



# CREaTE

Canterbury Research and Theses Environment

Canterbury Christ Church University's repository of research outputs

<http://create.canterbury.ac.uk>

Please cite this publication as follows:

Billingsley, B., Nassaji, M. and Abedin, M. (2017) Entrenched compartmentalisation and students' abilities and levels of interest in science. *School Science Review*, 99 (367). pp. 26-31. ISSN 0036-6811.

Link to official URL (if available):

[https://www.ase.org.uk/system/files/SSR\\_December\\_2017\\_026-031\\_Billingsley\\_Nassaji\\_Abedin.pdf](https://www.ase.org.uk/system/files/SSR_December_2017_026-031_Billingsley_Nassaji_Abedin.pdf)

This version is made available in accordance with publishers' policies. All material made available by CReaTE is protected by intellectual property law, including copyright law. Any use made of the contents should comply with the relevant law.

Contact: [create.library@canterbury.ac.uk](mailto:create.library@canterbury.ac.uk)



# Entrenched compartmentalisation and students' abilities and levels of interest in science

*Berry Billingsley, Mehdi Nassaji and Manzoorul Abedin*

**ABSTRACT** This article explores the notion that asking and exploring so-called 'big questions' could potentially increase the diversity and number of students who aspire to work in science and science-related careers. The focus is the premise that girls are more interested than boys in the relationships between science and other disciplines. The article also examines the view that the practice of entrenched compartmentalisation is squeezing students' curiosity and channelling their thinking away from creative activities such as identifying good questions to ask and devising ways to address them. Based on their findings, the authors suggest that entrenched compartmentalisation could be a barrier in schools to students' intellectual progression and to students', particularly girls', interest in science.

Your phone is about to get a personality and move into the driver's seat of your driverless car. Your next toaster will sense your mood, notice you are down in the mouth and call out in an appropriately cheery tone that your toast is getting cold. Your fridge is about to be your personal counsellor and shoulder to cry on at the end of a bad day (forget the ice cream in the freezer). Your next kettle will monitor your water quality for the water board. The upgrade on your current doormat will be your hotline to your doctor with regular posts on your BMI.

And if all of this is merely a breath away, what kind of world, work and self-identities will be realities for our students once they reach their adult lives? Perhaps along with their intelligent doormat they will have access to faster-than-light travel, artificial telepathy, quantum computing, a fusion-powered space lift and an underground wildlife park on the Moon?

It is often said that our education system is trying to second-guess what attitudes, knowledge and skills will best prepare young people for a very different kind of reality to the one we experience today. It is also a regular grumble by university tutors that the students they receive are dependent on being told what question to address, what method to use, what answer to expect and what it looks like once written up.

Are there some changes we can make now in order to better prepare our young people to be the knowledge producers and political leaders in a world that has (for example) technologies such as gene editing and increasingly human-like robots?

We suggest that the answer is 'yes' and that there are strategies currently neglected or missing that would help young people to achieve a higher level of independence and confidence as learners and researchers.

Epistemic insight, the theme of this issue of *School Science Review*, broadly speaking refers to 'knowledge about knowledge' and relates more particularly to students' scholarly expertise and their capacity to be wise about how knowledge is and can be formed and tested. This includes not only an understanding of how scholarship and knowledge work within an individual discipline but also an understanding and appreciation of how to work with big questions that bridge subject boundaries.

Further, and as one of the key motivations for developing students' epistemic insight, the idea is too that students will gain a deeper understanding about the nature of science or of a given science discipline if they have opportunities to consider its history, power, relevance and limitations and to examine what makes that discipline distinctive in relation to others.

The research that underpins this claim includes a series of studies funded by the John Templeton Foundation and Templeton World Charity Foundation. The LASAR (Learning about Science and Religion) project looked at how questions and ideas that bridge science and religion are perceived and managed in schools at key points in students' education. The findings highlighted that entrenched subject compartmentalisation tends to stifle students' curiosity and capacity to ask and explore big questions and also to leave students with a number of gaps, confusion and misperceptions about scholarship and knowledge. When compartmentalisation is entrenched we mean that organisational, social and pedagogical practices have become habits and now dictate students' and teachers' expectations about what should happen in the classroom (Tyack and Tobin, 1994).

The walls around these compartments are sustained by subject-specific curriculum documents, examinations, teacher education and – in secondary schools – specialist teacher recruitment and subject-specific classrooms. The impacts are particularly noticeable in the case of students learning about science, as the science classroom tends to have the most impermeable boundary of all (Bernstein, 2000). In interviews with teenagers, for example, we found many cases of students saying they would like to know more about how we should understand the implications of science in relation to personhood, human significance and our capacity for moral responsibility, but who said they had learnt not to ask these questions for fear of going off-topic or causing offence. Further, because students were in many cases holding back about their curiosity and reasoning about these questions, the need and opportunities for formative assessment were passing teachers by.

In taking this stance we emphasise that situating and studying a science discipline within a multidisciplinary arena is not the same as moving to a cross-curricular topic-based curriculum. The conceptual framework underpinning current thinking about epistemic insight posits that students will gain a deeper understanding about the nature of each science discipline by interrogating its history, power, relevance and limitations and by examining what makes that discipline distinctive in relation to others (Billingsley, 2017). Immersing students in

the questions, methods and norms of thought of a single discipline at a time is critically important to helping students get a feeling for how each discipline works and there is no intention here to do away with subject compartments. At the same time, however, students also need opportunities to see the value and significance of questions that do not sit neatly in one subject or another. They also benefit, we argue, from examining questions about the implications of science and technology within a wider frame than only science. An example that we discuss later is where a workshop prompts students to reflect on whether they have an uncritical acceptance of labels used to describe technology that imply humanlike qualities and capabilities.

These findings suggest the need for students to become more confident and expert in asking questions and more resilient to the pressures of organisational and pedagogical boundaries. They also suggest that teachers need to be more mindful of the potential of boundaries in education to fragment and disrupt students' capacities to learn how scholarship works and to explore key areas of interest.

Once we begin to look at students' experiences of learning, there are abundant examples of these pedagogical boundaries. For example, a typical term of school science may consist of a series of individual topics that follow one after another in an order that is orchestrated via a textbook. This has advantages in terms of creating a relatively manageable trek through the curriculum that works pedagogically for students and teachers. At the same time, it means that students' experience of science is of short truncated and isolated topics. This example of pedagogical engineering is accompanied by a hard pedagogical boundary, particularly in secondary school science and other subjects. When we talk to young people, their reasoning about how to characterise science includes inferences from these experiences. They frequently say that science, as well as their science lessons, is characterised by the need to get to a single and definite answer quickly and by the idea that we should use experiments to get proof. Meanwhile, they suppose from their studies of history and religion that these disciplines are more discursive and have stories and space for discussion and multiple opinions. These inferences can then lead to tensions if and

when students become aware that a given topic is studied in more than one classroom. At that point, students are missing a clear sense from their teaching about how to work with more than one discipline and – when thinking about questions that bridge science and religion – whether they need to choose (Billingsley *et al.*, 2013; Billingsley, Nassaji and Abedin, 2016).

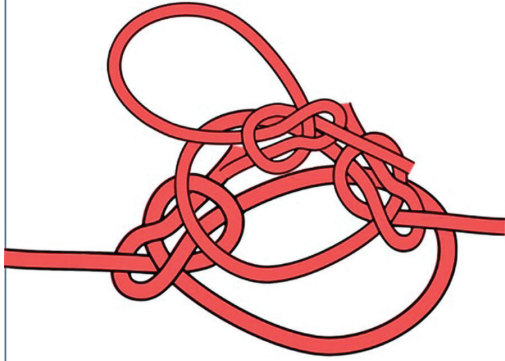
What would help students is the kind of learning they would gain if they put the questions associated with different disciplines side by side. Consider the following question, which might be asked in a history lesson: *'What were the causes of the Second World War?'* A student responding to this question would be expected to go beyond providing only one answer. Putting the question beside the type of question that is typically addressed in science makes it more apparent why.

With this said, it is also interesting to look at the extent to which students should be encouraged to expect that in science there will be an experiment followed by an overwhelming case for a single 'right' answer. Arguably, in

practice it requires a teacher to very carefully control the equipment provided to students, the method and the question if the intended outcome is that a class produce a similar set of results. In our research workshops we have given students an expected answer in the form of a relatively accessible scientific paper reporting a relatively simple experiment (Figure 1). The write-up, as it transpires, has some room for ambiguity on the equipment and details about how to do the experiment. It has also transpired that it is much less likely than the students suppose for the expected answer to emerge. There are more details about the workshop and article on the website: [www.epistemicinsight.com](http://www.epistemicinsight.com).

In the typical approach today, teachers tend to focus on giving students a question and then move them swiftly into the business of getting answers. This misses out the steps of thinking about what question to ask and then thinking about what type of answer or answers to expect. It also means that students are unlikely to consider why the answer or answers they find have limitations.

Do knots form by themselves?



We performed experiments in which a string was tumbled inside a box and found that complex knots often form within seconds.

Remarkably, almost all were identified as prime knots: 120 different types, having minimum crossing numbers up to 11, were observed in 3,415 trials

Physical Sciences - Physics: Dorian M. Raymer and Douglas E. Smith Spontaneous knotting of an agitated string <http://www.pnas.org/content/104/42/16432.full>

Epistemic Insight

Epistemicinsight.com

**Figure 1** Slide from the workshop 'Teaching epistemic insight to key stages 2 and 3' from [www.epistemicinsight.com](http://www.epistemicinsight.com)

One way to enrich students' understanding of the nature of science and its relationships with other disciplines would be to ask students to look at a given question and examine it. Focus questions would include: *'Looking at the question we have in front of us, what kind of answer or answers are you expecting and why?'* and *'Think about each of the disciplines in turn – maths, physics, history, geography. Which of these disciplines can help us to address this question?'*

We call this process of workshoping and working with a question 'epistemological analysis'. The premise, which we are currently testing through research, is that by conducting this kind of analysis, students will increase their understanding of the nature of science by thinking about how science works within this wider frame of scholarship and knowledge.

We move next to describe a workshop that plays with some of these ideas while looking at possible futures and the advance of humanlike machines.

### Humans and robots

A comparison between a humanoid robot and a human being can be helpful for learners to appreciate the links and limitations of science in relation to humanities. In particular, in this comparison, school students become critical of labels used to describe technology that imply humanlike qualities and capabilities. For instance, they are asked to consider what criteria they feel should be used to decide whether or not the robot really can hear. Is it sufficient if the robot responds to a sound? Should the robot also demonstrate a level of understanding and if so how and what level? This helps students find the critical questions to ask when reporters use words associated with human experiences and capacities when talking about technology. It also introduces the idea that some questions are more amenable to science than others. Materials and a fuller description of this workshop are available on the website: [www.epistemicinsight.com](http://www.epistemicinsight.com).

We move next to another potential benefit to exploring the nature of science in this wider cross-subject context, which emerged in our research.

### Girls' enthusiasm for science

It is frequently said that girls 'think differently' from boys and that their contribution would benefit science. However, it is not particularly

clear in such discussions what this contribution would be. The hypothesis we explore here is that one dimension of this 'thinking differently' is that, compared with boys, a greater proportion of girls are interested in exploring the wider contextual, metaphysical and multidisciplinary picture around science questions. The basis for this possibility will be explored further in the next section. As we have noted, this becomes significant in a school context because, at the same time, opportunities to stimulate students' curiosity by introducing philosophical and historical perspectives relating to the sciences tend to be squeezed out by 'entrenched compartmentalisation' in schools.

Looking first at some existing research, Gilligan (1982) has made the case that girls think about concrete situations in a more personal way, rather than in concise, abstract and idealised rule systems. This inference is drawn from noting that girls are more likely to talk about science in ways that relate science to themselves and their environment. It appears that, compared with boys, girls are often looking for a wider view and resist saying that they understand a concept until they can see how it fits into a broader context. Thus, when working in physics, girls' frame for understanding is located between the 'world' and the 'system of physics' and is characterised by links between the two. The more links are perceived, the more the girls feel that they understand. Boys, in contrast, tend to accept physics and technology as valuable in themselves. They appear to be more interested in the internal coherence of physics (and technology). It seems that boys are less likely to want to situate physics (and technology) formulae into a worldly context in order to feel that they have understood them. Thus, their understanding is identified with physics itself. These differences are consistent with findings of other studies that girls tend to prefer integrative kinds of thinking that avoid alienation from their everyday experiences.

These findings seem to indicate that if girls are looking for coherence between subjects then, because this external coherency is neglected by the practice of entrenched compartmentalisation in schools, they might be more negatively affected.

Some supporting and relevant findings have also emerged in our own work, including via a survey that was designed to discover students'



attitudes to scientism. Scientism is a metaphysical position that science alone can provide reliable knowledge. Someone who holds to scientism takes the position that other disciplines will either give way to science or will be dismissed and that *'Whatever knowledge is attainable, must be attained by scientific methods; and what science cannot discover, mankind cannot know'* (Russell, 1935: 243).

A survey was administered to 311 teenagers, setting out a series of statements, some of which were supportive of scientism while others took a non-scientistic stance. In order to compare girls and boys, a scale was designed with a range from 3 to 15, a higher score meaning a less scientific view. For girls and boys in our sample the scores were 10.62 (SD = 2.13) and 9.57 (SD = 3.05) respectively, which suggests that girls are less scientific than boys. The finding is statistically supported by an independent samples *t*-test ( $t = 3.290$ ,  $df = 275$ ,  $p = 0.01$ ).

The data indicate that a significant and higher proportion of girls have taken stances that science is not an exclusive way to understand the world. As such, providing students with opportunities to ask questions about the boundaries around science and to see that a range of metaphysical positions are consistent with what we know today about science would arguably mean that a wider cohort can see that science is consistent with their worldview and potentially help girls to feel inclined to choose science for further study and as a future profession.

In another survey, data gathered from 670 upper-secondary students in England indicate that boys are more interested in having a career in science than girls. However, if we ask students to consider the relationship between science and other disciplines then girls show more interest than boys. For example, girls showed more interest than boys to *'learn about brain science and the soul'* (Billingsley et al., 2016). This suggests that teaching science within a wider context, incorporating questions that bridge subjects, may encourage more girls into considering scientific professions.

The statement *'I would like more focus on links between science and other subjects, such as how science and psychology each explain human thought'* was included in a number of our survey studies. The data from more than 1200 secondary school student responses in England reveals that

girls are highly interested in focusing on links between science and other subjects or science and everyday life. More than 76% of respondents in our study strongly agreed or agreed with the statement. Additionally, the data from the 1200 responses revealed that more than 77% are interested in discussing the relevance of science to everyday life. However, fewer than half of the girls (47%) indicated interest in focusing on the questions that had only right and wrong answers.

A survey of 263 secondary school students in England revealed that girls are more concerned about bigger questions related to science and engineering. We found that a majority of students said they preferred teachers to make links between what they cover in different subjects. We also noted that proportionally twice as many boys (near to 50%) as girls (fewer than 25%) agreed with the statement that *'given a choice, I prefer to learn how a machine works rather than thinking why it matters'*. These findings are also consistent with the view that an approach including cross-discipline contextualisation of science alongside in-discipline teaching is likely to lead to increased levels of interest in science by girls in particular.

Comments from a survey of more than 500 secondary students show that girls are more interested in making links between subjects. The following comments were made by girls (there were no similar comments from boys):

*I am unlikely to enter a field of straight science but I am very interested in the idea of bio-ethics.*

*I like both science and humanities so I want to do a career that incorporates both.*

*I want to go into psychology with learning which requires knowing the brain. So I'm interested in helping others and also learning how the brain works and due to wanting to be an educational psychologist, knowing how the brain learns.*

*I love science and enjoy the fact that science can answer many questions, while I would love to be a part of this and find my own answers to life's questions, my aspirations lead me to pursue a different career.*

## Conclusion

Today, students with the potential to be successful in STEM-related careers such as engineering must, in most cases, first progress through the

highly compartmentalised organisation of subjects in secondary school. In this article we have suggested that there is value in exploring new ways to increase the engagement of students, particularly girls, with science by teaching about science in ways that bridge with the teaching that takes place in other subjects and in wider contexts.

We have made the case that girls favour and benefit from a cross-disciplinary approach to learning about science and knowledge. We have noted that this suggests that girls' learning preferences are squeezed by entrenched compartmentalisation in schools, and proposed

that addressing entrenched compartmentalisation may mean that girls are more likely to discover a greater enthusiasm for science.

Currently we are developing a project called 'Classrooms with Permeable Walls' (see Billingsley and Ramos Arias, 2017, this issue). In this project, teachers exchange information across subject divides to give students a more joined up experience of education. Our aim is to discover whether and how crossing the boundaries of different subjects in the classroom may help to improve attainment and attitudes to learning. This pilot project is one step towards that goal.

---

## References

- Bernstein, B. (2000) *Pedagogy, Symbolic Control and Identity*. Revised edn. Oxford: Rowman & Littlefield.
- Billingsley, B. (2017) Teaching and learning about epistemic insight. *School Science Review*, **98**(365), 59–64.
- Billingsley, B. and Ramos Arias, A. (2017) Epistemic insight and Classrooms with Permeable Walls. *School Science Review*, **99**(367), 44–53.
- Billingsley, B., Nassaji, M. and Abedin, M. (2016) *Can science tell us everything about being human? Research based intervention to teach secondary students about the nature of scientific questions*. Paper presented at the TEAN (Teacher Education Advancement Network) Annual Conference, Birmingham.
- Billingsley, B., Taber, K. S., Riga, F. and Newdick, H. (2013) Secondary school students' epistemic insight into the relationships between science and religion – a preliminary enquiry. *Research in Science Education*, **43**(4), 1715–1732.
- Gilligan, C. (1982) *In a Different Voice*. Cambridge, MA: Harvard University Press.
- Russell, B. (1935) *Religion and Science*. New York: Holt.
- Tyack, D. and Tobin, W. (1994) The “grammar” of schooling: why has it been so hard to change? *American Educational Research Journal*, **31**(3), 453–479.

---

**Berry Billingsley** is a Professor of Science Education at the LASAR Centre in Canterbury Christ Church University. Email: [berry.billingsley@canterbury.ac.uk](mailto:berry.billingsley@canterbury.ac.uk)

**Mehdi Nassaji** is a Research Fellow at the LASAR Centre in Canterbury Christ Church University. Email: [mehdi.nassaji@canterbury.ac.uk](mailto:mehdi.nassaji@canterbury.ac.uk)

**Manzoorul Abedin** is a Research Fellow at the LASAR Centre in Canterbury Christ Church University. Email: [manzoorul.abedin@canterbury.ac.uk](mailto:manzoorul.abedin@canterbury.ac.uk)

---

# Dual reality

Matt Pritchard

**ABSTRACT** Magicians and scientists have a curious relationship, with both conflicting views and common ground. Magicians use natural means to construct supernatural illusions. They exploit surprise and misdirected focus in their tricks. Scientists like to deconstruct and explain marvels. They methodically measure, evaluate and repeat observations. However, at the core of both is a shared sense of wonder and the drive to share that with their audiences.

Magicians live with a dual reality. During a performance, they aim to create for their audiences a sense of wonder as they witness the impossible. Behind the scenes, various secret methods are employed to create this illusion of supernatural powers. What the audience and magician experience during a show are quite different. To use simple labels, I shall call these views ‘effect’ and ‘method’.

Take, for example, the vanishing of a coin. The magician borrows a coin and places it in their closed hand. Moments later the coin has vanished. That is the effect on the audience. The magician has a different view. They pick up a coin and, while apparently transferring it into their other hand, secretly retain it in their first hand and conceal it from view. The coin is never placed into the closed fist. A simple vanish but also one that can be trivial for the spectator to figure out if performed without extra elements.

A key concept in magic is ‘misdirection’. This is an all-encompassing term for directing the audience away from the method onto the effect (Figure 1). The label is not the best choice of word but it is one that is universally used by magicians (and in some areas of psychology). Many people think they have only been fooled because the magician made them look away at the wrong time. Misdirection is about manipulating a spectator’s attention and perception, thinking and

memory: minimising the method and maximising the effect.

It is more than just words, eye movement, body language and timing. In a well-crafted magic show, there is a constant stream of new information to grasp. No time is left to process old information because if a spectator starts to think about the trick they might start to unravel it. The audience is carried along on a wave and at the end of the ride they have not had time to think and deconstruct. Memories of details have been blurred. In fact, a magician will often take deliberate steps to blur or rewrite a spectator’s memory by falsely recapping or embellishing previous events. A golden rule for beginners in magic is to only perform a trick once, because audience members who know what to expect are primed to be sceptical. On first viewing, inconsistencies can easily be overlooked.

In a lot of ways, a scientist is the opposite of a magician. An observer spots something curious: an unexpected event, a coincidence, a pattern. They then work towards understanding how that phenomenon came about (Figure 2). Rather than a rushed blur of activity and sensory overload, the scientist deliberately deconstructs the phenomenon and eliminates any superfluous elements. They will use empirical testing and mathematics. They will repeat the experiment to eliminate coincidences and errors.



**Figure 1** Magicians use a covert method to create an overt effect



**Figure 2** Scientists observe an effect and deduce an underlying method



When a spectator discovers how a magic trick works, the power of both the effect and the magician vanishes. Magician’s secrets are therefore closely guarded to retain the power imbalance. Science is about revealing rather than concealing: taking a mystery, opening it up to examination and sharing the discovery:

*It’s still magic even if you know how it’s done.*  
(Terry Pratchett, *The Wee Free Men*)

For scientists, often the physical workings of nature are more magical, more beautiful, more mind-stretching than the initial curious observation. There are mysteries within mysteries, an intellectual adventure, a deeper magic.

An outsider will often view science as destructive – taking apart, cutting up, categorising – like a frog dissection where you have turned something remarkable into a pile of useless flesh and bones. However, science is also an exceedingly creative subject to pursue, not just because of the diverse range of problem solving that goes on but because once you grasp the ‘How?’ you can then ask the predictive ‘Now what if...?’ Changing variables, combining and extending can lead to new discoveries. Magicians and scientists may differ on explaining workings but both groups value wonder and where that takes them.

**Matt Pritchard** researched physics before working as an Education Officer at Thinktank Science Museum, Birmingham. In 2010, he set up a science communication company and presents shows in around 100 schools each year, fusing science, maths and magic. Matt is an Associate of the Inner Magic Circle. Email: [matt@sciencemagicshows.co.uk](mailto:matt@sciencemagicshows.co.uk)

**Have you discovered Practical Action's FREE teaching resources?**

Our primary and secondary material will help you deliver the **UK science curriculum** within a GLOBAL context

**Science**

Enquiry based science activities including concept cartoons, Upd8s and a document showing where resources fit the UK science curriculum



**STEM challenges**

Problem solving, hands on challenges including the Plastics Challenge, Beat the Flood, Floating Garden Challenge and our ever popular Squashed Tomato Challenge



**Videos, images and posters**

Great secondary sources of information in a number of areas including energy, food and agriculture, climate change, water and sanitation and the NEW global goals



**STEM Careers**

A careers poster and inspiring case studies which help 20 pupils see how taking STEM subjects can lead to a range of careers that really make a difference.



**Taking inspiration from Practical Action's projects in the developing world our resources:**

- ✓ Are set in real world contexts to engage and inspire pupils
- ✓ Include Global Upd8s and Concept Cartoons produced with the ASE and Millgate House
- ✓ Provide complete packs with lesson plans, pupil worksheets and Power-Points
- ✓ Provide secondary sources of information e.g. technical briefs and case studies



[practicalaction.org/schools](http://practicalaction.org/schools)

