Billingsley, B. and Ramos Arias, A. (2017) Epistemic insight and classrooms with permeable walls. School Science Review, 99 (367). pp. 44-53. ISSN 0036-6811.

Link to official URL (if available):

https://www.ase.org.uk/resources/school-science-review/issue-367/epistemic-insight-and-classrooms-permeable-walls

# Epistemic insight and Classrooms with Permeable Walls

*Berry Billingsley and Andrea Ramos Arias*

ABSTRACT The boundaries between subject disciplines in secondary education today make it difficult for students to see their subjects in context. However, examining the secondary curriculum in England shows that there are a wealth of opportunities for making links and helping to develop students' epistemic insight and scholarly thought. This article provides concrete examples of these opportunities and offers a view into ongoing research by the LASAR Centre at Canterbury Christ Church University (UK), which supports teachers in bridging subject boundaries through a strategy called Classrooms with Permeable Walls.

Pedagogically, secondary education today tends towards compartmentalisation: the creation of rigid boundaries between subject disciplines that make it difficult, if not impossible, for students to bridge those disciplines. The problem with compartmentalisation is the loss of a context that, for many scientists and science professionals, adds to their interest and engagement in science. Research conducted by the Learning About Science and Religion (LASAR) Centre at Canterbury Christ Church University (Billingsley, 2013; Billingsley *et al.*, 2014; Billingsley *et al.*, 2016) has revealed some of the gaps, confusions and misperceptions in students' reasoning that are unintended side effects of a pedagogy of compartmentalisation.

Several factors of entrenched compartmentalisation are indeed quite visible and it is not surprising that they impact on students' assumptions about science. Examples include discipline-specific textbooks, disciplines arranged in slots in timetables, and secondary teachers who rarely collaborate across disciplines (Billingsley, 2017). LASAR data suggests that a significant proportion of students, particularly girls, feel constrained by subject compartmentalisation. They tend not to see science as a way to fully explain reality and they enjoy deliberating on the place of science in the context of bigger multidisciplinary questions. These findings resonate with other research, which shows that boys appear to be more interested in the internal coherence of physics (and technology), whereas girls tend to be interested in the wider coherence of ideas and are reluctant to say they understand a concept until they can put it into a broader (non-scientific) context (Stadler, Duit and Benke, 2000).

Epistemic insight refers to 'knowledge about knowledge' and to having the expertise and self-assurance to ask epistemological questions such as: '*Why and how do different disciplines approach and understand what knowledge is?*', '*What do we mean by evidence?*', '*What constitutes an experiment and what are the limitations that apply for any given enquiry?*' and '*What is the very purpose of knowledge?*' Focusing on epistemic insight within education engenders a pragmatic approach to helping students make better sense of the messages they receive in different subjects about how scholarship works and how knowledge claims are tested (Billingsley and Hardman, 2017). This approach is motivated by research that looked at how questions bridging science, religion and the wider humanities are managed in school. The findings of that research indicated that in science lessons students are tending to subvert their interests and confusions about what they are learning in favour of ensuring that the lesson stays 'on-topic' and that they will be prepared to give the expected answer in an exam.

In the teaching and learning of epistemic insight, we recommend a particular focus in science lessons on creating strategies to develop students' appreciation of the power, relevance and limitations of science in real-world and multidisciplinary arenas. This is because the boundary around each of the science subjects tends to be particularly impermeable (Bernstein, 2000). For example, it may not occur to the teacher or the students that the question the class is addressing in science could also be explored in another discipline. The pedagogy and social structures around science lessons persuade both teachers and students that this subject can operate in a silo, with no need to call on any other subject.

Another and complementary strategy developed by LASAR, Classrooms with Permeable Walls, works across a number of curriculum areas and focuses on developing students' scholarly character and a more joined-up approach by subject teachers who teach about the nature of knowledge. This article describes and discusses the strategy and its relevance and value for science teachers.

## Creating classrooms with permeable walls

The LASAR Classrooms with Permeable Walls project is an initiative designed to help teachers to work across subject boundaries to develop students' epistemic insight and so help them to better understand each of a range of disciplines.

Classrooms with Permeable Walls is aimed at key stage 3 (ages 11–14) teaching and students in particular and sits within a wider epistemic insight rationale, which aims to create an education system that more effectively:

- engages students' intellectual curiosity and recognises the value of both single and multidisciplinary questions;
- creates experiences that stimulate young people's natural curiosity, develops their cross-disciplinary scholarly expertise and widens the pipeline from school to science and science-related careers;
- equips students (at every level) with the best ideas and strategies we can offer to help them make decisions rationally and compassionately;
- develops teachers' and students' scholarly characters and self-esteem by enhancing their appreciation of how education, scholarship and knowledge work.

It especially creates research opportunities for the student teacher, teacher and teacher educator, so that teachers now and in the future are not trapped inside narrow compartments within education.

Classrooms with Permeable Walls is an intervention-based project in which teachers of year 8 (ages 12–13) in England pick out pedagogies and activities from a menu of choices for one week. They look for themselves at the impact on students' experiences of and attitudes to learning when joining up their subjects. Students and teachers who take part complete surveys at the beginning and end of this intervention.

## 'GCSE specifications should enable students to . . .'

Before delving into the strategies we have designed to help teachers to cross subject compartments and develop epistemic insight, it is useful to compare how England's Department for Education's curriculum requirements for different subjects identify the aims of each subject. Table 1 contains the aims of the GCSE (age 16 exam) programmes of study requirements for nine subjects: computer science, mathematics, combined and single science, religious studies, geography, English literature, English language and history. The programmes of study outline the content that exam boards must evaluate in national tests, which means there are specific outcomes each student should reach in each subject. They are key to understanding the core content that is delivered to students in the classroom. Studying the text in each box reveals that unless a teacher is clued up to look

**Figure 1** Classroom walls create an artificial boundary around a science lesson. How can science teachers communicate the power, relevance and limitations of science to their students when and if those walls become permeable?

further, he or she may not see any prompt or call to examine how this subject sits among other subjects. However, the National Curriculum explicitly states in its aims that it (and its associated documents) provides an 'introduction' for students, and its contents are expected to be only one element in children's education. Teachers are encouraged to go beyond it to develop exciting and stimulating lessons. By providing the core knowledge to be delivered

**Table 1** Programmes of study requirements for nine National Curriculum GCSE subjects (Department for Education, 2013, 2014a, 2014b, 2015a, 2015b, 2015c)

| | |
|---|---|
| **Computer science** | **GCSE specifications should enable students to:**<br>• understand and apply the fundamental principles and concepts of computer science, including abstraction, decomposition, logic, algorithms, and data representation<br>• analyse problems in computational terms through practical experience of solving such problems, including designing, writing and debugging programs<br>• think creatively, innovatively, analytically, logically and critically<br>• understand the components that make up digital systems, and how they communicate with one another and with other systems<br>• understand the impacts of digital technology to the individual and to wider society<br>• apply mathematical skills relevant to computer science. |
| **Mathematics** | **GCSE specifications should enable students to:**<br>• develop fluent knowledge, skills and understanding of mathematical methods and concepts<br>• acquire, select and apply mathematical techniques to solve problems<br>• reason mathematically, make deductions and inferences and draw conclusions<br>• comprehend, interpret and communicate mathematical information in a variety of forms appropriate to the information and context. |
| **Single science** | **GCSE specifications should enable students to:**<br>• develop scientific knowledge and conceptual understanding through the specific disciplines of biology, chemistry and physics<br>• develop understanding of the nature, processes and methods of science, through different types of scientific enquiries that help them to answer scientific questions about the world around them<br>• develop and learn to apply observational, practical, modelling, enquiry and problem-solving skills, both in the laboratory, in the field and in other learning environments<br>• develop their ability to evaluate claims based on science through critical analysis of the methodology, evidence and conclusions, both qualitatively and quantitatively.<br>• Furthermore the sciences should be studied in ways that help students to develop curiosity about the natural world, insight into how science works, and appreciation of its relevance to their everyday lives. The scope and nature of such study should be broad, coherent, practical and satisfying, and thereby encourage students to be inspired, motivated and challenged by the subject and its achievements. |
| **Combined science** | **GCSE specifications should enable students to:**<br>• develop scientific knowledge and conceptual understanding through the specific disciplines of biology, chemistry and physics<br>• develop understanding of the nature, processes and methods of science, through different types of scientific enquiries that help them to answer scientific questions about the world around them<br>• develop and learn to apply observational, practical, modelling, enquiry and problem-solving skills, both in the laboratory, in the field and in other learning environments<br>• develop their ability to evaluate claims based on science through critical analysis of the methodology, evidence and conclusions, both qualitatively and quantitatively. |

**Table 1** *(continued)*

| | |
|---|---|
| **Geography** | **GCSE specifications should enable students to:**<br>• develop and extend their knowledge of locations, places, environments and processes, and of different scales including global; and of social, political and cultural contexts (know geographical material)<br>• gain understanding of the interactions between people and environments, change in places and processes over space and time, and the interrelationship between geographical phenomena at different scales and in different contexts (think like a geographer)<br>• develop and extend their competence in a range of skills including those used in fieldwork, in using maps and Geographical Information Systems (GIS) and in researching secondary evidence, including digital sources; and develop their competence in applying sound enquiry and investigative approaches to questions and hypotheses (study like a geographer)<br>• apply geographical knowledge, understanding, skills and approaches appropriately and creatively to real world contexts, including fieldwork, and to contemporary situations and issues; and develop well-evidenced arguments drawing on their geographical knowledge and understanding (applying geography). |
| **History** | **GCSE specifications should enable students to:**<br>• develop and extend their knowledge and understanding of specified key events, periods and societies in local, British, and wider world history; and of the wide diversity of human experience<br>• engage in historical enquiry to develop as independent learners and as critical and reflective thinkers<br>• develop the ability to ask relevant questions about the past, to investigate issues critically and to make valid historical claims by using a range of sources in their historical context<br>• develop an awareness of why people, events and developments have been accorded historical significance and how and why different interpretations have been constructed about them<br>• organise and communicate their historical knowledge and understanding in different ways and reach substantiated conclusions. |
| **Religious studies** | **GCSE specifications in religious studies should:**<br>• develop students' knowledge and understanding of religions and non-religious beliefs, such as atheism and humanism<br>• develop students' knowledge and understanding of religious beliefs, teachings, and sources of wisdom and authority, including through their reading of key religious texts, other texts, and scriptures of the religions they are studying<br>• develop students' ability to construct well-argued, well-informed, balanced and structured written arguments, demonstrating their depth and breadth of understanding of the subject<br>• provide opportunities for students to engage with questions of belief, value, meaning, purpose, truth, and their influence on human life<br>• challenge students to reflect on and develop their own values, beliefs and attitudes in the light of what they have learnt and contribute to their preparation for adult life in a pluralistic society and global community.<br>**GCSE specifications in religious studies** m**ust require students to:**<br>• demonstrate knowledge and understanding of two religions<br>• demonstrate knowledge and understanding of key sources of wisdom and authority including scripture and/or sacred texts, where appropriate, which support contemporary religious faith<br>• understand the influence of religion on individuals, communities and societies<br>• understand significant common and divergent views between and/or within religions and beliefs<br>• apply knowledge and understanding in order to analyse questions related to religious beliefs and values<br>• construct well-informed and balanced arguments on matters concerned with religious beliefs and values set out in the subject content below. |

**Table 1** *(continued)*

| | |
|---|---|
| **English literature** | **GCSE specifications should enable students to:**<br>• read a wide range of classic literature fluently and with good understanding, and make connections across their reading<br>• read in depth, critically and evaluatively, so that they are able to discuss and explain their understanding and ideas<br>• develop the habit of reading widely and often<br>• appreciate the depth and power of the English literary heritage<br>• write accurately, effectively and analytically about their reading, using Standard English<br>• acquire and use a wide vocabulary, including the grammatical terminology and other literary and linguistic terms they need to criticise and analyse what they read. |
| **English language** | **GCSE specifications in English language should enable students to:**<br>• read a wide range of texts, fluently and with good understanding<br>• read critically, and use knowledge gained from wide reading to inform and improve their own writing<br>• write effectively and coherently using Standard English appropriately<br>• use grammar correctly, punctuate and spell accurately<br>• acquire and apply a wide vocabulary, alongside a knowledge and understanding of grammatical terminology, and linguistic conventions for reading, writing and spoken language.<br>**In addition, GCSE specifications in English language must enable students to:**<br>• listen to and understand spoken language, and use spoken Standard English effectively. |

in each subject, the National Curriculum also gives teachers opportunities to create links between different subjects and enhance children's experience of education beyond the core requirements.

Each subject curriculum refers to the discipline at its heart repeatedly in three or more of the listed aims (Table 2). This is hardly surprising: one expects to learn history in a history class, for example. However, in each curriculum document we can also see a number of 'scholarly' words that repeat throughout: words such as 'knowledge', 'data' or 'evidence' appear across multiple subjects and indeed are inherent to a range of disciplines. This creates an opportunity to bridge subject boundaries and to look with

**Table 2** Occurrence of discipline-related terms in the subject aims listed in Table 1 and in the whole subject curriculum document

| Discipline | Term | Number of appearances in the listed aims | Number of appearances in whole document |
|---|---|---|---|
| Computer science | 'computer science', 'computational' | 3 | 10 |
| Mathematics | 'mathematical' | 4 | 33 |
| Single science | 'science', 'scientific' | 7 | 56 |
| Combined science | 'science', 'scientific' | 3 | 73 |
| History | 'history', 'historical' | 5 | 53 |
| Geography | 'geographical', 'geography', 'geographer' | 4 | 50 |
| Religious studies | 'religious', 'religion' | 8 | 101 |
| English language | 'language', 'linguistic', 'read' or 'reading' or 'reader', 'write' or 'writing' or 'writer' | 12 | 55 |
| English literature | 'literature', 'write' or 'writing', 'read' or 'reading' or 'reader', 'English' | 12 | 57 |

students at what each of that range of disciplines mean by, for example, 'evidence'. How do the types of evidence we look at in history compare with those we work with in physics? These words shared across the subjects offer the possibility for contextualising disciplines, and especially for understanding the nature of scientific knowledge and working scientifically in relation to the knowledge and working associated with other disciplines.

Table 3 shows the findings of a simple search for several words related to scholarly practice, and how they were distributed around the text. For example, the word 'knowledge' appears in almost all of the curriculum guidance documents examined, with the exception of computer science. The use of the word is in relation to developing students' knowledge and having them demonstrate said knowledge. Its appearance across such a varied array of disciplines, from English language to single sciences, suggests an opportunity to draw out and discuss the nature and power of knowledge, the differences between different kinds of knowledge and what knowledge is, how it is created, understood or constructed across different disciplines.

Similarly, the word 'data' appears in five of the nine examined guidance documents. Again this is an opportunity to cross the boundaries of individual subjects to gain an understanding of what data is in different disciplines and domains, how it may behave and how it may be sought, found, constructed or analysed. Guidance for several disciplines also includes 'critical thought' or 'criticality', 'evidence' and 'analysis', among others. These and other reoccurring appearances of terms that are part of scholarly practice and of a scholarly understanding provide a rich context for understanding science, its power and its limitations.

As well as looking at curriculum documents to see some of the shared words, it is also useful to look at them to see what is distinctive about different disciplines. Without giving a thorough analysis here, one of the notable features of the science curriculum is the number of times the words 'observe,' 'observing' and 'observation' appear, for example in contrast with the history curriculum, across the different stages

**Table 3** Occurrence of the same 'scholarly' words in the different subject curriculum documents

| Term | Appearances in whole document | Discipline |
|---|---|---|
| Data | 7 | Computer science |
| | 19 | Geography |
| | 8 | Mathematics |
| | 18 | Combined science |
| | 18 | Single science |
| Evidence | 8 | Combined science |
| | 6 | Geography |
| | 2 | History |
| | 6 | English language |
| | 12 | Single science |
| | 1 | English literature |
| Hypothesis or hypotheses | 1 | Geography |
| | 4 | Combined science |
| | 4 | Single science |
| Enquiry | 3 | Combined science |
| | 1 | History |
| | 5 | Geography |
| | 1 | Single science |
| Knowledge | 17 | Geography |
| | 8 | History |
| | 3 | Mathematics |
| | 9 | Religious studies |
| | 7 | Combined science |
| | 7 | Single science |
| | 4 | English language |
| | 5 | English literature |
| Critical, in reference to thinking critically | 1 | Computer science |
| | 1 | Combined science |
| | 4 | History |
| | 2 | Geography |
| | 1 | Mathematics |
| | 8 | English literature |
| | 6 | English language |
| | 1 | Single science |
| Creatively, in reference to thinking creatively | 1 | Computer science |
| | 1 | Geography |
| | 2 | English language |
| Innovatively, in reference to thinking innovatively | 1 | Computer science |
| Think or thinker, in reference to learning a particular way of thinking | 1 | Computer science |
| | 2 | History |
| | 1 | Geography |
| | 1 | Combined science |
| | 1 | Single science |
| | 1 | English literature |
| Research or researching | 1 | Geography |
| Methodology | 1 | Combined Science |
| | 1 | Single science |
| Analysis, analyse or analytical | 1 | Computer science |
| | 10 | Combined science |
| | 11 | Single science |
| | 1 | Religious studies |
| | 4 | Geography |
| | 2 | History |
| | 2 | Mathematics |
| | 3 | English language |
| | 6 | English literature |

of schooling, from key stage 1 to key stage 4 (Table 4).

**Table 4** Occurrence of the words 'observe,' 'observing' and 'observation' in curriculum documents for science and history

| | Science | History |
|---|---|---|
| Key stage 1 (ages 5–7) | 20 | 0 |
| Key stage 2 (ages 7–11) | 31 | 0 |
| Key stage 3 (ages 11–14) | 7 | 0 |
| Key stage 4 (ages 14–16) | 7 | 0 |

## Strategies for creating permeable walls in the classroom

Below are some strategies we developed for teachers to use in the classroom to bridge subject compartments. They are designed for teachers to incorporate into their usual teaching and, although some reframing or adjusting of the normal course of teaching may be necessary, the idea is not to do away with subject compartments. Rather, it is to communicate across them: to make their boundaries permeable. If you try any of these or if you have thoughts about these suggestions, we would very much welcome your feedback. Our write-up and recommendations here draw on feedback we have already received.

### 1. Crossing the curriculum

Review Table 1 above again. Teachers have told us that they have found it useful to have in mind requirements of other disciplines when planning their lessons. How do they link with science? Which if any could be referenced in one of your forthcoming lessons?

### 2. Question box

Put a designated box in the classroom and encourage students to write questions raised by the lesson that have prompted their curiosity, but which seem to go beyond the boundary of what is currently being taught. These questions can be put in the box when students are leaving and can be reviewed by staff at regular intervals. They can also pave the way for other strategies outlined below.

Teachers have told us that it can take some time and encouragement on the teacher's part for students to begin using the box. It might also be useful to adapt it to a different format – such as a 'question wall' – that better suits your particular class, as long as it can contain students' questions in sight.

### 3. Asking about other lessons

Typically in a secondary school, each teacher focuses only on promoting his or her own subject to students, which from a student's perspective can create a sense of subjects that are working competitively and firm subject boundaries. In contrast, the view of knowledge that we are suggesting sees the disciplines as potentially and frequently working together. One way that teachers can move their teaching towards this more harmonious view is to sometimes ask students to say something about the lesson they have just come from, and thus to visibly value and show interest in other disciplines. On occasion, these fishing trips may also reveal opportunities to create a link to a topic in your lesson: for instance, if you are teaching the water cycle and the students have come from geography, you may be able to draw several links between the two subjects.

### 4. Collaborative teaching

Plan a lesson with a colleague from a different discipline, finding connections in topics to bridge it with science. Then teach the lesson together, explaining the two disciplinary perspectives to the students in the one lesson.

### 5. Scientific cross-matching

Science topics can be explored in the context of their links to other disciplines. Choose one such topic to discuss and designate a small group of students (two or three) to the other discipline. These students are now 'designated scholars' of the other discipline. Give them the background information into the other discipline's perspective on the topic at hand. For example, you could choose to give them the historical context to Hooke's Law. The designated scholars will have the task of contributing that perspective to the lesson. You can find some more examples in Box 1.

### 6. Scholarly posters

Divide the students into teams of 'scholars'. Assign a scientific topic that they have learned this year to each group, and a second designated discipline. The students use data, evidence and research methods from two different disciplines, and exercise critical thinking and analytical skills

**BOX 1 Examples for cross-disciplinary topics**

Many scientific topics have clear links with other disciplines. This is just a very short list to inspire you; you can probably think of many other topics you can use in class to encourage and teach about bridging disciplines:

- Science and history: Hooke's Law
- Science and geography: water cycle
- Science and mathematics: graphs of relationships
- Science and religion: the origins of life and why humans exist.

More in-depth questions:

- Can everything we know via science be expressed using mathematics. Is physics more mathematical than the other natural science disciplines and if so why?
- Is science less creative than other subjects and where is the creativity in science?
- Is it possible to live by one or two disciplines alone? Which would you choose and why?
- Is scientific data/evidence different to other kinds of data? If so, is science the only discipline to take this kind of data into account?

to understand and decide how they fit together, which information is more important, and what each discipline can contribute to an understanding of the topic.

### 7. Disrupt the labels

Teach in a different labelled classroom: counter expectations by teaching history in a science lab or vice versa. Use the opportunity to explain differences and links between the questions, methods and norms of thought that are explored in different disciplines.

### 8. Discipline hats

Organise the students in teams of five and assign a discipline to each: science, geography, history, and so on. Each group is now formed of scholars in their assigned discipline. Give them a question that they can analyse and interpret through each of their disciplines. Suppose they were in competition for research funding: who has the more important question? How can they decide which question is most important and how can each discipline's question contribute to helping us with the original question?

For example, suppose you ask the question '*Should robots be considered electronic persons?*' What kinds of research questions can arise from each discipline to attempt to answer such a question? Encourage students assigned to each discipline to consider the question from that particular perspective and how different disciplines, such as history, computer science or religious studies, can formulate their own questions that aim to address the original quandary. Award bonus points if they ask multidisciplinary questions!

### 9. Data-centric mind mapping

Explain and explore different types of 'evidence' and 'data' from different disciplines. For example, make a mind map about data, and ask the students to think about what data might be and how it could be defined. You could use the discipline wheel shown in Figure 3 as an aid. Link their ideas and examples to different disciplines on the wheel. Later you can use a scientific phenomenon in the wheel, and focus on finding evidence for or against it from different disciplines.

### 10. Researching for evidence

Ask your students to consider a cross-disciplinary question, such as '*Why did the Titanic sink?*'

What kinds of evidence would scholars of science and scholars of history call on to construct a response? How would this evidence be obtained? Is there any evidence that both disciplines might find useful and is there evidence that is more likely to be favoured by one discipline and not the other? To prompt students' imaginations, they could begin by researching the incident and list types of evidence that are discussed or that occur to them. They could then create the case that a scholar of each discipline might present to support a perspective on what happened.

We will be putting resources and links to support these kinds of activities on a website, www.epistemicinsight.com – please visit soon.

### 11. Sorting science topics

Sorting science topics is an activity aimed at explaining the limitations of science interactively. Start with three bubbles, like the ones in Figure 2, which can help you organise questions (such as the ones in your question box) by their amenability to science. Use the bubbles to sort different questions to see how much they

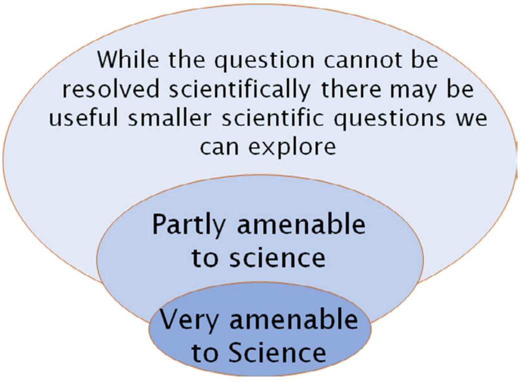


**Figure 2** Sorting questions according to amenability to science

relate to science, and to discuss the extent to which a question can be answered by science, or by science alone. You can use the questions suggested in Activity 5 to get started. Encourage the students to discuss data that points towards how science may address each question, think about how they would collect such data and compile the evidence for each case.

### 12. Discipline wheel

The discipline wheel (Figure 3) can be used at the start and end of a lesson to contextualise the focus of the lesson in a wider epistemological picture. To use the wheel, place a question or topic of discussion in the middle. You can ask a very big question, such as '*What makes us human?*', or what might at first appear to be a question that is specific to one discipline/subject such as '*Why does water boil at 100 degrees Celsius?*' You can also pose conundrums such as '*Why are there flightless birds on all of the continents, if birds evolved after the continents separated?*'

You can then go through the different disciplines in the wheel and try to view the question or topic through that particular perspective: how do theology, geography, history and mathematics seek to answer '*What makes us human?*' In this way, you can show students how the disciplines connect across topics and questions, and how much is lost if we only use one discipline lens to learn about and make sense of our reality. The discipline wheel and the subjects contained within it can be adapted to different stages of education to ensure students have an adequate understanding of each discipline depicted.


**Figure 3** The discipline wheel for contextualising the focus of a lesson

## Conclusion

The tendency towards entrenched compartmentalisation is one that can be overcome by creating and implementing pedagogies to relate disciplines as part of the teaching students receive. The National Curriculum and programmes of study in England offer opportunities for talking about the natures of the disciplines in relation to each other, both within each subject space and also and more particularly by bridging the boundaries around subjects. Using this wider multi-subject space, teachers can explain how key terms and ideas, such as 'data', 'evidence' and 'findings', differ across disciplines, without it signifying a preponderance of one type over the next. Simply, each discipline carries an epistemic perspective that corresponds with its own needs, power and limitations.

The activities above are intended to guide teachers towards enacting those bridges between subjects, thus enabling students to inhabit those wider spaces and develop the epistemic insight necessary to transcend subject knowledge silos. They act as a starting point for teachers to develop lessons that cultivate scholarly character traits and understanding. The activities can also help students focus on a context that they find particularly interesting, and then explore the contributions that different disciplines can make. In this way, students could be encouraged to consider the power and limitations of science, and ways that science can work alongside other disciplines to address complex questions, including those at the frontiers of knowledge.

The LASAR Centre is currently recruiting participant teachers and schools to conduct the Permeable Walls intervention in year 8 (ages 12–13) in 2018. If you wish to take part or receive more information, please email us at lasar@canterbury.ac.uk.

## References


Bernstein, B. (2000) *Pedagogy, Symbolic Control and Identity*. Oxford: Rowman & Littlefield.

Billingsley, B. (2013) Students' perceptions of apparent contradictions between science and religion: creation is only the beginning. In *Science Education for Diversity*, ed. Mansour, N. and Wegerif, R. pp. 329–338. New York: Springer.

Billingsley, B. (2017) Teaching and learning about epistemic insight. *School Science Review*, **98**(365), 59–64.

Billingsley, B. and Hardman, M. (2017) Theme Editorial: Epistemic insight: teaching and learning about the nature of science in real-world and multidisciplinary arenas. *School Science Review*, **98**(365), 57-58.

Billingsley, B., Brock, R., Taber, K. S. and Riga, F. (2016) How students view the boundaries between their science and religious education concerning the origins of life and the universe. *Science Education International*, **100**(3), 459–482.

Billingsley, B., Riga, F., Taber, K. S. and Newdick, H. (2014) Secondary schoolteachers' perspectives on teaching about topics that bridge science and religion. *Curriculum Journal*, **25**(3), 372–395.

Department for Education (2013) *Mathematics GCSE Subject Content and Assessment Objectives*. (Subject content for teaching from 2015.) Available at: www.gov.uk/government/uploads/system/uploads/attachment_data/file/254441/GCSE_mathematics_subject_content_and_assessment_objectives.pdf.

Department for Education (2014a) *Geography GCSE Subject Content*. (Subject content for teaching from 2016.) Available at: www.gov.uk/government/uploads/system/uploads/attachment_data/file/301253/GCSE_geography.pdf.

Department for Education (2014b) *History GCSE Subject Content*. (Subject content for teaching from 2016.) Available at: www.gov.uk/government/uploads/system/uploads/attachment_data/file/310549/history_GCSE_formatted.pdf.

Department for Education (2015a) *Combined Science GCSE Subject Content*. (Subject content for teaching from 2016.) Available at: www.gov.uk/government/uploads/system/uploads/attachment_data/file/593774/Combined_science_GCSE_formatted.pdf.

Department for Education (2015b) *Computer Science GCSE Subject Content.* (Subject content for teaching from 2016.) Available at: www.gov.uk/government/uploads/system/uploads/attachment_data/file/397550/GCSE_subject_content_for_computer_science.pdf.

Department for Education (2015c) *Religious Studies GCSE Subject Content.* (Subject content for teaching from 2016.) Available at: www.gov.uk/government/uploads/system/uploads/attachment_data/file/403357/GCSE_RS_final_120215.pdf.

Stadler, H., Duit, R. and Benke, G. (2000) Do boys and girls understand physics differently? *Physics Education*, **35**(6), 417–422.



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

**Andrea Ramos Arias** is a Research Fellow at the LASAR Centre in Canterbury Christ Church University. Email: andrea.ramos-arias@canterbury.ac.uk