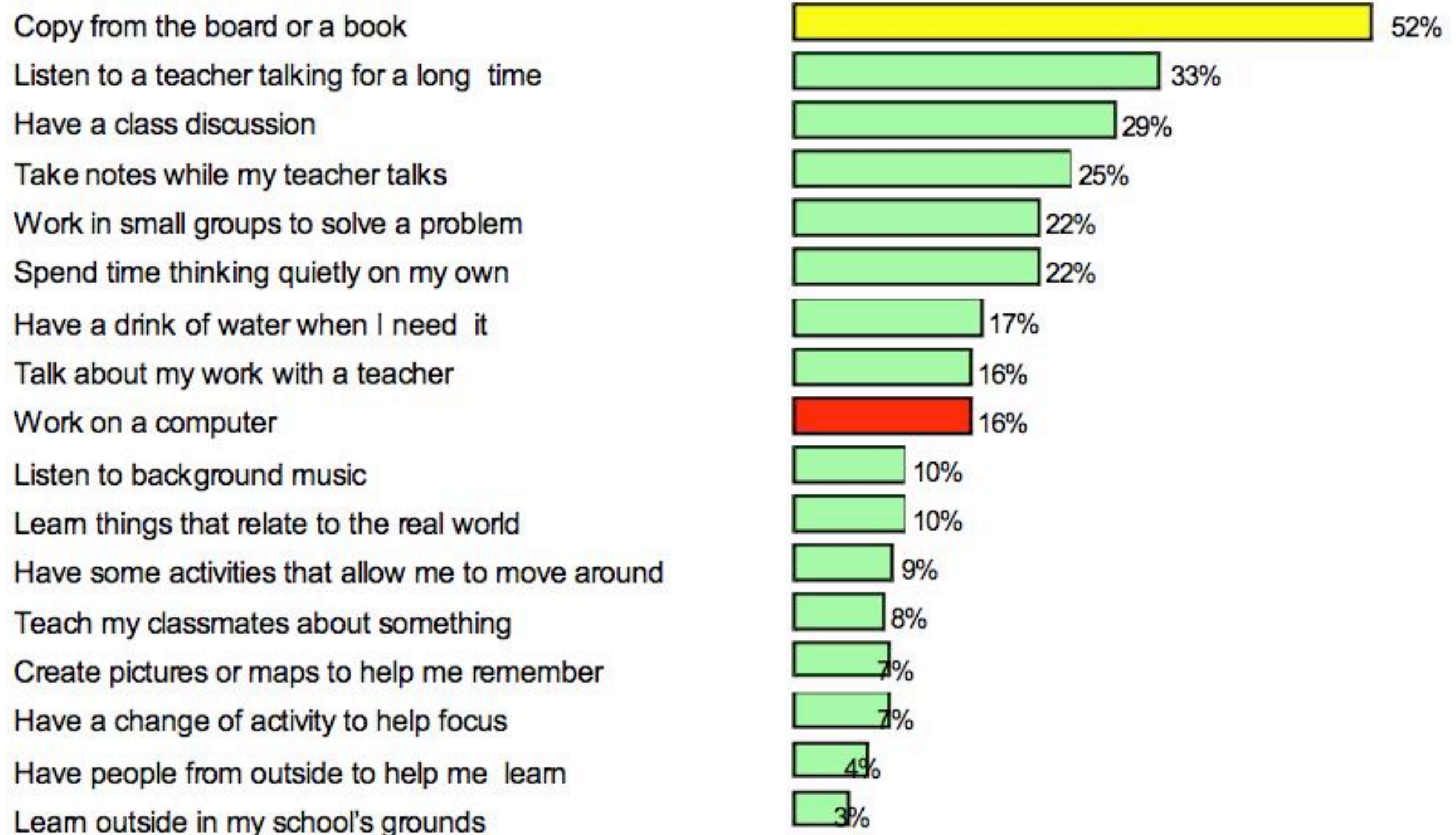


A Vision of Science Education

- Science and Maths education needs to do more than simply explaining *what* we know. As important is an understanding of *how* we know, *why* that particular understanding of the world matters and *how* it came to be.
- Transcend the default pedagogy of teaching – one of transmission.

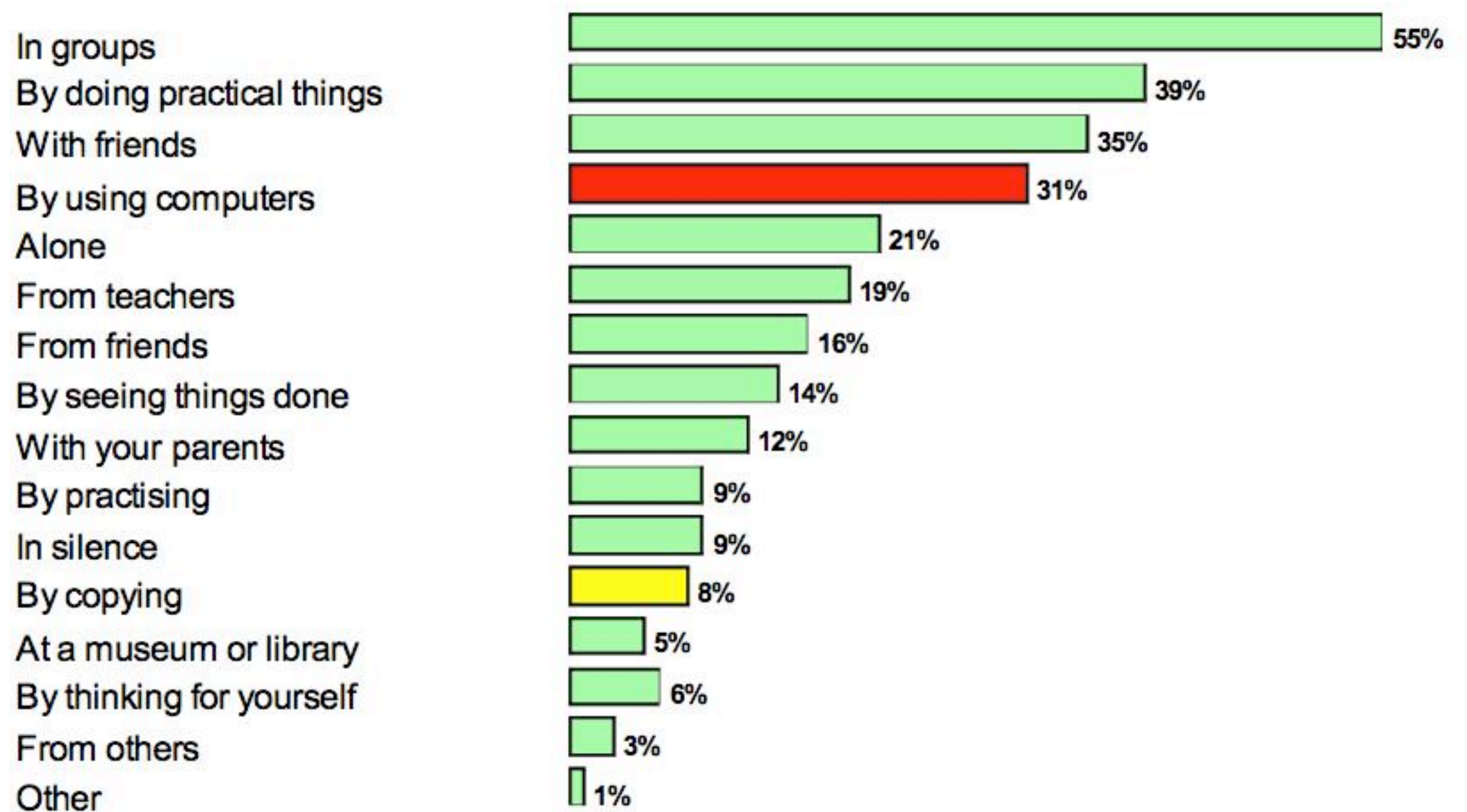
Common classroom activities

Which three of the following do you do most often in class?



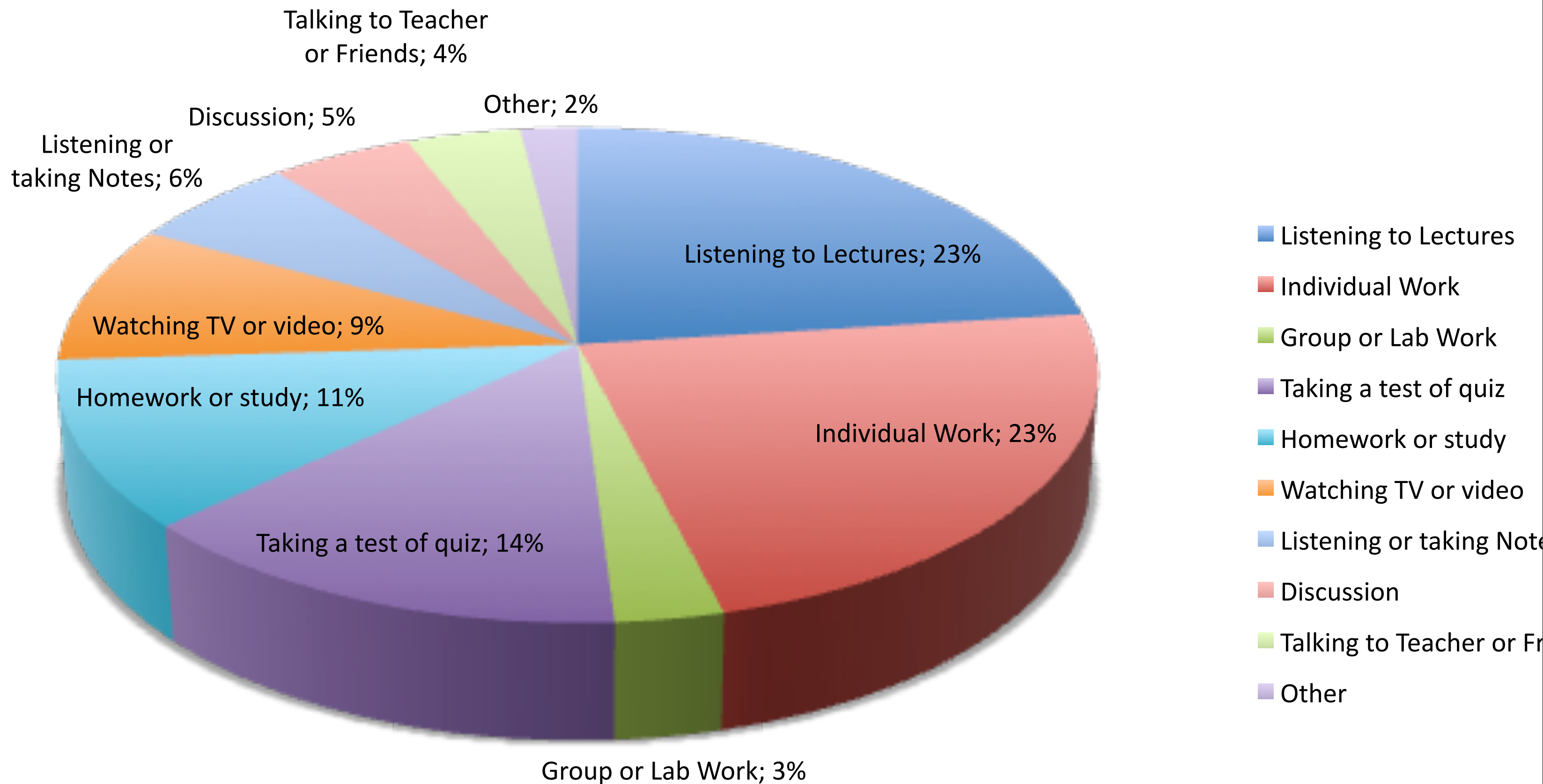
Most preferred ways to learn

Which three of the following ways do you prefer to learn?



Source IPSOS Mori
Base: All pupils (2,417)

How do Students spend their time in class?



Csikszentmihalyi, M., & Schneider, B. (2000). *Becoming Adult: Preparing Teenagers for the World of Work*. New York: Basic Books.

The Lack of Discussion

This morning we were talking about genetic engineering. [The teacher] didn't want to know our opinions and I don't reckon that the curriculum lets them let us discuss it further.

A lot of the work was just copying, just notes, there wasn't a lot of opportunity for discussion or anything like that. That's what has been good about this year there's been a lot of talking and discussion.

School Science v Contemporary Science

The blast furnace, so when are you going to use a blast furnace? I mean, why do you need to know about it? You're not going to come across it ever. I mean look at the technology today, we've gone onto cloning, I mean it's a bit away off from the blast furnace now, so why do you need to know it?

The Overcrowded Curriculum

Holly: If you, like, give suggestions they just ignore it and go 'No it's written in the syllabus that you've got to do this', and it's just kind of fixed upon the syllabus and you're like, 'Well can't we find a gap for it?' And they're like, 'No.'

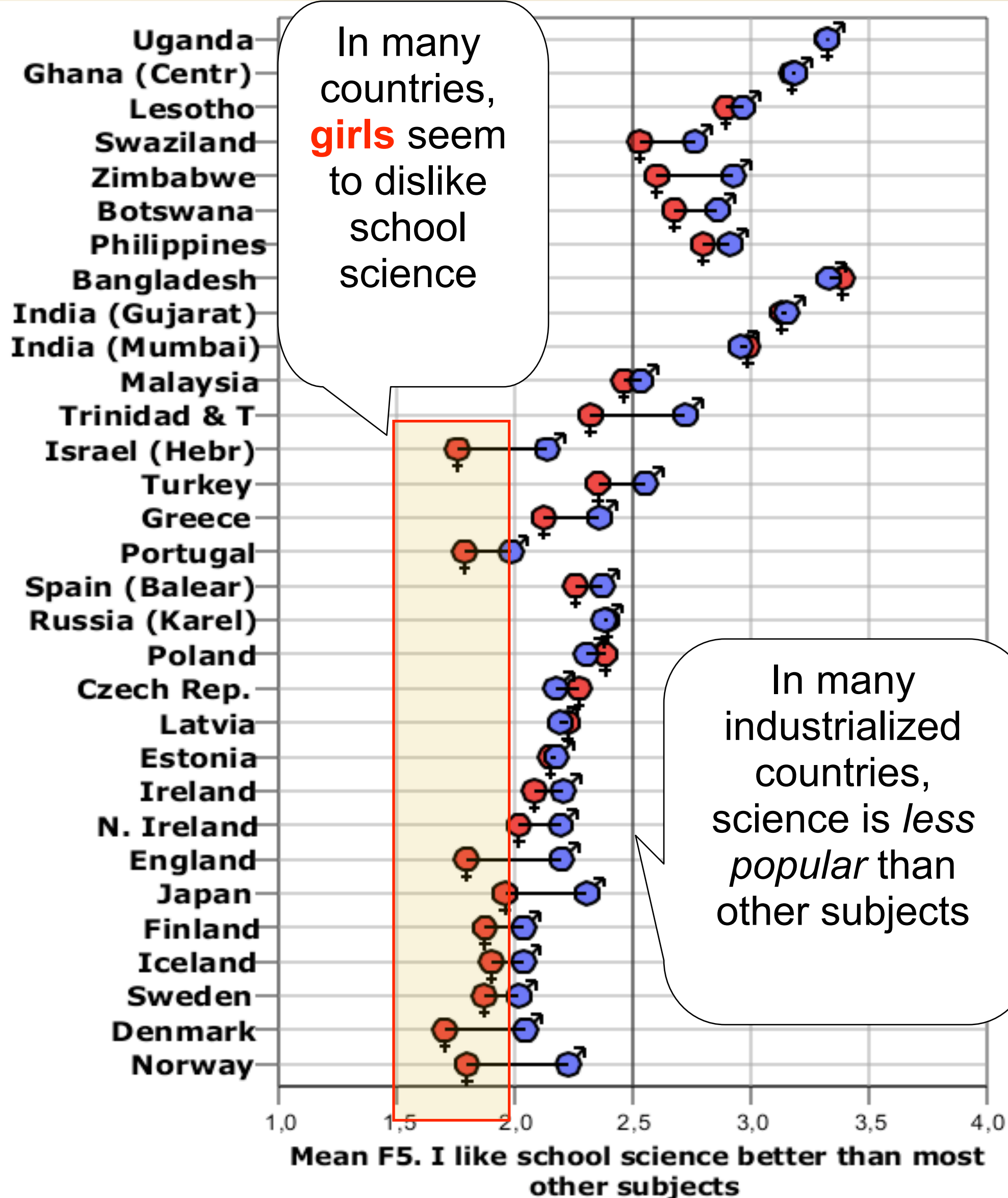
Alice: And some of our teachers just completely rush us off our feet, I mean not mentioning any names, they take you completely off your feet.

We learnt all these amazing things in year 7 that we'd never heard of before, like molecules and atoms and electrons. I don't know about you guys but I got really excited about it, I rushed home and told my mum about it.

And then in year 9, we're doing the same thing, year 10, doing the same thing, year 11, doing the same thing..... and it's so repetitive.



I like school science better than most other school subjects



What would you like to learn about?

- 108 Items
- No less than 80 generated statistically significant differences between girls and boys

Boys

1. Explosive Chemicals
2. How it feels to be weightless in space
3. How the atomic bomb functions
4. Biological and Chemical Weapons and what they do to the human body
5. Black holes, supernovae and other spectacular objects in space

Girls

1. Why we dream when we are sleeping and what the dreams may mean
2. Cancer, what we know and how we can treat it
3. How best to perform first-aid and use basic medical equipment
4. How to exercise to keep the body fit and strong
5. Sexually transmitted diseases and how to be protected against them.

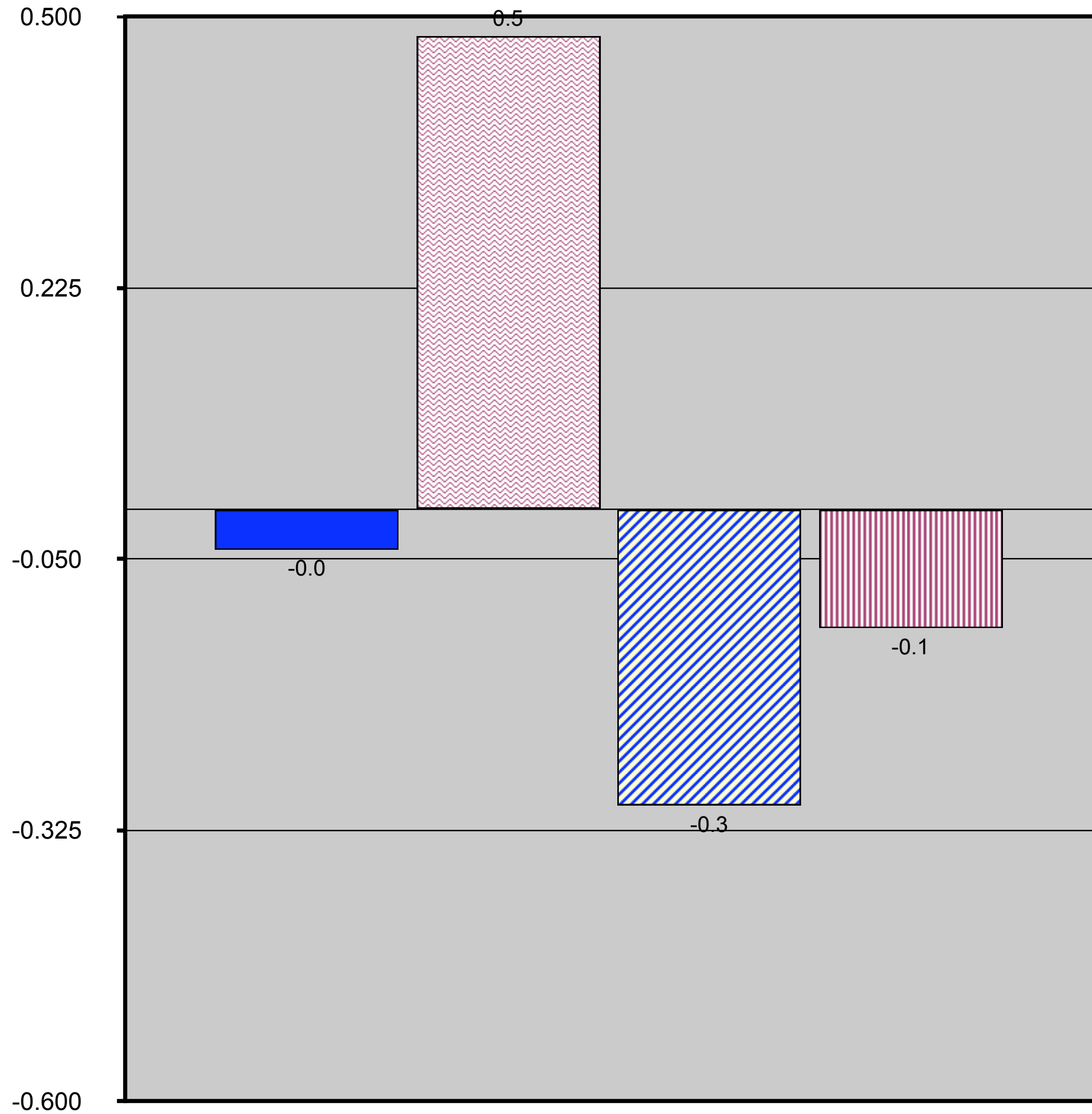
Four patterns or clusters of values emerged from Factor analysis

- Trust in the benefits of science
- Science in my life
- Ethical scepticism
- Facts And Hi-Tech Fixes

Science In My Life

**Positive
Factor
Scores**

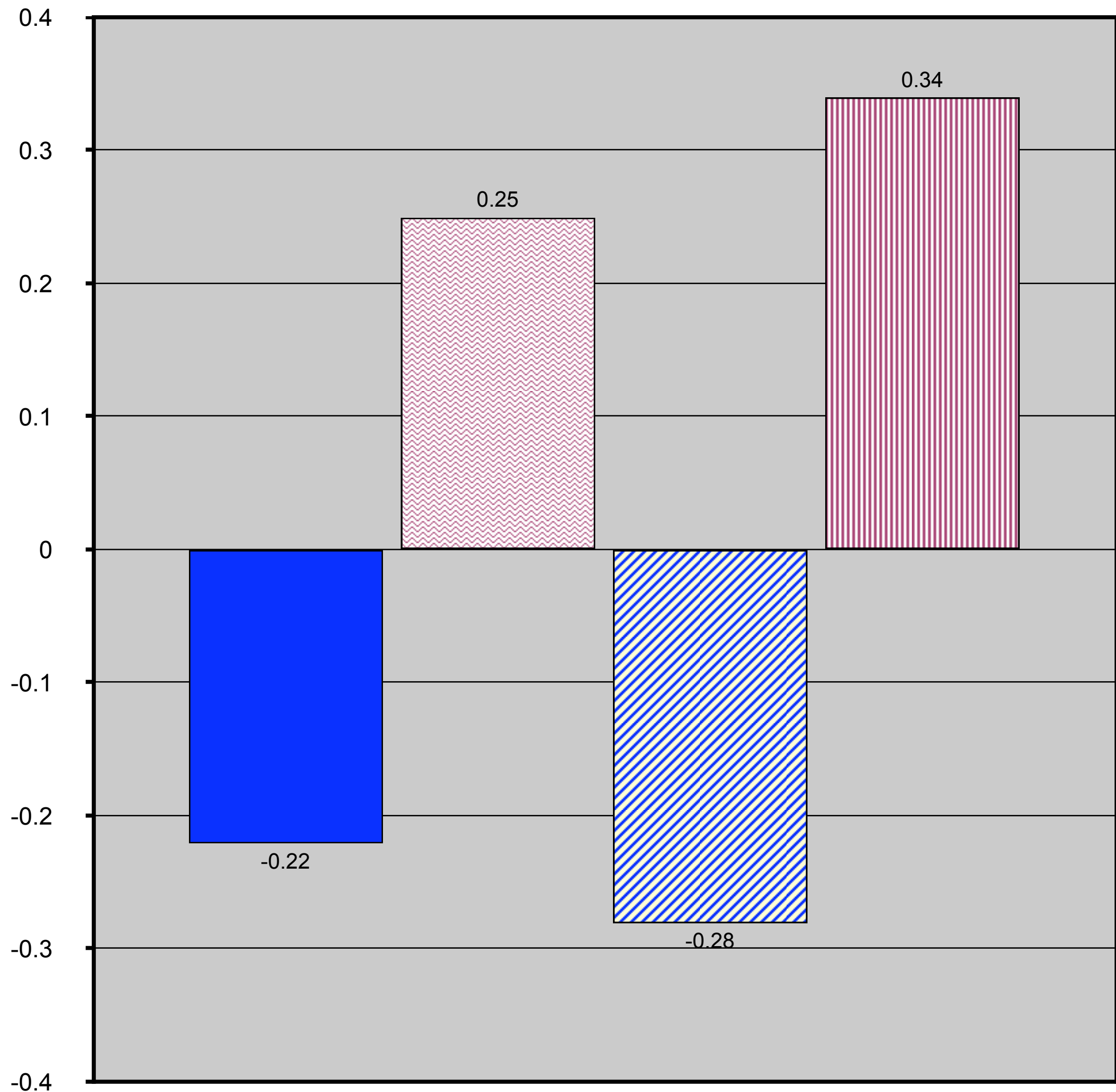
**Negative
Factor
Scores**



Ethical Scepticism

**Positive
Factor
Scores**

**Negative
Factor
Scores**



Traditional Vision of Science Education

- Body of Received Knowledge
 - ❖ Unequivocal
 - ❖ Uncontested
 - ❖ Unquestioned
- Authoritative
 - ❖ Grounds for accepting knowledge claims are no different from the Young African villager's grounds.
 - ❖ Essentially a pre-Enlightenment practice
 - ❖ Last surviving authoritarian socio-intellectual systems in Education

- Science Education as an ***Education***
 - ❖ Science as a Way of Knowing
 - ❖ Conceptual Coherence

Versus

- Science Education as a Pre-Professional ***Training***
 - ❖ Authoritarian
 - ❖ Foundationalist
 - ❖ Atomised
 - ❖ Lacking coherence

The Distinguishing Feature of Science?

‘The rationality of science is secured by its commitment to evidence; the fostering of a commitment to evidence is a fundamental educational aim. Science's rationality thus makes it particularly well suited to the general task of education, and science education can, and should be seen as a central component of an education dedicated to the fostering of rationality and critical thinking.’

Siegel, H. (1989). The Rationality of Science, Critical Thinking and Science Education. *Synthese*, 80(1), 9-42.

- **Platonic:** The existence of mathematical objects is an objective fact. Infinite sets, uncountably infinite sets, infinite-dimensional manifolds, space-filling curves – all the members of the mathematical zoo are definite objects, with definite properties, some known, many unknown.
- **Formal/Axiomatic:** Math is a self-consistent set of axioms
- **Socio-Cultural Artefact:** Constructed within the culture of mathematics

The Goal of Science and Math Education?

- Depth rather than Breadth
- Coherence rather than Fragmentation
- Insight rather than Mystification

Beyond 2000
science education
for the future

Beyond 2000 2001

a report with
ten recommendations

To borrow an architectural metaphor, it is impossible to see the whole building if we focus too closely on the individual bricks. Yet, without a change of focus, it is impossible to see whether you are looking at St Paul's Cathedral or a pile of bricks, or to appreciate what it is that makes St Paul's one the world's great churches. In the same way, an over concentration on the detailed content of science may prevent students appreciating why Dalton's ideas about atoms, or Darwin's ideas about natural selection, are among the most powerful and significant pieces of knowledge we possess.

The Elements of a Science or Math Education

- **Conceptual**
 - ❖ Developing Knowledge is an Interactive Process
- The **Epistemic** and **Social Practices** of Science/
Mathematics
- **Cognitive**
 - ❖ Goal of developing intellectual autonomy
 - ❖ Value as a pedagogic heuristic
- The **Affective** and the **Social**

What is Argument?

'Argumentation is verbal, social and rational activity aimed at convincing a reasonable critic of the acceptability of a standpoint by putting forward a constellation of propositions justifying or refuting the proposition expressed in the standpoint.'

IDEAS



Ideas, Evidence and Argument in Science (IDEAS) Project
funded by the Nuffield Foundation, London, 2003

Video based in-service training materials for training teachers to teach ideas, evidence and argument in KS3 science classrooms. The pack is intended for KS3 science teachers, consultants, advanced skills teachers, head-teachers, university teacher educators.

In-Service Training Pack

- Session 1: Introducing Argument
- Session 2: Small Group Discussions
- Session 3: Teaching Argument
- Session 4: Resources for Argumentation
- Session 5: Evaluating Argument
- Session 6: Modelling Argument

Resources Manual - Lesson activities

Professor Jonathan Osborne, King's College London
Dr Sibel Erduran, King's College London
Dr Shirley Simon, Institute of Education

IDEAS

Ideas, Evidence and Argument in Science (IDEAS) Project

Video



I. The Conceptual Value of Argumentation

- Past decade a body of work has emerged exploring the teaching of ideas, evidence and argument.
- Leads to enhanced conceptual understanding
 - ❖ Alverman and Hynd - refutational text
 - ❖ Zohar and Nemet

‘integrating explicit teaching of argumentation into the teaching of dilemmas in human genetics enhances performance in both biological knowledge and argumentation’

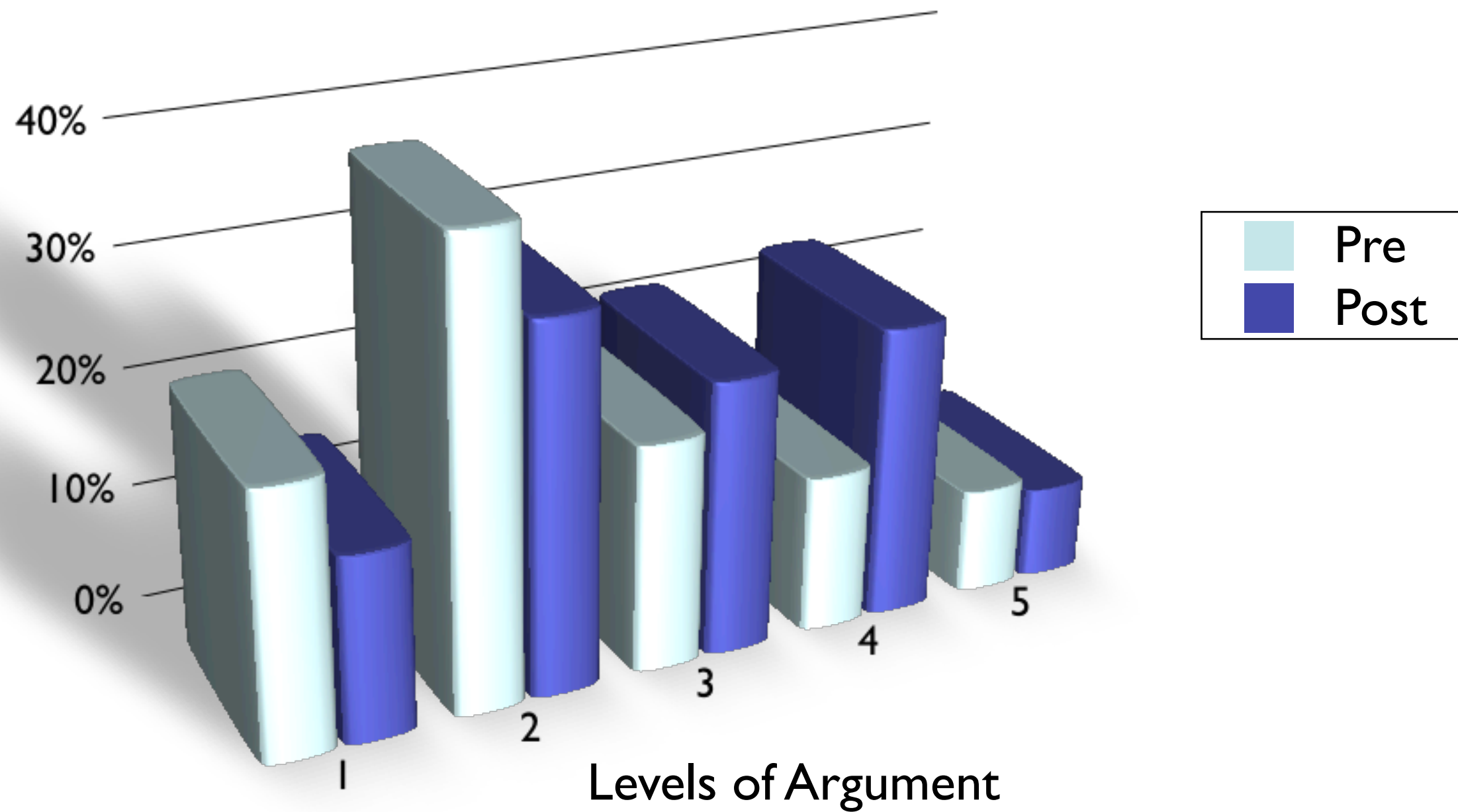
Mercer at al. Indicator words used by pupils

<i>Word</i>	<i>Pre-intervention</i>	<i>Post-intervention</i>
because	13	50
I think	35	120
would	18	39
could	1	6
TOTALS	67	215

Mercer et al. Science concept mapping test

	Numbers	Score before	Score after
Target class	115	1.52	6.02
SD		1.46	3.36
Control classes	129	1.08	3.97
SD		1.47	2.76
Effect size		0.74	

Results: Osborne, Simon & Erduran



Psychological Evidence

Tolmie et al., 1993

Howe, Tolmie et al., 1995

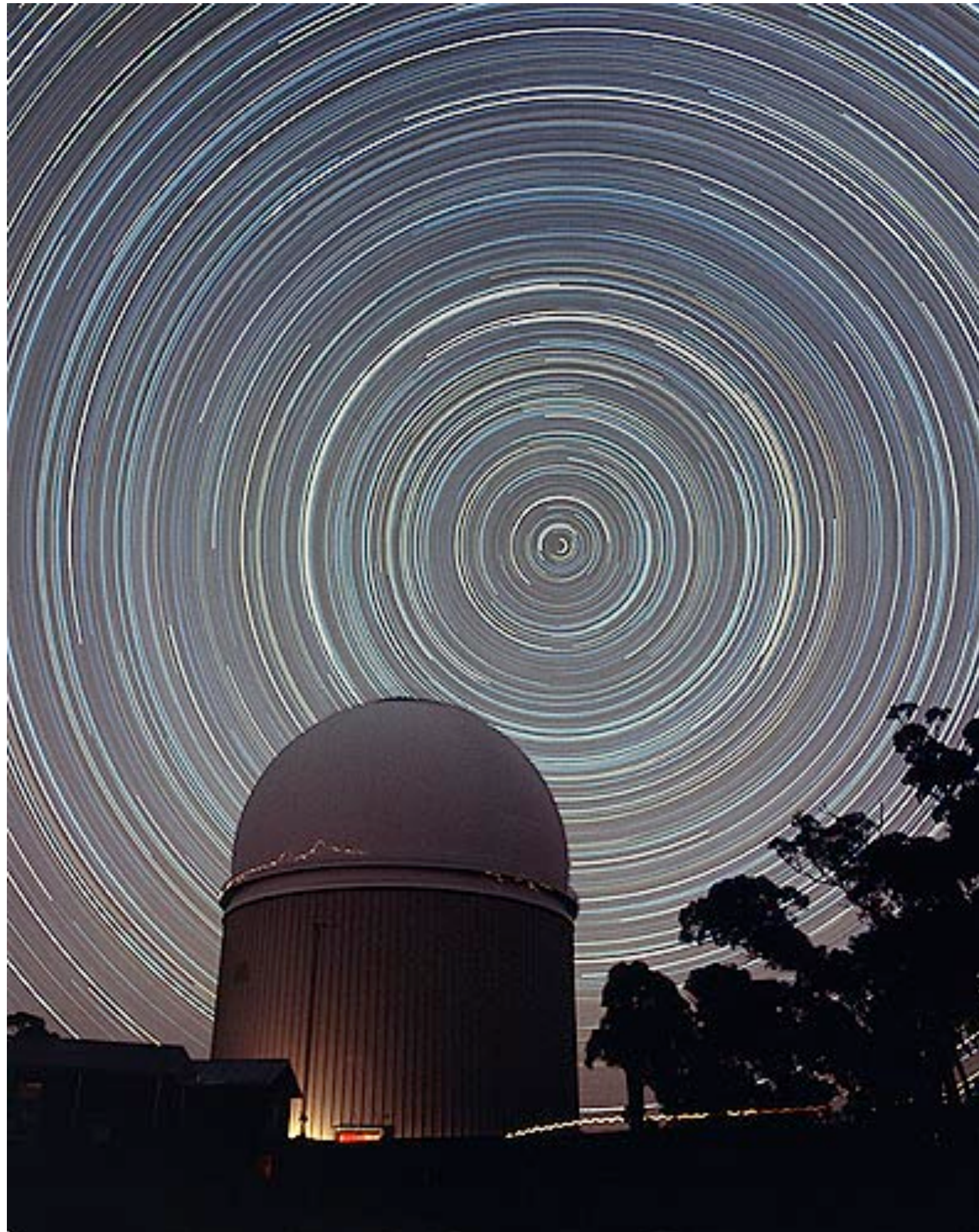
Howe et al., 2005

Argument 2: The Epistemic Case for Argument

- That Day and Night are caused by a spinning Earth
- Arguments Against:
 1. The Sun moves
 2. If you jumped up you would not land in the same spot
 3. If the Earth was spinning at that rate, the speed at the equator is over a 1000 mph and you should be flung off.
 4. There should be an enormous wind as the



Why we believe the Earth spins?



The Mathematical Argument

Why is $-2 \times -2 = +4$?

Because

$$-2 \times (-2 + 2) = -2 \times (0)$$

And since -2×0 must $= 0$ and $-2 \times +2 = -4$

Then -2×-2 must $= +4$ so that:





$$+4 - 4 = 0$$

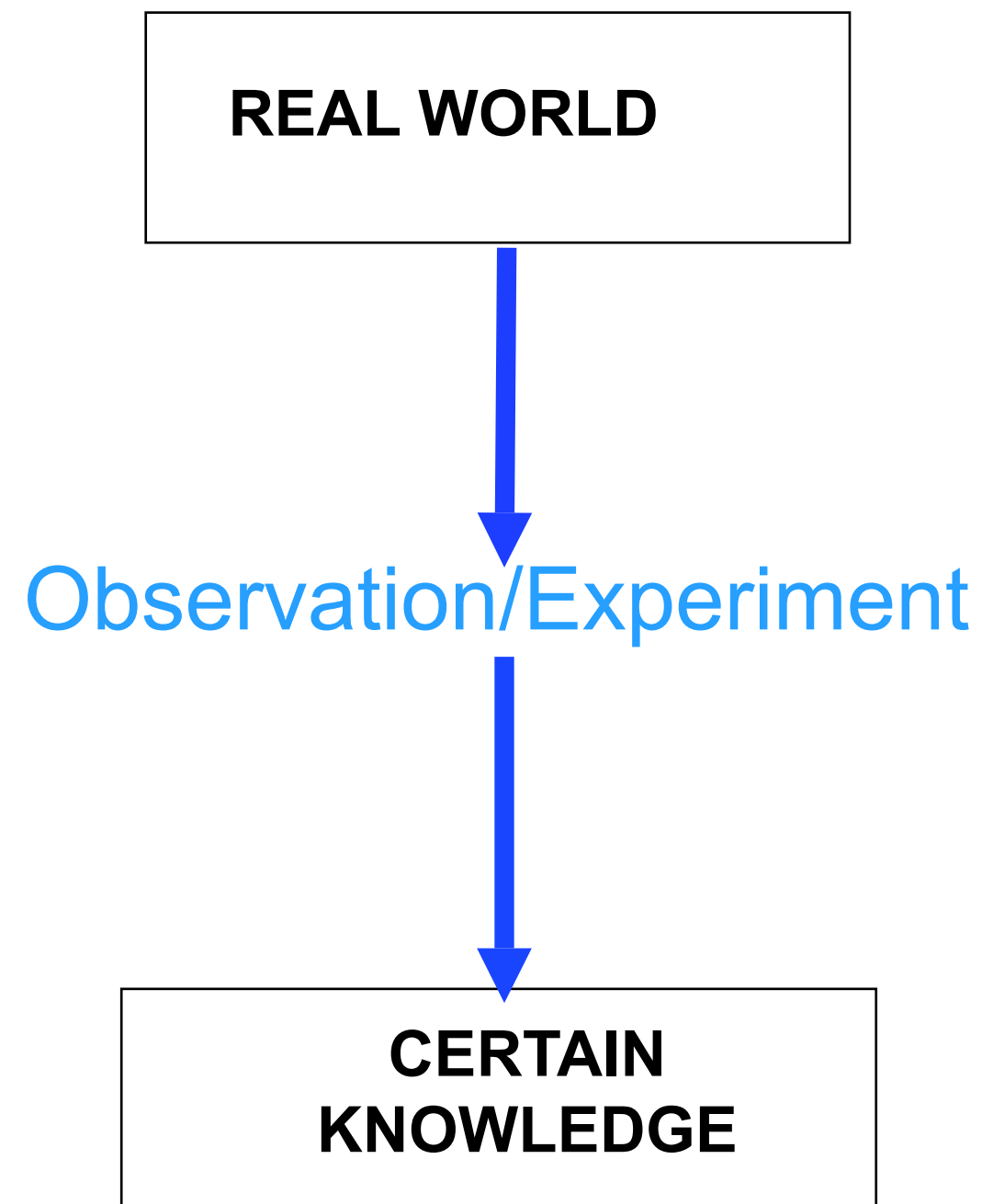
Argument in a Mathematical Context

Which one of these statements is true?

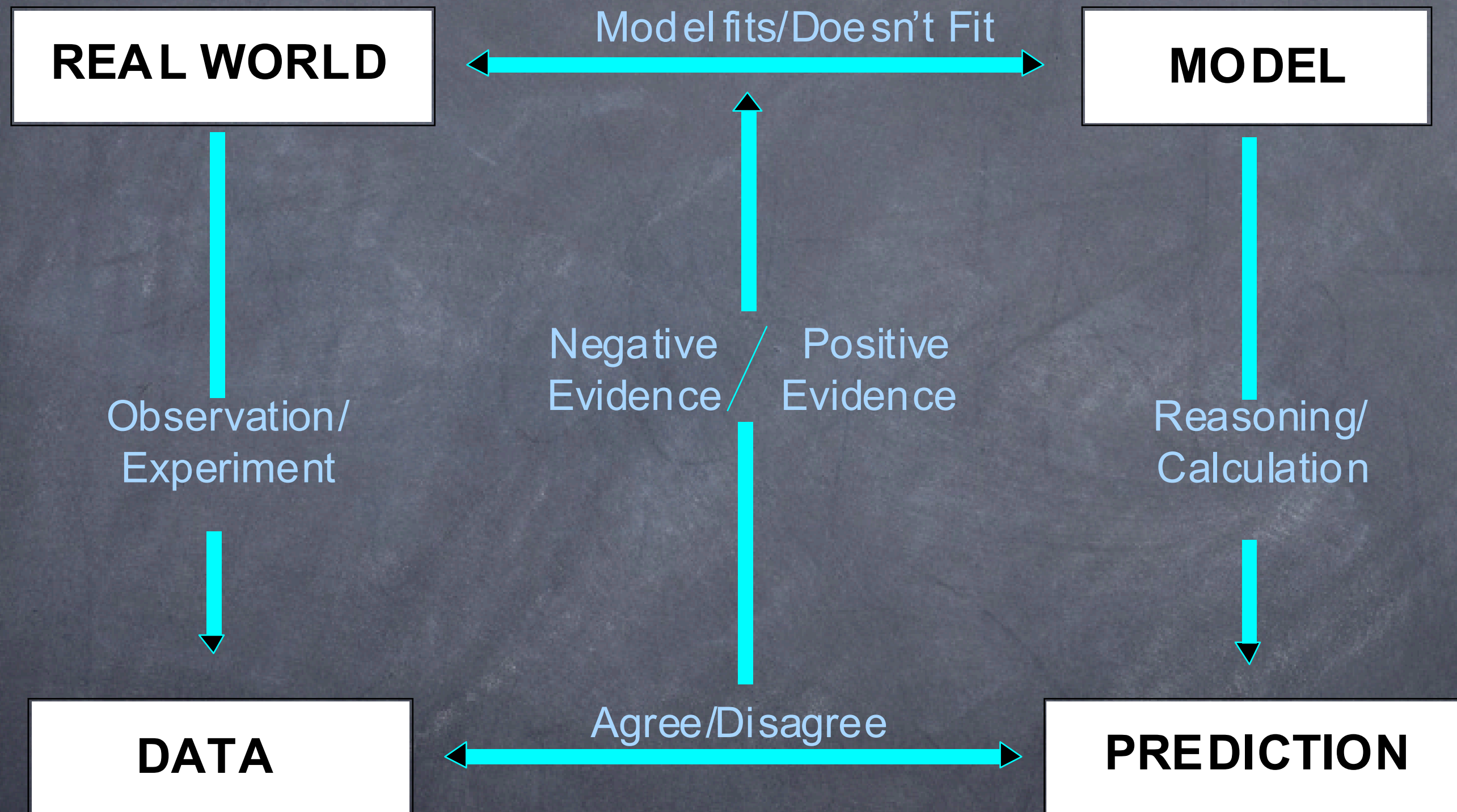
- A. 0.33 is bigger than $1/3$
- B. 0.33 is smaller than $1/3$
- C. 0.33 is equal to $1/3$
- D. You need more information to be sure

How do We Know?

-  That we live at the 'bottom of a sea of air?
-  That matter is conserved in a chemical reaction?
-  That plants take in carbon dioxide and give out oxygen
-  That you look like your parents because every cell carries a chemically coded message about how to replicate itself?



Driver, R., Leach, J., Millar, R., & Scott, P. (1996). *Young people's Images of Science*. Buckingham: Open University Press.



Giere, R. (1991). *Understanding Scientific Reasoning* (3rd ed.). Fort Worth, TX: Holt, Rinehart and Winston.

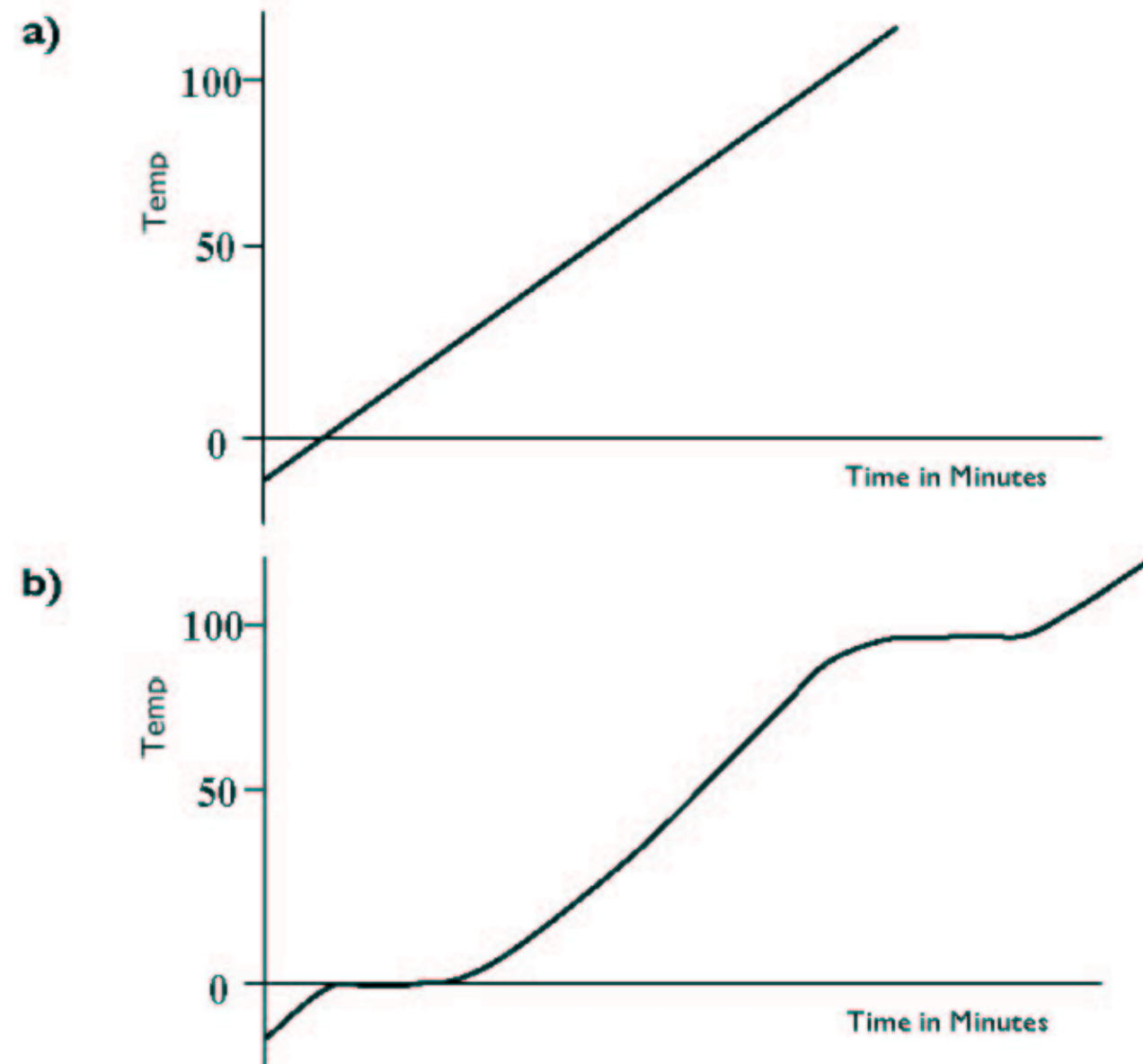
Heating Ice to Steam

Handout 1.4

Some year 8 students have been studying how water heats up

They had to predict the shape of the graph to show how the temperature would change as they heated ice to steam.

Below are two different graphs that they came up with.



In your groups discuss which graph is most likely to show how the temperature of water changes as it heats up. Your group must have at least **ONE** reason to support your argument.

Components of Argument Handout 1.5

Ice will melt when it is heated and turns into water.

In solids there are bonds between the particles that hold them together in fixed shape

When you heat a substance the supply of heat energy is usually constant

Energy is needed to break bonds between particles

Ice melts at 0°C and boils at 100°C

Whilst energy is being used to break bonds between particles then there will be no temperature change.

When substance are heated the particles in them absorb heat energy and move about more quickly.

Argument 3: The Moral Argument

To ask of other human beings that they accept and memorize what the science teacher says, without any concern for the meaning and justification of what is said, is to treat those human beings with disrespect and is to show insufficient care for their welfare. It treats them with a disrespect, because students exist on a moral par with their teachers, and therefore have a right to expect from their teachers reasons for what the teachers wish them to believe. It shows insufficient care for the welfare of students, because possessing beliefs that one is unable to justify is poor currency when one needs beliefs that can reliably guide action. (p. 252)

Norris, S. (1997). Intellectual Independence for Nonscientists and Other Content-Transcendent Goals of Science Education. *Science Education*, 81(2), 239-258.

Argument 4: Improved Satisfaction with Learning

- Nolen, S. B. (2003). Learning Environment, Motivation and Achievement in High School Science. *Journal of Research in Science Teaching*(40), 4.
- Osborne, J. F., Duschl, R., & Fairbrother, R. (2002). *Breaking the Mould: Teaching Science for Public Understanding*. London: Nuffield Foundation.

1. What is the relationship between conceptual knowledge and the quality of argumentation?
2. How do we assess students' ability at argument and argumentation?
3. How do we support, develop teacher's use of argumentation as a pedagogic practice?

The IDEAS Pack

1. Introducing Argument
 2. Managing Small Group Discussion
 3. Teaching Argumentation
 4. Resources for Argumentation
 5. Evaluating Argument
 6. Modelling Argument
- & 28 Video Clips



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- <http://www.kcl.ac.uk/schools/sspp/education/research/projects/ideas.html>