Teaching and learning about epistemic insight

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ABSTRACT Epistemic Insight is a research and education initiative that is seeking to establish effective ways to help school students to appreciate the power and limitations of science. In particular, the idea is that experiences and explanations devised by a teacher who is focused on what happens inside the science classroom might not be interpreted as intended by students – who in turn are 'generalists' moving from subject to subject and in and out of school.

There is a vast body of research that looks at the influences of students' experiences in lessons on what they suppose about branches of scholarship such as science and mathematics. The findings emphasise the significance of pedagogy on students' developing ideas about the nature of science and what kind of person might want a STEM-related career.

Recent research carried out by LASAR (Learning about Science and Religion) contributes to this research by revealing gaps and confusions created by the entrenched compartmentalisation of subjects. For many decades, the common practice at almost every level of education has been to teach students about scholarship and knowledge via a compartmentalised system of individual curriculum boxes. While immersing students in the questions, methods and norms of thought of a single discipline at a time is critically important, students also need frameworks and bridges to enable them to move successfully between their subject compartments. There is, for example, a lack of a cohesive framework for students on words and ideas such as 'evidence' that are referred to in many subjects and modules.

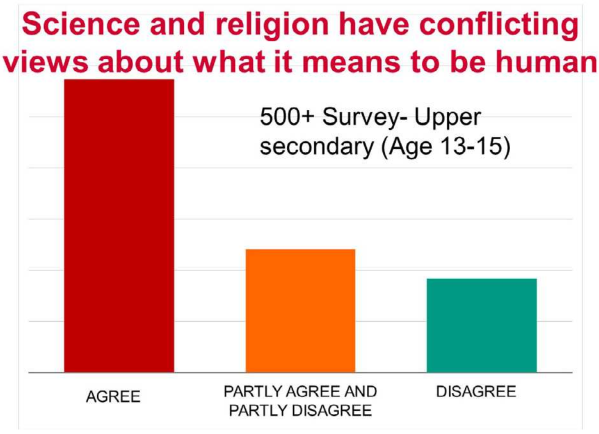
This rationale underpins an international research and education initiative called Epistemic Insight. Epistemic insight refers to 'knowledge about knowledge' and includes, in particular, students' progression to more informed views of how knowledge and scholarship work. The research is designing and testing strategic and creative ways for education to better communicate the nature of science and the power, relevance and limitations of science in real-world and multidisciplinary arenas.

There is no call here to do away with the teaching of disciplines and to instead teach students about a series of cross-curricular topics; rather, this is a call to use the spread of subjects and outside opportunities available to effectively communicate to students the nature of science and what it means to work in science and science-related careers.

Research background

LASAR was established in 2009 to look at how questions and themes bridging science and religion are managed in schools. The first project gathered data from students and teachers to find out how schools approach teaching about the origins of life and the universe. Our more recent research has looked at students' learning, questions and reasoning about what it means to be human. This has included looking at students' perceptions of what science says about behaviour and personality – and whether students perceive science to be compatible with what they believe for themselves; the project also ran workshops to explore questions with students such as whether a robot can and should one day have the status of electronic person.

To gather data, the project uses surveys, interview studies and workshops to discover students' reasoning and questions about themes that bridge science and religion (Figure 1). We are interested in their perceptions of what science and religion say and also in whether they see science as compatible with their own beliefs. We also interview and survey teachers to find out the pressures and opportunities that shape how



Survey to probe teenagers' reasoning about what it means to be human.

"Here is your timetable for next year"

Monday	Tuesday	Wednesday	Thursday	Friday
Registration	Registration	Registration	Registration	Registration
Maths	Hugging teddy	Science	Art	Maths
French			Art	TV watching
Break	Break	Break	Break	Break
Geography	History	Science	Hunting sharks	Science and Geography
English	English			
Lunch	Lunch	Lunch	Lunch	Lunch
History	Sharing Secrets	Science	Science and Religion	Eating sweets
Science				History

Classroom game devised to look more closely at the impacts of subject compartmentalisation. Children in year 6 (age 10) tell us what's making them giggle when they see this timetable. Why does the school timetable they expect to see have some of these 'boxes' and not others?

Figure 1 LASAR research tools and findings

they approach these topics. Thirdly, we use focus groups and classroom games to try to find out how students are making sense of the pedagogies they experience.

A particular focus in LASAR has been to understand how a combination of factors, including 'recipe' investigations in science lessons combined with entrenched compartmentalisation in schools, impact on students' developing ideas about the nature of science (Billingsley, 2016).

The finding by LASAR that entrenched curriculum compartmentalisation influences students' perceptions of science is perhaps not surprising. Some of the relevant factors are very visible and include textbooks that are labelled with one discipline or another, a timetable with slots for disciplines in turn and (particularly in secondary school) specialist teachers who rarely if ever plan or collaborate together. These habits of mind and practice are sustained by subject curricula, examinations and teacher education (Fensham, 2016).

When compartmentalisation is entrenched, it means that organisational, social and pedagogical practices have become habits and now dictate students' and teachers' expectations about what should happen in the classroom (Tylack and Tobin, 1994). The science classroom tends to have the most impermeable boundary of all (Bernstein, 2000). At the end of a lesson that has nominally explored what science can tell us about human personality and the choices we make, it may not occur to the teacher or the students to ask whether a question they are addressing in science could also be explored in another discipline (Billingsley, Brock, Taber and Riga, 2016).

Questions that students perceive would push the lesson off course tend to be withheld and students' curiosity is hidden from their teachers. Students learn in science lessons not to push the boundaries of what is being covered in class and there is a shared sense on the part of both teachers and students that it's important to stay 'on-topic' and away from anything that is likely to be sensitive (Billingsley, Taber, Riga and Newdick, 2010, 2013). Fourteen-year-old David was one of many students participating in our research who explained that in science lessons students resist asking questions they perceive as 'off-topic' and/or culturally sensitive: '*We don't ask science teachers questions any more at the moment, because we don't think that they'd answer them…* [pause] *oh they won't answer that because it's not on their topic*' (Billingsley, Taber, Riga and Newdick, 2013: 1725).

The 'silent treatment' that follows can seem to some students to support the idea that science is or at least purports to be exclusive.

Science as enquiry and science as a body of existing knowledge

Many of the key objectives associated with teaching about the nature of science are already recognised in the science curriculum in England and more widely; however, they are neglected because teachers are already working within the walls of their subject compartment. So, for example, the curriculum for primary school science in England says that children should ask relevant questions and then look at how scientific evidence can help them to address their questions. Typically, in practice, students are told the question – and how to address the question – and often indeed what answer they should expect to find.

These 'recipe' investigations are included in students' education not so much to teach them what it is like to be a scientist but rather to reinforce and support content teaching about scientific concepts and relationships (Fensham, 2015). All the groups of students in the classroom are following the same instructions and arrive at the same finding. It is a practice that dampens students' creativity and also disrupts and oversimplifies their understanding of experimental design, while maximising their chances of successfully getting the answer in the book,

Students' experiences can suggest to them a kind of positivistic, simple view of science in which (apparently) a question is introduced, it is directly investigated using a one-stop-shop experiment and this produces 'evidence' (or 'proof') to support a single 'right' answer. By identifying epistemic insight as an important idea in students' learning, we draw teachers' and students' attention to the wider multidisciplinary and real-world arenas where we see and can address these gaps, confusions and misconceptions.

Scientism

The current science curriculum in England states that children should develop an appreciation of '*the power and limitations of science*' (Department for Education, 2014). Scientism has multiple definitions and broadly speaking is a commitment to the view that science is the only valid way to construct knowledge and that nothing exists beyond the material universe (Stenmark, 2013). Scientism can be a considered position but there are findings from our own research, as well as in other research, that indicate a tendency among upper secondary students to respond with a kind of uncritical scientism when they encounter a 'Big' (cross-discipline) question (Billingsley, Nassaji and Abedin, 2016; Hansson and Redfors, 2007). We found many examples of secondary school students who took this stance. Some of the comments made by students aged 10 also reflected this stance:

Well, if it wasn't for science we wouldn't know much about the world or anything, really.

I only believe science and logical answers and theories.

I think the universe was up to science and science did everything.

Working with older students on the question of what it means to be human, we found that, while some students form a scientistic stance for themselves, there is another group who suppose that this is what science says but are uncomfortable about accepting this position as their own. Some illustrative comments by teenagers include:

I suppose everything you do is a result of the brain, but I feel uneasy saying that I'm not a person – I'm just a brain in a shell.

I'd still believe it's free will instead of just a mass of atoms, but I think it's because I like to believe that. I like to believe it's free will because then it shows that [...] *there's more of a purpose to life.*

Multidisciplinary thinkers

These findings give a basis to say that school science courses should do more to develop students' appreciation of the relevance, power and limitations of science in multidisciplinary contexts. There is also a basis to say that students who enjoy multidisciplinary ways of thinking are more strongly drawn to science when they see it contextualised in a wider cross-discipline arena (Billingsley and Chappell, 2016). Data collected from 263 students in secondary school revealed that more than half of students agree that 'I like it when teachers in one subject make a link to something we're learning in another subject'; in comparison, the level of disagreement was 12%.

Further, we noted from the data that girls' interest in particular can be engaged or disengaged depending on the breadth of the discussion. While almost 50% of boys agreed with the statement that 'given a choice, I prefer to learn how a machine works rather than thinking why it matters', fewer than 25% of girls agreed with the same statement. Girls are also more inclined to think critically about the power and limitations of the scientific explanations they are taught, and the attitudes they present tend to be less scientistic than those presented by boys. This is reflected in their responses to questions about the influence of genetics on personality, where girls seem to be less likely than boys to agree with the suggestion that our personalities and the choices we make can eventually be predicted by science. Additionally, when asked whether 'intelligence' is determined by genes, 13% of boys and 6% of girls answered yes.

These findings resonate with other research showing that boys appear to be more comfortable than girls with teaching that is focused on explaining physics concepts in scientific terms. Girls are more likely to want to know why this matters in their lives and will often resist saying they understand a concept until they have considered its meaning in a broader context (Stadler, Duit and Benke, 2000).

Teachers and collaboration

We have noted already that opportunities for dialogue between classrooms are limited by the challenges of timetabling, courses and other organisational factors. The practice of working alone is so entrenched in teachers' approaches to designing their lessons that teachers of religious education (RE) and science rarely if ever speak with each other to share strategies to develop students' reasoning about how science and religion relate. For one of the earlier studies, we interviewed science and RE teachers in eight schools to discover their experiences of teaching topics bridging science and religion (Billingsley, Riga, Taber and Newdick, 2014). This highlighted the separation of the two classrooms, with the comments below being typical:

We've had no cross-curricular sessions here since I've been here – which is [pause] *19 years.* [laughs] *I think they may be useful, so that at least we know what* [the] *teacher there is teaching.* (science teacher)

There is no relationship between religious studies and science… it is very hard for pupils to actually see where those two can work together. (science teacher)

I'm not terribly familiar with the science curriculum; I don't think they're terribly familiar with mine. (RE teacher)

For students, science tends to be associated with facts, experiments and proof, whereas students' accounts of religion typically refer to 'beliefs', 'opinions' and 'choices' and the idea that in religion '*you can believe what you want*' (Billingsley, Brock, Taber and Riga, 2016).

Some of the factors that are shaping students' thinking become apparent when they talk about what happens in their lessons. Isobel (year 9) explained that '*In RE lessons it's an open discussion… there's still that freedom in RE to choose your own beliefs… whereas in science there is much more taking notes and "This is how it is"*'. Glenn (year 7) contrasted the way his RE and science teachers taught about the origins of life and the universe, saying that RE teachers asked '*"What do you believe?"*' whereas a science

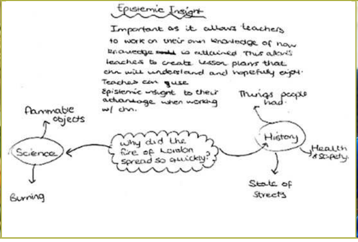
<table>
<tr><th colspan="3">Vision for Epistemic Insight research and design</th></tr>
<tr><td>Scholarly character development</td><td>Research in teacher education</td><td>Prospect of a broader spiral curriculum</td></tr>
<tr><td></td><td></td><td></td></tr>
<tr><td>The proposal is to offer students a more joined-up view of scholarly ways of working, which includes more effective teaching about the power, relevance and limitations of science.</td><td>We are engaged in research to develop new strategies to develop epistemic insight in schools and teacher education and more widely across the education ecosystem. This includes sharing strategies, resources and pedagogies.</td><td>We envisage a spiral curriculum to show how epistemic insight builds up as students move up through school, through college, through university and beyond.</td></tr>
<tr><td></td><td>
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Figure 2 Elements of the Epistemic Insight initiative

teacher is more '*"This is what happened," you know, "These are the facts I've been told to teach you"*'. In the view of Ewan (year 7), if students put forward a number of different ideas in a science lesson… '*at the end of the day if something like that happens our science teacher will overrule*'.

Finally, there is a basis to say that teacher education courses are also frequently compartmentalised at the expense of engaging teachers with the broader question of how we can nurture young people's developing intellectual curiosity, teach scholarly attitudes and ensure learners have opportunities to develop single-discipline and multidisciplinary approaches and expertise. These elements are summarised in Figure 2. The website for the Epistemic Insight project is at www.epistemicinsight.com.

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