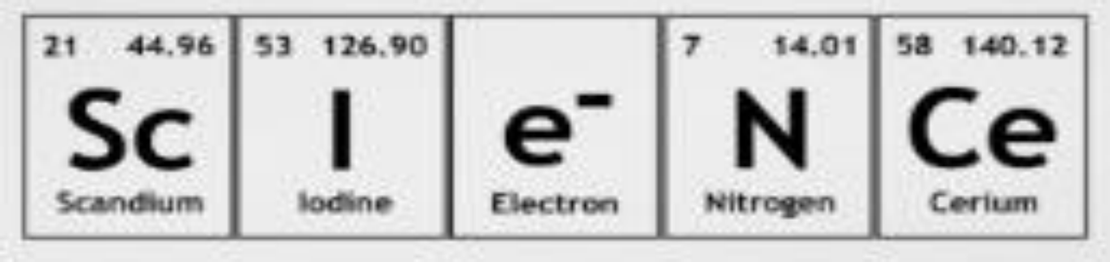
CAMBRIDGE
UNIVERSITY PRESS



Understanding the impact of informal science learning

Dr Mark Winterbottom, University Senior Lecturer in Science Education, Faculty of Education, University of Cambridge

Brighter Thinking
Better Learning

Building Brighter Futures **Together**

Welcome!

Brighter Thinking
Better Learning

We're going to start with a task which you might find in a science centre or science museum…

Brighter Thinking
Better Learning

You should use the newspapers and sticky tape provided

You should work in pairs

Cambridge University Press

Build a structure out of newspaper, which will slide down a slope, but as slowly as possible.

You can create a slope by propping up the table legs at one end

Build a structure out of newspaper, which will slide down a slope, but as slowly as possible.

STOP!

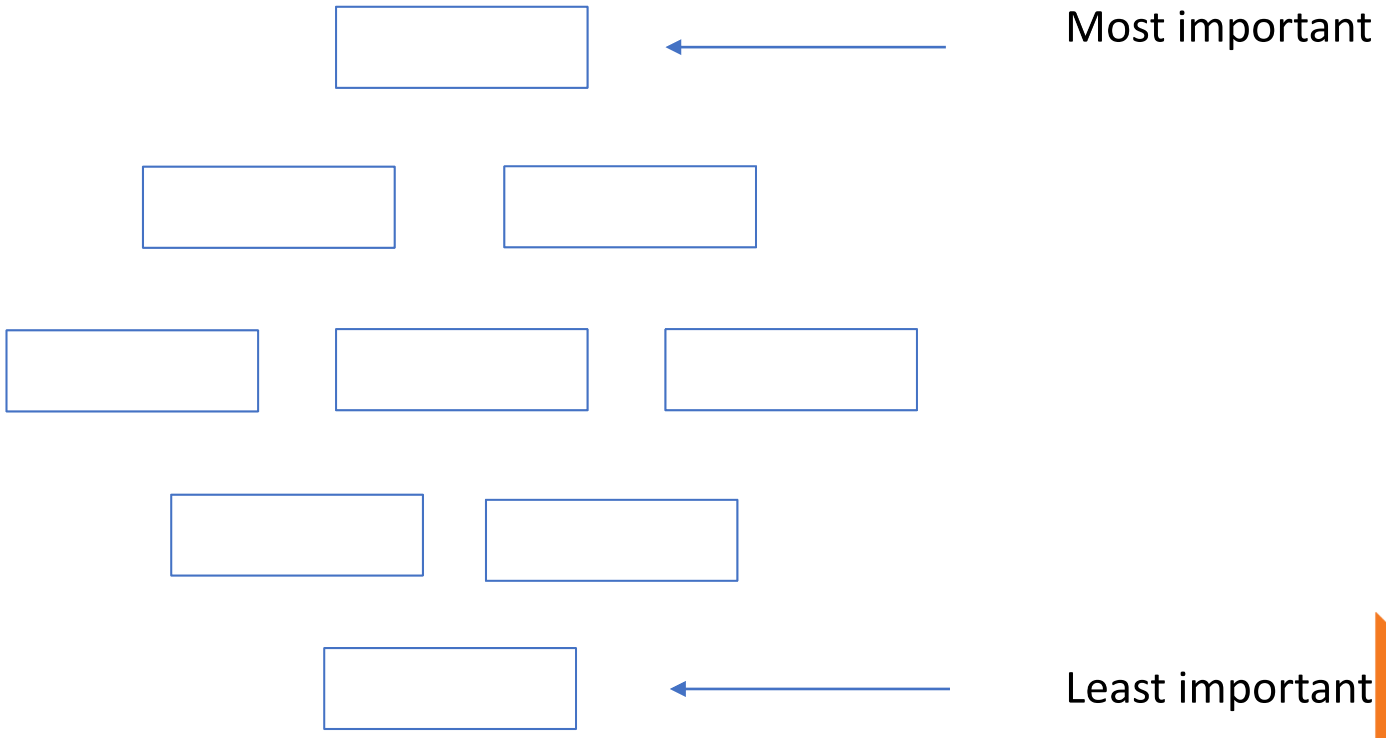
On the sticky notes…

Write down a total of at least 9 different words which characterise the activity. Put one word on each sticky note. You may want to think about:

- What you did?
- What you may have learnt?
- What skills you practised?
- Any other words which are relevant.

Arrange your sticky notes in a diamond shape…

You will have to discuss which are most important, and which are least important:



CAMBRIDGE
UNIVERSITY PRESS

Explain your diamond to another pair, making clear why you placed your sticky notes in the order you did

Brighter Thinking
Better Learning

Join your diamond shapes together into a bigger diamond.

The most important should still be at the top.

What key words underpin the activity?

https://www.wordclouds.com/

CAMBRIDGE UNIVERSITY PRESS

The Exploratorium in San Francisco undertook research to explore the value of this approach

The outcomes overlap with your own word cloud

Brighter Thinking Better Learning

Initiative & Intentionality

- Setting one's own goal
- Taking intellectual and creative risks; working without a blueprint
- Complexifying over time
- Persisting through and learning from failures
- Adjusting goals based on physical feedback and evidence


STAFF


MUSEO
NAZIONALE
SCIENZA
E TECNOLOGIA
LEONARDO
DA VINCI
ERICA

As critical thinking is developed, students' inquiries become more focused and intentional, and less a matter of trial-and-error (which can be a good place to start, in the "playful" stages of the inquiry).

Problem Solving & Critical Thinking

- Troubleshooting through iterations
- Moving from trial-and-error to fine tuning through increasingly focused inquiries
- Developing work-arounds
- Seeking ideas, assistance, and expertise from others

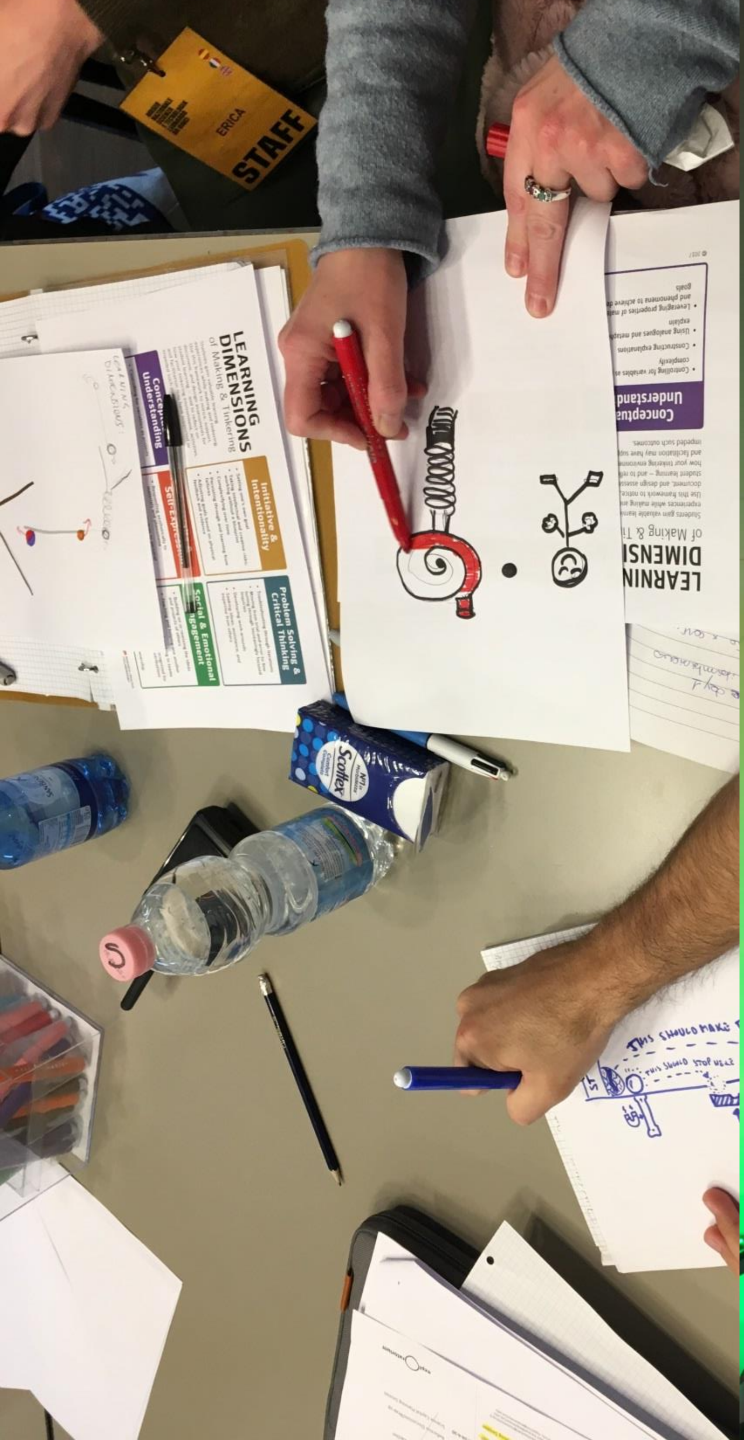
Social & Emotional Engagement

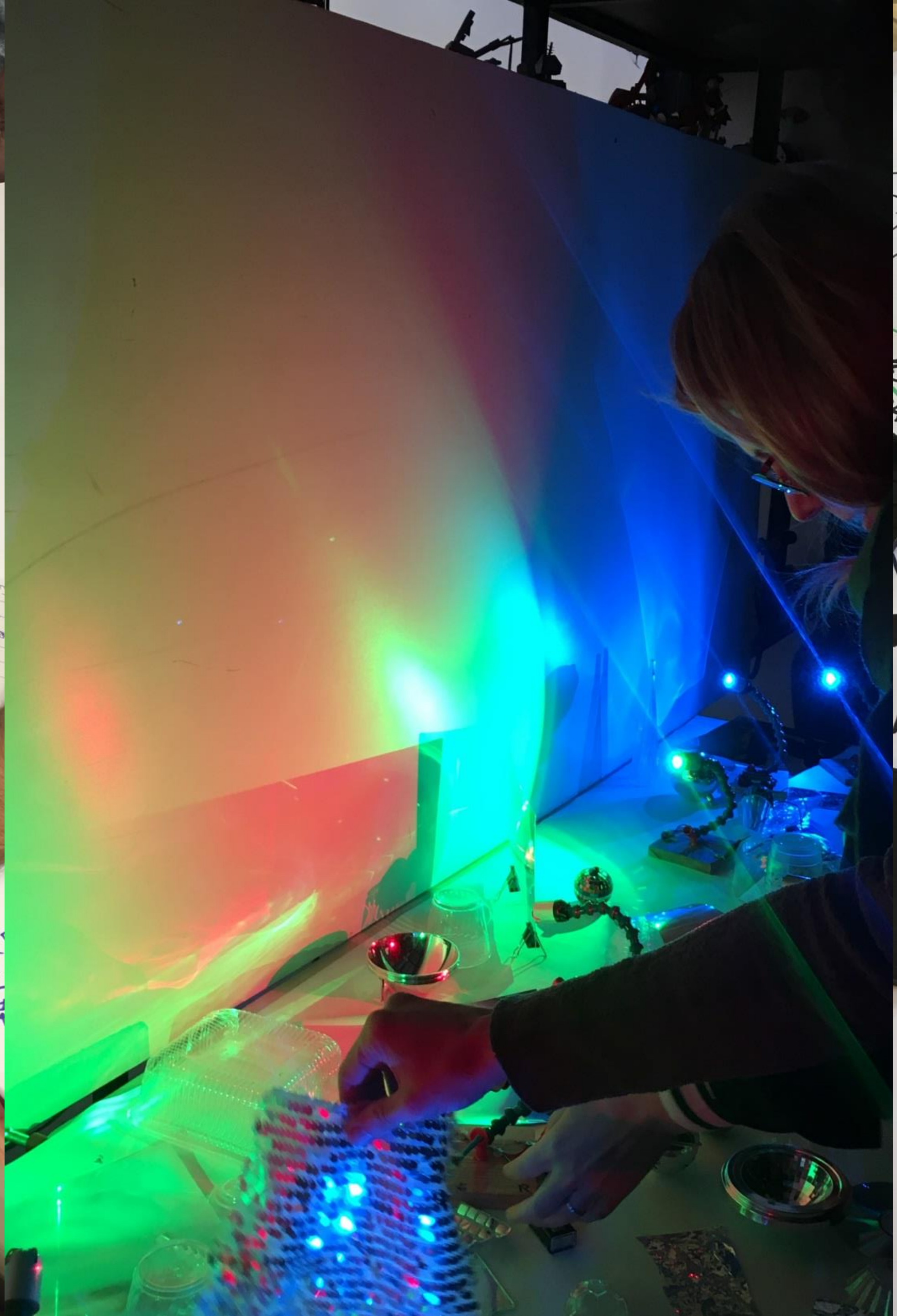
- Building on or remixing the ideas and projects of others
- Teaching and helping one another
- Collaborating and working in teams
- Recognizing and being recognized for accomplishments and contributions
- Developing confidence
- Expressing pride and ownership


DAS
MAG

Conceptual Understanding

- Controlling for variables as projects complexify
- Constructing explanations
- Using analogues and metaphors to explain
- Leveraging properties of materials and phenomena to achieve design goals


STAFF
ERICA
LEARNING DIMENSIONS of Making & Tinkering




UP
DOWN
TURN LEFT & RIGHT

Creativity sits at the heart of Tinkering. Developing an idea, one's own idea, and creatively working with materials and phenomena to realize it makes the experience deeply satisfying and personal.

Unlike more recipe-like Making activities, Tinkering activities that don't come with blueprints tend to encourage and amplify students' creative ambitions that in turn create unintended constraints that can complicate and drive ongoing complexification and care in their work—requiring careful measurements, balancing, positioning, or finishing touches—which can lead to richer learning activities that can deepen understanding over time.

Tinkering also frequently involves "audiences" for the work—fellow Makers, the broader school community, or parents or friends for whom the objects are presented as gifts. This dimension of activity leads to great focus on craftsmanship, entailing mastery of materials, tools, and phenomena.

Creativity & Self-Expression

- Responding aesthetically to materials and phenomena
- Connecting projects to personal interests and experiences
- Playfully exploring
- Expressing joy and delight
- Using materials in novel ways



Think back to the activity.

Write down at least one example of how you experienced each dimension

e.g. "Problem Solving and Critical Thinking: I kept trying over and over again, refining my design each time"

Initiative & Intentionality

- Setting one's own goal
- Taking intellectual and creative risks; working without a blueprint
- Complexifying over time
- Persisting through and learning from failures
- Adjusting goals based on physical feedback and evidence

Problem Solving & Critical Thinking

- Troubleshooting through iterations
- Moving from trial-and-error to fine tuning through increasingly focused inquiries
- Developing work-arounds
- Seeking ideas, assistance, and expertise from others

Social & Emotional Engagement

- Building on or remixing the ideas and projects of others
- Teaching and helping one another
- Collaborating and working in teams
- Recognizing and being recognized for accomplishments and contributions
- Developing confidence
- Expressing pride and ownership

Conceptual Understanding

- Controlling for variables as projects complexify
- Constructing explanations
- Using analogues and metaphors to explain
- Leveraging properties of materials and phenomena to achieve design goals

Creativity & Self-Expression

- Responding aesthetically to materials and phenomena
- Connecting projects to personal interests and experiences
- Playfully exploring
- Expressing joy and delight
- Using materials in novel ways

So this kind of activity has significant impacts on children

This activity is a form of inquiry learning

Inquiry learning enables students to build ideas in similar ways to professional scientists / historians / designers etc.

Inquiry type	Merits	Problems
Structured • Strongly teacher-directed. • Students follow teacher's direction in pursuing an investigation or to produce a prescribed product.	• Structured investigation (lab work) is associated with a higher degree of student confidence than guided or open inquiry. • Offers specific teaching techniques to achieve particular learning outcomes, and clear assessment strategies, which reduce the chance of failure.	• Could constrain the development of critical thinking.
Guided: • More loosely scaffolded (supported). • Students take more responsibility for establishing the direction and methods of their inquiry.	• Could help students to transition into more open inquiry. • Seems to helps students to develop understanding of complex scientific concepts and, at the same time, to acquire scientific process skills, or competencies, necessary for conducting scientific investigations, and understand the nature of science. • Offers specific teaching techniques to achieve particular learning outcomes, and clear assessment strategies, which reduce the chance of failure.	• Potentially less effective at advancing students' conceptual and procedural understanding as compared to 'open' inquiry.
Open • Students take the lead in establishing the inquiry questions or investigation methods.	• Employs high-level critical thinking skills. • Greater opportunity for students to experience the authentic nature of science. • Seems to be effective at supporting students' conceptual and procedural understanding.	• Risk of failure is increased as compared to structured and guided inquiry.

So can teachers benefit from the use of inquiry in the classroom?

We undertook two research studies about teachers' perceptions of inquiry

Study 1

Sample

- Interviews with 32 science teachers
- They identified examples from their teaching practice which they believed to be inquiry-based.
- A smaller group of 7 teachers then discussed the criteria they believed categorised activities as inquiry-based.

Study 1

Methods

- Data included audio-recordings of interviews, field notes and participants' SWOT analyses of inquiry-based approaches.
- Analysis through transcription and microanalysis of transcripts.
- Essentially, we look at what people say, and try to work out what factors underpin what they say.

Study 1

Findings

- Large variety of conceptualisations
- Open-ended project work with student autonomy
- Highly structured recipe-style tasks, under close supervision of the teacher
- Lengthy process
- Shift in control from teachers to students
- Open inquiry (with full student autonomy) incompatible with curriculum pressure

Study 2

Sample

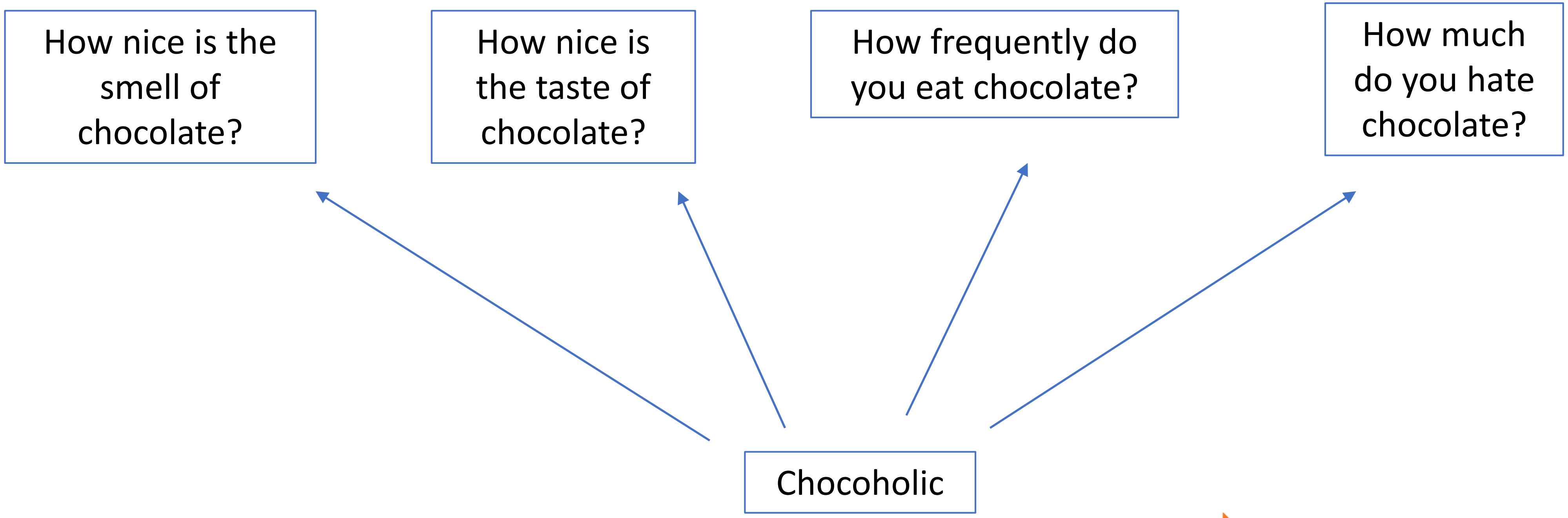
- 710 teachers from UK and international schools (thank you to CUP for facilitating access)

Study 2

Methods

- Questionnaire to explore teachers perceptions of teaching and learning through inquiry
- Factor analysis - find groups of questions whose answers are tightly correlated together, and try to work out (through interpretation) what factors underpin them

Study 2


How nice is the smell of chocolate?
How nice is the taste of chocolate?
How frequently do you eat chocolate?
How much do you hate chocolate?
Chocoholic

Study 2

Findings (what factors did we find)

- Student-led or ‘open’ inquiry
- Teacher/curriculum-led or ‘closed’ inquiry
- Learning through (critical) thinking
- Students **doing** research

Brighter Thinking Better Learning

Findings

Student-led or 'open' inquiry (low)

- I expect students to find answers to science questions by researching these themselves
- My students take into account alternative viewpoints when explaining their findings
- I encourage my students to follow up any questions arising from an investigation by embarking on further research
- My students research topics from the science curriculum themselves by using the internet
- I allow my students as much time as they need to make sense of the findings of an investigation
- My students make their own decisions about how to analyse and present data collected from an inquiry
- I refer back to my students' ideas during investigations
- My students are able to choose which investigations to carry out
- I require my students to make links between science and ethics / policy making
- I use assessment techniques which require students to apply their knowledge outside of the classroom

Findings

Teacher/Curriculum-led or ‘closed’ inquiry (high)

- I encourage my students to learn content first before planning their own investigations
- I conduct investigations as teacher demonstrations and the students analyse and write up the results
- I set my students the topics / questions to research
- I only set investigations or projects where I already know what the results / answers will be
- A teacher elicits questions on a concept she has just presented / taught
- A teacher introduces a class discussion a concept she has just presented / taught
- Pupils follow a set of step-by-step instructions to do a practical
- A teacher asking pupils questions throughout a lesson to check understanding
- Pupils confirming a scientific principle by doing an activity in which the results are known in advance
- A teacher gives pupils sets of results and asks them to analyse them
- Working through practice exercises which will help pupils to better understand an answer exam questions
- Pupils writing a report of their investigation following a pre-set format

Findings

Learning through (critical) thinking (Medium)

- My students consider the validity of the data obtained from an investigation
- I have a question box in the classroom
- I help students identify possible sources of error
- I encourage my students to repeat measurements / observations to ensure accuracy
- I make sure students have time to reflect on what they have done and found out
- I encourage my students to compare and discuss their group's results with those of other groups
- I make sure students are aware of the tentative nature of their findings
- My students use their understanding gained from an investigation to develop new knowledge or ideas
- My students work in small mixed ability groups when undertaking investigations
- I ask questions that are phrased 'What do you think is…' rather than 'What is…'
- Pupils developing explanatinos from evidence they have collected in an experiment / activity they have done

Findings

Students **doing** research (low)

- Pupils designing/selecting appropriate research procedures during investigation
- Pupils undertaking their own chosen research projects and presenting their findings to the class
- Pupils undertaking research projects from a list of topics set by the teacher and presenting their findings to the class
- Pupils thinking up their own scientific question to research individually or in groups
- Teacher and pupils researching a scientific question together, without the teacher knowing the results beforehand

So teachers think that open inquiry is not easily compatible with curriculum learning

But they do recognise the value of students thinking, and the role of closed inquiry in delivering curriculum objectives

But is there any other way to exploit the benefits of inquiry which we saw earlier?

CAMBRIDGE
UNIVERSITY PRESS

Facilitating inquiry

Brighter Thinking
Better Learning

One way is to think about our own behaviour in the classroom

Spend two minutes (only!) making a list of ways in which I facilitated the activity earlier on

I’m going to show you some descriptions of how I intended to facilitate.

For each, I want you to think about whether you do this in your normal classroom practice.

Pose questions instead of giving answers

- Resist the urge to explain much or fix problems.
- Instead, support learners in their explorations by asking questions, pointing out interesting phenomena, and wondering aloud about alternative possibilities. (Resnick & Rosenbaum, 2013).

Create a supportive and inspiring learning environment

- Articulate people’s successes to them and to others in the room to encourage confidence and pride and to motivate people to work through problems.
- Try to get a clear picture of what everyone is doing so that you are ready to respond to different individual responses and needs.
- Avoid the urge to jump in or instruct.
- Manage the space e.g. balance ‘mess’ against inspiring creativity, make sure materials and tools are readily available.
- Build relationships with the learners by listening, encouraging, questioning and being genuinely interested in what people are doing and thinking.
- Photograph work to give it value.
- Focus on the individual as well as what they are doing e.g. ask them how the process is making them feel.

Help people to experience frustration and failure in a positive and supportive way

- Offer just enough support to help them get unstuck. Know when to step in and when to step back. Sometime you need to ‘sit on our hands’ and give the learner time to ponder and reflect on an obstacle. (Petrich & Wilkinson, 2013).
- Support the learner to be resilient in the face of frustration e.g. when they perceive that things are ‘going wrong’. For example, you could encourage them to reflect on what they think is going wrong or suggest that they try a new approach/material or tool.
- Notice when the learner is working at the edge of what they can do alone and provide a scaffold. It might be enough to simply offer them a different material or tool to try or suggest they look at something someone else is trying.
- Encourage reflexive/reflective conversation that helps the learner to clarify what they are trying to do and that can help the learner to see why they may be finding something difficult. E.g. ‘I like what you have done there, can you tell me why you chose that material?

Encourage learner-negotiated goals and pursuit of personal interests

- Carefully plan introductions-provide enough encouragement and explanation to get people started but not so much that they are given a set of instructions or a closed-down goal. You should be creating an invitation to explore, rather than an expectation to do something specific (Petrich & Wilkinson, 2013).

- Allow the learner to change their plans. Encourage them and show enthusiasm when they demonstrate a desire to set their own goals, problem or challenge.

- Encourage risk taking and exploration e.g. ‘don’t worry if you think it might not work, have a go anyway’.

- Help people to focus on the process and not outcome. ‘e.g. I like they way that you are using that material in a new way’

Encourage collaboration with others

- Encourage engagement with people, not just materials. Learners benefit from having conversations (and collaborations) with other people. (Resnick & Rosenbaum, 2013).
- Actively observe what people are doing and encourage the learners to do the same.

Facilitate classroom learning in the same way as inquiry is facilitated in informal learning centres

Big Messages

- Classroom teachers can learn from informal science learning approaches
- Informal science learning approaches can foster:
  - Initiative and intentionality
  - Problem solving and critical thinking
  - Social and emotional engagement
  - Conceptual understanding
  - Creativity and self-expression
- Designing classroom activities and facilitating learning drawing on inquiry-based informal learning approaches can be beneficial to learning and inclusion

Further study

Inquiry, science capital and inclusive learning

What is science capital?

It’s what you know about science, how you think and your attitudes towards science, what you do, and who you know as you go through life.

DIMENSIONS OF SCIENCE CAPITAL

1 SCIENTIFIC LITERACY

A young person's knowledge and understanding about science and how science works. This also includes their confidence in feeling that they know about science.

2 SCIENCE-RELATED ATTITUDES, VALUES AND DISPOSITIONS

The extent to which a young person sees science as relevant to their everyday life.

3 KNOWLEDGE ABOUT THE TRANSFERABILITY OF SCIENCE

Understanding the utility and broad application of scientific skills, knowledge and qualifications.

4 SCIENCE MEDIA CONSUMPTION

The extent to which a person, engages with science-related media including television, books, magazines and internet content.

DIMENSIONS OF SCIENCE CAPITAL

5 PARTICIPATION IN OUT-OF-SCHOOL SCIENCE LEARNING CONTEXTS

How often a young person participates in informal science learning contexts, such as science museums, science clubs and fairs.

6 FAMILY SCIENCE SKILLS, KNOWLEDGE AND QUALIFICATIONS

The extent to which a young person’s family have science-related skills, qualifications, jobs, and interests.

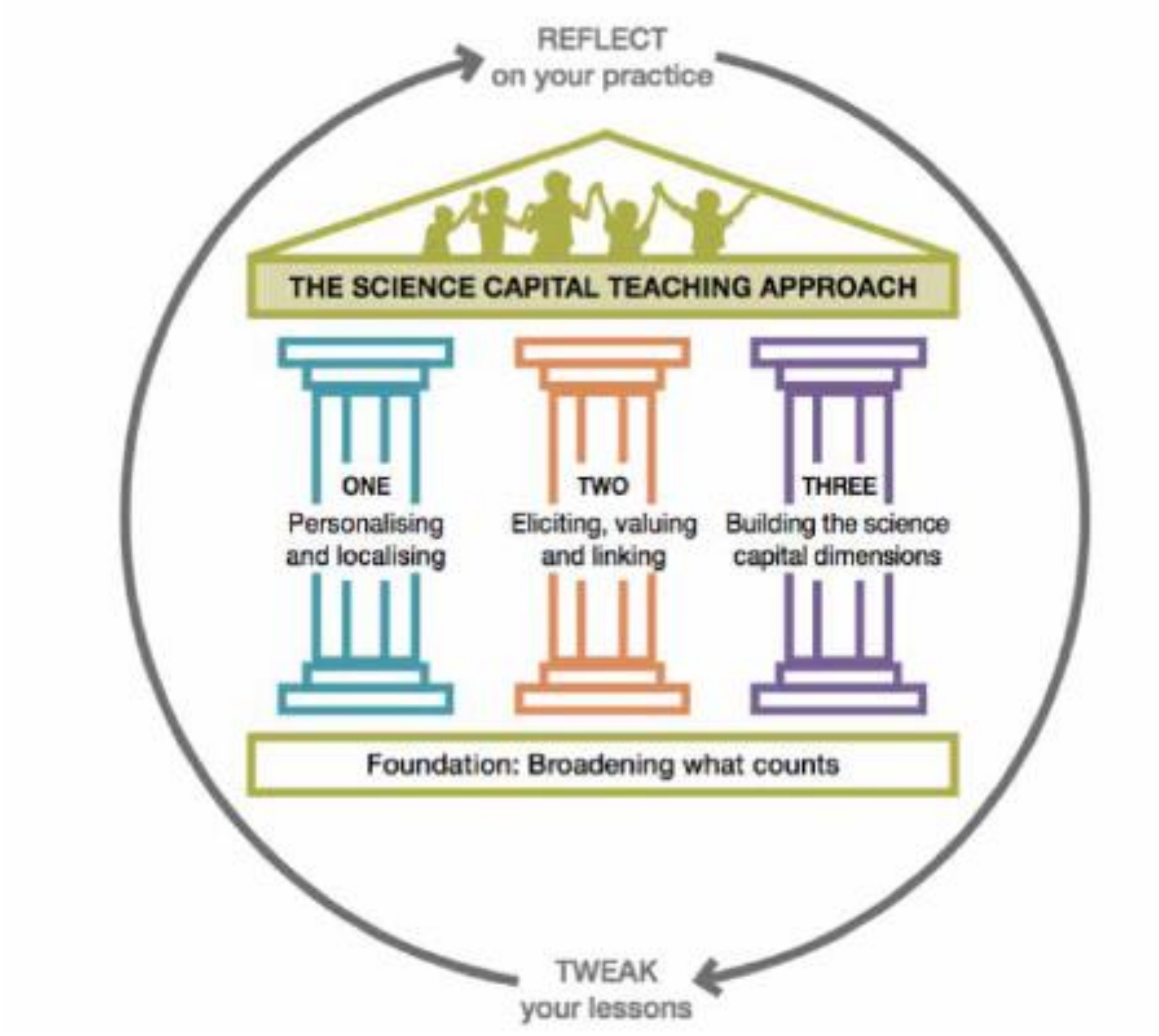
7 KNOWING PEOPLE IN SCIENCE-RELATED JOBS

The people a young person knows (in a meaningful way) among their wider family, friends, peers, and community circles who work in science-related roles.

8 TALKING ABOUT SCIENCE IN EVERYDAY LIFE

How often a young person talks about science with key people in their lives (friends, siblings, parents, neighbours, community members).

The science capital teaching approach



Broadening what counts

- Establishing classroom ground rules where all contributions are welcomed and respected.
- Making sure that certain students do not dominate.
- Creating opportunities to express themselves in ways that they feel comfortable.
- Highlighting the scientific nature of student contributions.
- Talking about different types of people who work in science-related jobs.
- Broadening students’ views of what counts as doing science in the classroom so that curiosity, questioning, sharing experiences and relating science through personal experience are valued.
- Challenging stereotypes that science is for certain sorts of students

Personalising and localising

- Creating lesson content that builds from students’ interests, aspirations, local community life and life experiences.
- Using examples and settings that are familiar and local to students as ‘hooks’ into the science content.

Eliciting, valuing and linking

- Explicitly inviting students to think about and share their own lived experiences.
- Using open questions.
- Sharing relevant examples from their personal life experiences to create an environment where all sorts of contributions are valid.
- Following up on student comments and deeply valuing them – recognising that these come from personal interest and may be of relevance to others in the class.

…inquiry approaches overlap with the science capital teaching approaches

…using such approaches may produce an inclusive classroom, particularly for those with low science capital…

How are we investigating that?

- Children visit a science centre to do tinkering
- Teachers undertake a series of structured observations
- Teachers undertake a structured reflection to identify developments for their own practice
- Teachers define an action research study to explore such developments in relation to inclusive science teaching