Article

**Towards designing a tool for evaluating school students’ level of Epistemic Insight**

Berry Billingsley 1\*, Mehdi Nassaji 2 and Finley I. Lawson 3,

|  |
| --- |
| **Citation:** To be added by editorial staff during production.Academic Editor: Firstname LastnameReceived: dateRevised: dateAccepted: datePublished: date**Copyright:** © 2023 by the authors. Submitted for possible open access publication under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/). |

1. Canterbury Christ Church University, Department of Education; berry.billingsley@canterbury.ac.uk
2. Canterbury Christ Church University, Department of Education; mehdi.nassaji@canterbury.ac.uk
3. Canterbury Christ Church University, Department of Education; finley.lawson@canterbury.ac.uk

**\*** Correspondence: berry.billingsley@canterbury.ac.uk

**Abstract:** This paper introduces a tool for measuring school students’ levels of ‘Epistemic Insight’ (EI) and the extent to which schools can be considered ‘EI-friendly’. Epistemic insight is broadly understood as knowledge about knowledge and how disciplines interact with each-other - by thinking critically about the nature of knowledge, its application, and how it can be communicated. After introducing the concept of EI and the necessity to pay attention to this cognitive skill in school education, we report our analysis and findings from a survey we conducted among 720 lower-secondary-school students in England. For measuring the level of EI as well as schools being EI-friendly, we suggested four constructs and then we checked if the model with these constructs fits with the data. The key indicators of the analysis validated the model. Moreover, our analysis showed that there are high correlations between the components of EI, which means that EI relationships make a cohesive group. If someone is good at one aspect of EI, then it is likely that they will be good at other aspects of EI. The implications of these findings have been discussed.

**Keywords:** Epistemic Insight; Big Questions; Secondary Science

1. Introduction

 This paper demonstrates a tool we have developed which measures student levels of ‘Epistemic Insight’ and the extent to which schools can be considered ‘EI-friendly’. Epistemic insight is broadly understood as knowledge about knowledge and how disciplines interact with each-other - by thinking critically about the nature of knowledge, its application, and how it can be communicated.

Epistemic Insight (EI) encourages people to engage with big questions and real world opportunities and problems from cross-disciplinary perspectives. Such an approach is intended to help overcome the fragmentation of knowledge and the tendency that substantive knowledge (content knowledge) often receives greater focus than epistemic knowledge (disciplinary knowledge). The ability to think across disciplinary boundaries and to understand the nature of knowledge formation within disciplines has been recognised internationally as a crucial skill for today's students to acquire in order to be "future ready" [1].

Research has revealed that without effective teaching, students are unlikely to develop the Epistemic Insight they need to critically engage with big questions and real world opportunities and problems from interdisciplinary perspectives [2,3]. In other words, if students are low in EI their understanding remains fragmented, lacking the ability to critically reflect about the knowledge they are presented with. For example, students low in EI are unable to explain that science and religion are not necessarily incompatible, or engage effectively with similar questions that bridge disciplines [4].

Acknowledging the existence of these gaps, we seek ways to help engage students ‘critically’ by encouraging them to become more epistemically insightful. In essence, through our work, we have identified areas of concern and, informed by further research, hypothesised solutions, to enable students to become more epistemically insightful. However, to help measure the impact of our current and future work it is clear to us that possessing a tool that could be used to measure a student’s level of EI would be invaluable; to create a base-line and also a reference point for future impact studies. Based on our previous research, as well as reviewing the literature, we have hypothesized that there are three areas of epistemic concern and pressures that impede students’ understanding of how knowledge works, as well as one main institutional barrier that leads to school students’ lack of EI. For each of these factors we have designed a set of statements to measure. All these statements are extracted from our previous research and the validity of the individual statements are already established. We put together these statements and designed a survey that we conducted among 720 lower-secondary-school school students in England (ages 11-14). The aim was to check through a confirmatory factor analysis whether we can create a tool to measure school students’ level of EI as well as how school students assess the institutional barrier.

In what follows, we first introduce EI and its necessity for school students, then we will introduce the four constructs that capture the four factors that we will be analysing. In the rest of the paper, we will report our analysis and findings from the survey we conducted among 720 lower-secondary-school students and discuss whether we can use the survey as a tool for measuring EI.

**2. Epistemic Insight: what is it and why it is important?**

Epistemic insight refers broadly to the attitudes and understandings that are associated with thinking and working like a scholar in the sense of knowing how knowledge works. An Epistemically insightful student has a set of epistemic skill that are necessary for asking and investigating big questions in the real world.

Central to our research is the idea that 'Big Questions' are an untapped point of fascination for young people - but/and they need tools and structured opportunities to explore them. Without these structured tools and opportunities- conversations at school tend to become amorphous and difficult to assess as moments for learning. Additionally, reasons that teachers sometimes give for limiting students’ opportunities to explore Big Questions are a perception of these issues as religiously or culturally sensitive. From our earlier research it has become apparent that questions relating to science and religion provide good insight into the degree of understanding about disciplinary boundaries and the nature of knowledge acquisition in each subject area. Meanwhile students hold back questions that they perceive to be sensitive and/or ‘off-topic’ in relation to the core learning identified for key subjects. Together, these factors help to limit the use of ‘Big Questions’ as a route to learning across discipline boundaries. Our recent research studies have reported the findings of baseline surveys in schools. These tested hypotheses about the impacts of missing out on opportunities in schools to explore these Big Questions. The findings revealed a significant level of uncritical scientism in teenagers’ reasoning about Big Questions such as ‘what does it mean to be human’. Specifically, approximately 10% of teenagers seem to have formed a stable and intransigent position associated with scientism. Across schools and ages, we also found a consistently high proportion of students (60-70%) saying that they are interested in Big Questions [5]

By consulting with expert groups of scientists, theologians, philosophers, curriculum writers and educational researchers we have developed a framework for improving school students’ epistemic insight. Although the details of the framework has been discussed elsewhere [4], we bring a summary of the framework here in order to highlight what type of EI is needed at different stages of education at schools:

We have suggested three epistemic objectives for primary school students. These objectives are appreciating that…

* Science begins with observations of the natural world and constructing ways to explain our observations.
* Science has some similarities and some differences with other ways of knowing that we learn about in school.
* Science and religion are mostly concerned with different types of questions, including different types of why questions.

For lower-secondary school students we have proposed understanding the following three statements about knowledge:

* Some questions are more amenable to science than others.
* Different disciplines have different preferred questions, methods and norms of thought.
* Some people say that science and religion are compatible and some people say they are not.

And finally, there are three epistemic objectives that we have argued upper secondary school students should meet about knowledge about knowledge:

* Scientism is not a necessary presupposition of science.
* Some questions are more metaphysically sensitive than others.
* Science and religion are not necessarily incompatible.

This framework has a number of underlying epistemic values that if ignored in education may lead to lack of EI. They will be discussed here, and an extensive discussion can be found in a number of our research publications [2,4,6].

Understanding the nature of science is part of science education which is usually neglected in school. School students need to know about what methods science uses for investigation as well as appreciating what types of questions these methods can address. They also need to know what questions are beyond the scope of science, which science cannot address or cannot fully address. Appreciating the power and limitations of science will help school students avoid uncritical scientism which we believe is an instantiation of lack of EI. Uncritical scientism has a resemblance to scientism, and some authors associate scientism with a lack of criticality (see for example [7]). Uncritical scientism, however, is the idea that the student holds scientistic views uncritically, without an appreciation that there are a range of views on the power and limitations of science and that scientism is a controversial stance to take. Stenmark [8] suggested that scientism includes a tendency to say that in the future, science will provide a full explanation of how nature behaves using simple ‘scientific**’** language. In our model of pedagogical pressures, a student might form this conclusion while influenced by simplified versions and interpretations of scientific ideas [9] . In an interview study that asked students aged 10 years old how they perceived the nature of science, there were several who made comments that conceivably reflected an uncritically scientistic stance [4] (p. 1120):

*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.*

There is also evidence that secondary school science teachers resist talking about the nature, power and limitations of science and that students have few opportunities to develop their criticality [10,11].

The second epistemic concern is the lack of understanding of the similarities and differences between different disciplines. One aspect of EI which is neglected in the current education system is understanding that knowledge tends to be organised into disciplines, each with preferred questions, methods and norms of thought. As such, the aim of developing students’ EI supports the aim of developing ‘disciplinary knowledge’ (reflecting the terminology of the UK education regulator Ofsted). However, it also builds on and enriches interdisciplinary knowledge (in the OECD’s terminology) by requiring that students are able to apply their disciplinary knowledge to explain and compare the strengths and weaknesses of different disciplines when making decisions about real world opportunities and problems [1]. The comparison between different disciplines will help school students to appreciate how different methods of enquiry can collaboratively work together to address a real-world problem.

In a recent study we have argued that the Covid-19 pandemic has highlighted the necessity of scientists working collaboratively with other disciplines in informing thinking about a complex, evolving real-world problem [12]. This draws attention to recent efforts, both in the UK and internationally, towards curriculum reform integrating EI with significant implications for the teaching of science in schools.

A third area of concern relating to being epistemically insightful is intellectual curiosity in big questions that bridge science, religion, and wider humanities. Questions such as ‘Why does the universe exist? Is life here by anything other than an accident? Do people have free will?’ are some of the so-called big questions [9,13] that occupy the minds of most people at some time during their lives. In other research studies, we have characterised big questions in three ways. Firstly, they are questions about human personhood and the nature of reality. Secondly, in the context of school education, they are questions that bridge science, religion, and the wider humanities**—**a characteristic that becomes important because of the way that school subjects are framed and organized [14]. Thirdly, they are questions on which both science and religion seem to have something to say [15]. The existence of a science-religion dialogue connected to big questions is widely stated [16-18]. The dialogue includes a vast literature of books and papers addressing the relationships and individual topics [18-20] and books that suggest and explain key questions and topics for students in education [3,17,21]. Alongside other factors, EI in the form of understanding the natures of science and religion and how they relate is important when thinking about these topics and questions [9,22,23].

Our field research shows that a majority of school students like to think about big questions, indicating their epistemic agency. As Suzanne Dillon argues, the education system follows a kind of industrial model in which knowledge is commercialised and learners learn what is needed to gain power and be absorbed in the labour market. This method of teaching and learning overlooks students’ agency and thinking about big question. Dillon states:

Traditionally classrooms have been managed on a kind of an industrial society model, you know kids come in there sat in rows the teacher is at the top and even that physical geography of the classroom space says something about the distribution of power in the classroom. That's a burden for both the teacher and the students [24].

However, in a classroom where student agency is encouraged, Students feel they have their own purpose in learning, they can direct their attention to that purpose that may not necessarily be a commercial purpose. Opening a space for epistemic agency gives school students a chance to think out of the box and they can be engaged and excited by thinking about big questions in the real world context. We believe, therefore, that opening space for epistemic agency is part of epistemic insight and a student who has the epistemic insight to think about big questions has the epistemic agency that Dillon has paid attention to.

The above three epistemic concerns which have been identified from our previous research, led us to design three constructs for measuring school students’ levels of EI. These are introduced and discussed below. In addition to identifying the constructs for capturing the level of EI, we have explored the barriers for being epistemically insightful. School entrenched compartmentalisation is the main institutional barrier that we have identified in a number of our research studies that leads to lack of EI in schools.

For many decades the practice at almost every level of education has been to teach students about scholarship and knowledge via a compartmentalised system of individual curriculum boxes [25] . While immersing students in the questions, methods and norms of thought of a single discipline at a time is critically important to help students get a feeling for how each discipline works, when compartmentalisation is entrenched it means that organisational, social and pedagogical practices have become habits and now dictates student and teacher expectations about what should happen in the classroom [26].

These artificial boundaries around knowledge mean 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. In one of our interview studies, a thirteen year old student said that while she appreciated that science and religion both address some topics like the origins of life, “When I’m in science, I don’t think about religion […] it just doesn’t come into your head [9]. Some other students, however, do give thought to these big questions when they study topics like evolution, cosmology, particles, laws and patterns in nature and genetics. The pressure they feel because of subject boundaries in these cases can lead them to hide their curiosity and concerns. David (14years old) 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.”[9].

There are also potential benefits if teachers compared their own and other subject resources. When subject silos become entrenched, the teaching that is provided by each compartment can be disjointed and even conflicting when the messages are viewed together. An example is where a resource produced for physics teachers characterises reductionism as how we think in physics while in parallel a resource for teachers of religious education uses the same word to characterise the mind-set that science alone can provide us with truth.

As knowledge becomes digital and the world-over move increasingly online – education does and will play a pivotal role in building students’ capacities to be questioning and to interact wisely and compassionately with the knowledge claims that are presented to them. Most student enquiries involve using a search engine like Google. There is a considerable effort going into equipping students with strategies to detect misinformation such as advising students to check for reputable sources [27]. Another and less widely discussed impact of online searching is the risk that students’ experiences with knowledge become focused on a narrow range of disciplines. An example is that content retrieved from a search query is often limited to a narrow range of popular domains with some queries providing page after page of content that is found in a single disciplinary silo. Author1 et al. have investigated and sought to build students’ understanding of sensationalism in science reporting [6]. They conclude that students benefit from epistemic teaching that helps with how to spot misleading accounts of the significance of science.

As such we are introducing a fourth construct that we will be analysing in the current paper. This construct is labelled as a school being EI-friendly and we would like to measure students' perceptions of their school setting as being EI-friendly.

We thus have three constructs that we believe can capture school students’ levels of EI and one construct that captures the level of a school being EI-friendly. These four constructs are discussed in the next section.

**3.** **EI and EI-friendly constructs**

Based on the research background briefly mentioned above we have hypothesized the following four constructs:

1. The nature of science in real world contexts and in relation to other disciplines is neglected in science lessons. ‘CONSTRUCT1’
2. Understanding different ways of knowing (methodological differences) and how they interact are not addressed in schools. ‘CONSTRUCT2’
3. Big questions that bridge science and religion - and which as such offer opportunities to explore how these domains interact - are squeezed out of lessons where the science teacher is present because they are sensitive. ‘CONSTRUCT3’
4. There are impermeable walls between subjects when there is entrenched subject compartmentalisation in a school. ‘CONSTRUCT4’

All four constructs relate to forms of dialogue intrinsic to, and indicative of, successful epistemic insight in schools.

Construct ‘1’, relating to the nature of science in real world contexts, pertains to the power and limits of science as a method and epistemic system. Here, science is located in a multidisciplinary arena and students are invited to consider what sorts of questions are appropriate to the scientific method. In primary school this begins with emphasising that science starts with observing the natural world and finding ways to explain our observations. Here students are introduced to the inductive nature of science, albeit not in so many words, and come to see that some methods are more scientific than others. Science, then, is introduced as an epistemic system rooted in real world encounter with phenomena and that seeks theories to explain empirical observations. By the lower secondary level of education students encounter how science, and information gained through scientific method, informs our thinking and worldview as a society in the 21st century. Science, then, impacts on every aspect of our lives. There are, however, some questions that are more amenable to science than others and there are many questions that have not yet been answered by science, and may never be answered by science. The power and limits of science are thus emphasised, and students encouraged to think about when science is most appropriate as an investigative and epistemic tool. Finally, in upper secondary levels of education, students encounter the notion of scientism and discover that this is not a necessary presupposition of science. This is not simply about the limits of science but principally about the appropriate way of framing questions appropriate to science and in interpreting information gained through scientific methods. Here, in Construct 1, we develop a model and view of science which emphasises its power as an epistemic tool but also leaves open the way to understanding that other forms of obtaining knowledge exist and have a role to play in answering questions, some of which may not be wholly amenable to scientific investigation. The world of gaining knowledge is multidisciplinary with science as a key part but not standing in isolation. Sessions falling into this construct should happen in science lessons to reassure that they are about science and can be enabled through teachers widening the scope of discussions beyond the simple presentation of ‘facts’ gained through scientific investigation.

Construct ‘2’ seeks to explain the different ways that we come to know in a methodological context and also how the interactions of these are not addressed in education. Building on Construct 1, primary school students are introduced to the similarities and differences that science has with other ways of knowing. This is placed in the context of other ‘subjects’ that they study and the concept of ‘disciplines’ is introduced, with science being placed as one discipline amongst other ways of understanding the world. By lower secondary education the idea that school itself is a multidisciplinary arena is developed to enable them to see themselves as embedded in multiple forms of knowledge acquisition. They are also invited to explore the nature of individual disciplines and that each has its own preferred questions, methods and norms of thought. Disciplines are thus explored more deeply and the concept of differing types of questions is introduced as an important part of how we come to knowledge. In upper secondary education students are then challenged to explore the nature of questions themselves and how they relate to different types of knowledge. In particular, the fact that some questions are more metaphysically focussed, and indeed sensitive to seeking answers on the metaphysical aspects of life, is considered. By this stage, then, students are taken from considering appropriate questions and methods relating to physical phenomena through to considering metaphysical questions and how those might be addressed. Sessions relating to these concepts are best achieved outside specific subjects and more in the context of conversations between traditional subject areas.

Construct ‘3’ considers big questions about science and religion, and how these disciplines interact. In the context of this research there is also embedded here a consideration of how confident students are to even consider these types of questions. In primary school, students are introduced to the concept that science and religion are generally concerned with different types of question. Also, when these disciplines ask similar types of questions – such as Why does a human behave in a certain way? - they are often asking ‘Why?’ in very different ways. In lower secondary school, students focus on questions about human personhood and the nature of reality. These questions bridge the disciplines of science and religion, and invite contributions from other disciplines they have encountered. Here, the different types of questions that these disciplines can ask and answer become more clearly focussed. Students are also encouraged to bring this knowledge to bear on the question of the compatibility of science and religion. They are introduced to arguments against the compatibility of science and religion and to arguments in favour of their compatibility. This is developed further in upper secondary school where students explore the relationship between science and religion in more depth and are invited to consider that they are not necessarily incompatible. This, of course, pertains directly to the high profile debate between science and religion but also, more broadly and in an analogous way, to the relationship between science and other disciplines. Appropriate places to run sessions for this construct area vary, they may be appropriately done in the science classroom, the RE classroom or, indeed, in a third place that bridges these disciplines. There are some tools available that measure this particular, though concerns has been raised about the validity of these instruments and lack of statistically validated justifications [28,29]. Recently, Mujtaba and Reiss, have developed a tool to measure secondary school students’ attitude to Science and Religion and validated it thorough factor analysis [30].

Construct ‘4’ pertains to the functioning and structures within schools. In particular, whether ‘permeable walls’ exist between subjects that facilitate and encourage teachers into dialogue that enables big questions that transcend particular subject areas to be considered. Where a high level of compartmentalisation exists, this is considered to be an ‘impermeable wall’ environment that inhibits understanding of the multidisciplinary context of knowledge, the types of questions that disciplines ask and seek to answer, and the ability to bring together multiple disciplines to consider a single big question. In this circumstance, interventions may be necessary and helpful to break down the impermeable barriers to dialogue.

1. **Research question**

As noted earlier, the aim of this study is to check whether we can find a set of statements that represent the number of constructs we introduced and discussed earlier in this paper. We have collected a number of statements for each construct. These statements are created and tested in our previous research studies; therefore, they are validated individually. What we aim here is to assess whether these statements together can represent the attributed construct and therefore we can propose a validated model for measuring school students’ level of EI and their school being EI-friendly.

1. **Method**

For measuring the validity of the model, we conducted a survey with 720 students and then, using a confirmatory factor analysis method, we tested whether the measured variables represent the number of constructs or not. The statistical software AMOS was used for measuring the model validity. If the analysis indicated that the data fits with the model, and the key indicators of this analysis meet the requirements, then the model can be used a tool for the purpose.

We positioned the survey questions from the data captured into four main constructs. The details of the statement categorisation can be found below with allocated numbers indicating their location within the questionnaire:

**CONSTRUCT1**

12.1. The topics we discuss in science relate to what I learn in other subjects

9.4. I can explain how questions we discuss in science relate to what I learn in other subjects like history and the arts.

12.3. I can explain the methods science uses to investigate questions

7.3. I can explain what makes a question amenable to science

12.2. I can sort questions that can be answered by science from bigger questions that require one or more other disciplines

12.4. I can give an example of a question that science cannot fully answer (could be 'yet' or could be 'ever')

**CONSTRUCT2**

10.4. I understand how my school subjects relate to each other

7.1. I understand what a discipline is

7.2. I can explain why a multidisciplinary approach to some questions is helpful

9.1. I understand the similarities and differences between disciplines

10.1. I can explain ways in which disciplines are similar or different

10.2. I can name two disciplines that use similar methods to answer their preferred questions

10.3. I understand how to word a question so that I can investigate it within a single subject at school

**CONSTRUCT3**

9.2. I like to think about Big Questions

9.3. I am confident about asking big questions in a range of subjects at school

7.4. I can respond to a big question like what does it mean to be human by analysing it through different disciplinary lenses

**CONSTRUCT4**

6.2. In my school, teachers encourage us to make links between the subject we are learning about with them, and other subjects we study.

6.4. In my school, teachers encourage us to think about questions from disciplines other than their own.

8.2. I have been taught how to work with questions that bridge disciplines

8.1. I have been taught why it might be beneficial to use more than one discipline to investigate a question

1. **Data analysis**

**Table 1. Sample size and age group:**

|  |
| --- |
|  |
|  | Frequency | Percent | Valid Percent | Cumulative Percent |
|  |  |  |  |  |
| Valid | Missing | 17 | 2.4 | 2.4 | 2.4 |
| Y12 | 130 | 18.0 | 18.0 | 20.3 |
| Y7 | 432 | 59.8 | 59.8 | 80.1 |
| Y8 | 75 | 10.4 | 10.4 | 90.5 |
| Y9 | 69 | 9.5 | 9.5 | 100.0 |
| Total | 723 | 100.0 | 100.0 |  |

**Table 2. Frequency of responses to the statements**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Strongly Disagree****%** | **Disagree****%** | **Partly Agree and Partly Disagree****%** | **Agree****%** | **Strongly Agree****%** |
| 12.1. The topics we discuss in science relate to what I learn in other subjects | **0** | **9.6** | **40.4** | **34.9** | **15.1** |
| 9.4. I can explain how questions we discuss in science relate to what I learn in other subjects like history and the arts.  | **0** | **14.4** | **39.2** | **32.8** | **13.5** |
| 12.3. I can explain the methods science uses to investigate questions  | **0** | **10.7** | **39.7** | **36.6** | **13.0** |
| 7.3. I can explain what makes a question amenable to science | **4.3** | **14.8** | **40.2** | **31.7** | **9.0** |
| 12.2. I can sort questions that can be answered by science from bigger questions that require one or more other disciplines  | **0** | **14.8** | **43.6** | **31.0** | **10.5** |
| 12.4. I can give an example of a question that science cannot fully answer  | **0** | **16.5** | **26.8** | **31.4** | **25.4** |
| 10.4. I understand how my school subjects relate to each other | **0** | **4.1** | **23.0** | **45.6** | **27.3** |
| 7.1. I understand what a discipline is  | **4.5** | **11.2** | **19.6** | **36.7** | **28.0** |
| 7.2. I can explain why a multidisciplinary approach to some questions is helpful | **6.5** | **11.4** | **33.8** | **36.3** | **12.0** |
| 9.1. I understand the similarities and differences between disciplines  | **0** | **16.2** | **29.7** | **39.8** | **14.3** |
| 10.1. I can explain ways in which disciplines are similar or different  | **0** | **13.1** | **35.4** | **39.6** | **11.9** |
| 10.2. I can name two disciplines that use similar methods to answer their preferred questions  | **0** | **22.1** | **43.6** | **24.7** | **9.6** |
| 10.3. I understand how to word a question so that I can investigate it within a single subject at school  | **0** | **9.1** | **32.9** | **44.9** | **13.1** |
| 9.2. I like to think about Big Questions  | **0** | **13.6** | **26.1** | **31.7** | **28.7** |
| 9.3. I am confident about asking big questions in a range of subjects at school  | **0** | **17.8** | **30.5** | **28.8** | **22.8** |
| 7.4. I can respond to a big question like what does it mean to be human by analysing it through different disciplinary lenses | **8.8** | **11.6** | **36.3** | **29.9** | **13.3** |
| 6.2. In my school, teachers encourage us to make links between the subject we are learning about with them, and other subjects we study.  | **2.5** | **6.6** | **27.0** | **47.1** | **16.8** |
| 6.4. In my school, teachers encourage us to think about questions from disciplines other than their own.  | **4.3** | **9.0** | **28.9** | **45.9** | **11.9** |
| 8.2. I have been taught how to work with questions that bridge disciplines  | **0** | **18.5** | **41.3** | **27.8** | **12.4** |
| 8.1. I have been taught why it might be beneficial to use more than one discipline to investigate a question  | **0** | **14.4** | **28.9** | **36.7** | **19.9** |

There are a number of statistical tools for in-depth analysis to provide insight into the model fit for data sets through confirmatory analysis. The AMOS package, which is an SPSS module, provides visual paths indicating the correlation between individual items and the constructs as well as the correlation between the constructs. The visual path for the analysis is set out in Figure

Figure 1. Visual Path for Confirmatory factor Analysis.

Elliptical boxes indicate constructs (F1=Construct 1 etc.). Solid rectangular boxes indicate questions with allocated numbers.



There are a number of key indicators that should be checked in order to validate the model. AMOS provides these indicators. The tables below show the summary of model fit and the key indicators for this analysis are highlighted in green. As can be seen (Table. 2), all the key indicators meet the cut off criteria: CMIN/DF should be less than 5 and ours is 2.522. GFI, AGFI, IFI and CFI parameters all must be >= than 0.9, and for our data this is also met So we can confidently say that our model is a good model.

One potential problem with the result is that the P value should NOT be less than 0.05, but ours is nearly zero. However, if the sample size is large (more than 250) this is not generally regarded as an issue, and this is the case for our data (N- 720) [31].

Table 2. Model Fit Summary

CMIN

| Model | NPAR | CMIN | DF | P | CMIN/DF |
| --- | --- | --- | --- | --- | --- |
| Default model | 55 | 390.943 | 155 | .000 | 2.522 |
| Saturated model | 210 | .000 | 0 |  |  |
| Independence model | 20 | 2860.929 | 190 | .000 | 15.058 |

RMR, GFI

| Model | RMR | GFI | AGFI | PGFI |
| --- | --- | --- | --- | --- |
| Default model | .031 | .946 | .927 | .698 |
| Saturated model | .000 | 1.000 |  |  |
| Independence model | .130 | .533 | .483 | .482 |

Baseline Comparisons

| Model | NFIDelta1 | RFIrho1 | IFIDelta2 | TLIrho2 | CFI |
| --- | --- | --- | --- | --- | --- |
| Default model | .863 | .832 | .913 | .892 | .912 |
| Saturated model | 1.000 |  | 1.000 |  | 1.000 |
| Independence model | .000 | .000 | .000 | .000 | .000 |

Parsimony-Adjusted Measures

| Model | PRATIO | PNFI | PCFI |
| --- | --- | --- | --- |
| Default model | .816 | .704 | .744 |
| Saturated model | .000 | .000 | .000 |
| Independence model | 1.000 | .000 | .000 |

NCP

| Model | NCP | LO 90 | HI 90 |
| --- | --- | --- | --- |
| Default model | 235.943 | 181.502 | 298.069 |
| Saturated model | .000 | .000 | .000 |
| Independence model | 2670.929 | 2501.531 | 2847.675 |

FMIN

| Model | FMIN | F0 | LO 90 | HI 90 |
| --- | --- | --- | --- | --- |
| Default model | .541 | .327 | .251 | .413 |
| Saturated model | .000 | .000 | .000 | .000 |
| Independence model | 3.963 | 3.699 | 3.465 | 3.944 |

RMSEA

| Model | RMSEA | LO 90 | HI 90 | PCLOSE |
| --- | --- | --- | --- | --- |
| Default model | .046 | .040 | .052 | .879 |
| Independence model | .140 | .135 | .144 | .000 |

AIC

| Model | AIC | BCC | BIC | CAIC |
| --- | --- | --- | --- | --- |
| Default model | 500.943 | 504.238 | 753.030 | 808.030 |
| Saturated model | 420.000 | 432.582 | 1382.516 | 1592.516 |
| Independence model | 2900.929 | 2902.127 | 2992.597 | 3012.597 |

ECVI

| Model | ECVI | LO 90 | HI 90 | MECVI |
| --- | --- | --- | --- | --- |
| Default model | .694 | .618 | .780 | .698 |
| Saturated model | .582 | .582 | .582 | .599 |
| Independence model | 4.018 | 3.783 | 4.263 | 4.020 |

HOELTER

| Model | HOELTER.05 | HOELTER.01 |
| --- | --- | --- |
| Default model | 342 | 368 |
| Independence model | 57 | 61 |

|  |  |
| --- | --- |
| Minimization: | .010 |
| Miscellaneous: | 1.310 |
| Bootstrap: | .000 |
| Total: | 1.320 |

Execution time summary

Based on the analysis above we can suggest a model for measuring the EI among school students with four underlying constructs.

Being Epistemically Insightful:

To effectively navigate the data and provide space for further analysis we have included a definition of what being an epistemically insightful student implies and what an EI-friendly school looks like, as follows:

1. By our definition, a student is Epistemically Insightful (EI) if they have high scores in constructs 1, 2 and 3.

Thus EI = construct1 + construct2 + construct3

1. By our definition, a school is EI-friendly, if students in our sample give the school a high score in construct 4.

Thus EI- friendly = construct 4

1. **Further research questions and analysis**

Based on the two definitions above, we propose 4 research questions and analyze the data to explore the answers.

Research Question 1:

The first question is about the correlation between the components of EI. In other words, we would like to know whether EI relationships make a cohesive group?

Analysis:

If we calculate the correlations between constructs, we see that the correlations are very high which suggest that the EI items make a cohesive group. The correlations (as shown in Figure.1) are as follows:

r between Construct 1,2 = 0.78

r between Construct 1,3 = 0.87

r between Construct 2,3 = 0.73

As can be seen the correlations are around 0.8 or more which are very high and positive correlations.

Research Question 2:

The second question is about whether school students in a given school tend to agree on how EI-friendly their school is? In other words, in a given school is construct 2 high for all students or low for all?

Analysis:

As we noted before, we defined EI friendly as the sum of students’ scores on 6.2, 6.4, 8.2 and 8.1 and then calculated the Intraclass Correlation Coefficient (ICC) for each school to check whether they are consistent in their responses or not. We used ICC to quantify the degree to which individuals in the same school resembled each other in terms of scoring their school for being EI-friendly.

The result for two types of ICC (Consistency and Absolute Agreement) are shown in Table 3 below.

Table 3. ICC Consistency and Absolute Agreement.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| School | Consistency correlation | Absolute Agreement correlation | EI friendly score | Df1 | Df2 | .sig |
| A | 0.56 | 0.57 | 2.36 | 301 | 903 | 0.001 |
| B | 0.66 | 0.65 | 2.91 | 23 | 69 | 0.001 |
| C | 0.50 | 0.50 | 2.02 | 86 | 258 | 0.001 |
| D | 0.33 | 0.34 | 1.5 | 115 | 345 | 0.05 |
| E | 0.58 | 0.60 | 2.46 | 91 | 273 | 0.001 |
| F | 0.52 | 0.51 | 2.07 | 26 | 78 | 0.05 |
| G | 0.41 | 0.42 | 1.72 | 67 | 201 | 0.001 |
| All | 0.53 | 0.54 | 2.21 | 715 | 2145 | 0.001 |

As can be seen in the table, all correlations (both Consistency and Agreement types) are statistically significant for individual schools as well as for all students which means that there is an agreement and the internal consistently between responses to the construct EI-friendly for each school.

Research Questions 3: Whether Students with high score in EI are in EI-friendly schools.

Analysis

The descriptive indicators for EI and EI-friendly for each school that are shown in tables 4 and 5 below.

Table 4: Descriptive Indicators for EI

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Skewness | Standard Deviation | Mean | Max | Min | Number of students | School  |
| -0.28 | 6.63 | 55.76 | 80.0 | 29.0 | 302 | A |
| 0.39 | 7.35 | 57.35 | 75.0 | 43.0 | 24 | B |
| 0.3 | 6.56 | 56.21 | 74.2 | 42.0 | 87 | C |
| 0.58 | 6.23 | 54.88 | 72.0 | 43.3 | 116 | D |
| 0.41 | 7.00 | 60.18 | 79.0 | 44.6 | 92 | E |
| 0.41 | 7.35 | 58.00 | 74.3 | 46.7 | 27 | F |
| -0.12 | 3.27 | 55.00 | 61.8 | 46.4 | 68 | G |
| 0.2 | 6.60 | 56.31 | 80.0 | 29.0 | 716 | All |

Table 5: Descriptive Indicators for EI-friendly schools

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Skewness | Standard Deviation | Mean | Max | Min | Number of students | School  |
| -0.18 | 2.34 | 14.2 | 20.0 | 7.0 | 302 | A |
| 0.29 | 2.10 | 14.8 | 19.0 | 10.5 | 24 | B |
| -0.24 | 2.08 | 13.6 | 18.0 | 8.0 | 87 | C |
| -0.58 | 1.70 | 13.8 | 19.0 | 6.0 | 116 | D |
| 0.31 | 2.04 | 15.1 | 20.0 | 10.52 | 92 | E |
| 0.32 | 2.10 | 14.1 | 19.0 | 11.0 | 27 | F |
| 0.38 | 2.06 | 13.3 | 18.0 | 7.0 | 68 | G |
| 0.12 | 2.20 | 14.1 | 20.0 | 6.0 | 716 | All |

Table 1 indicates that the means for EI in schools are 55.76, 57.35, 56.21, 54.88 60.18 and 55.58 and the mean for the whole sample is 56.31. As the skewness for each school is between -2 and +2 we can say that the distribution for EI in every school is normal. Similarly looking at the mean for EI-friendly in table 2 shows that they are 14.25, 14.86, 13.68, 13.89, 15.13, 14.16 and 13.36 respectively. And the mean for the whole sample is 14.17. Again, as the skewness for every school is between +2 and -2 we can say that the distribution for EI-friendly in every school is normal.

In order to check whether the differences in EI and EI-friendly are statistically significant in each school we used the one-way analysis of variance (ANOVA) technique. The result is shown in Table 6 :

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Sig | F | Mean square | Df | Sum of squares | ANOVA TEST FOR EI |
| 0.001 | 7.76 | 320 | 6 | 1922 | Between groups |
|  |  | 41.28 | 709 | 29272 | Within groups |
|  |  |  | 716 | 2301580 | Total |

Table 6: ANOVA test for EI and EI-friendly

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Sig | F | Mean square | Df | Sum of squares | ANOVA TEST FOR F2 |
| 0.001 | 6.18 | 28.58 | 6 | 171 | Between groups |
|  |  | 4.62 | 709 | 3279 | Within groups |
|  |  |  | 716 | 147243 | Total |

The ANOVA analysis shows that the differences between schools in EI and EI-friendly are both statistically significant. However, it does not show the source for the difference, and we need to run a Post Hoc test to identify the source.

Table 7: Post Hoc Test results for schools’ EI score differences

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| School | A | B | C | D | E | F | G |
| A | --- | -1.59 | -0.45 | 0.87 | \*\*42/4- | -0.2.2 | 0.73 |
| B |  | --- | 1.14 | 2.47 | -2.82 | -0.63 | 2.32 |
| C |  |  | --- | 1.32 | \*\*-3.97 | -1.77 | 1.18 |
| D |  |  |  | --- | \*\*5.3- | -3.1 | -0.14 |
| E |  |  |  |  | --- | 2.19 | \*\*5.15 |
| F |  |  |  |  |  | --- | 2.95 |
| G |  |  |  |  |  |  | --- |

The Post Hoc test for EI shows that the difference between EI score in school E is statistically significant compared to other schools except school B and F

Table 8: Post Hoc Test results for schools’F4 score differences

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| School | A | B | C | D | E | F | G |
| A | --- | -0.61 | 0.56 | 0.35 | -0.87 | 0.09 | 0.88 |
| B |  | --- | 1.17 | 0.96 | -0.26 | 0.70 | 1.49 |
|  |  |  |  |  |  |  |  |
| C |  |  | --- | -0.2 | \*\*-1.44 | -0.47 | 0.32 |
| D |  |  |  | --- | \*\*-1.23 | -.0.26 | 0.53 |
| E |  |  |  |  | --- | 0.97 | \*\*1.76 |
| F |  |  |  |  |  | --- | 0.79 |
| G |  |  |  |  |  |  | --- |

The Post Hoc test for EI-friendly shows that the difference between EI score in school E is statistically significant compared to other schools except school C and D

Figure 2 shows the differences between schools on their EI and EI-friendly scores

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| School G | School F | School E | School D | School C | School B | School A |

Figure 2: Mean of EI score for different schools

Based on the results shown in Figure 2 and the post hoc test results we can say that EI is the highest in School E and this difference is statistically significant except for school B and F. The number of attendees in these two schools are lower than other school and this might be the reason that the differences are not statistically significant.

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| School G | School F | School E | School D | School C | School B | School A |

Figure 3: means of F4 in different schools

Based on Figure 3 and the Post Hoc results we can say that the EI-friendly value is the highest in School E and this difference is statistically significant for schools B, C and G

We can conclude from the above analysis that: Students in school E have the highest score in EI-friendly and also school students in this school have the highest score in EI, this means that students who are in EI friendly schools are having higher score in EI.

Research Question 4: Does EI negatively correlate with Technologism?

Analysis:

Using Spearman rho correlation shows that although EI negatively correlates with the statement that indicates technologism, this correlation is very low and not statistically significant, (r= -0.08 sig=0.911.

1. **Discussion and conclusion**

The aim of this study was to create a tool to measure school students’ level of EI, through a confirmatory analysis method. We also aimed to suggest a construct that could be used for assessing schools’ being EI-friendly. We suggested four constructs and then we checked if the model with these constructs fits with the data. The key indicators of the analysis validated the model and therefore the model can be used as a tool for measuring EI and EI friendly schools. We defined EI as the sum of the first three constructs and then checked further research questions. Our analysis showed that there are high correlations between the three components of EI, which means that EI relationships make a cohesive group. If someone is good at one aspect of EI, then it is likely that they will be good at other aspects of EI.

Our Intraclass Correlation Coefficient calculation indicated that school students resembled each other in terms of scoring their school for being EI-friendly. This analysis suggests that school students can understand and agree on whether their school is helping them to be Epistemically Insightful or not.

Finally, our analysis showed that there is a relationship between schools’ being EI-friendly and school students’ level of EI. This finding suggest that EI is potentially a transferable learning objective and schools can play a role in improving school students’ level of EI.

In a series of research studies, as briefly reviewed at the beginning of this paper, we have introduced the concept of Epistemic Insight, its components and the necessity for teaching EI at schools. However, for a construct to be teachable, as well as measurable learning objectives and lesson plans, teachers and educators need some tools to assess the baseline knowledge and learning progress. The current study proposed a model for this assessment. This study and the previous studies are part of a research project called the -------- which is run by --------. The EI initiative was launched in --- and is a work in progress and is designed to enable researchers, tutors, student teachers and teachers to work together to understand and address gaps, confusions and misperceptions in students’ opportunities and understanding. The research will continue to develop and test strategies to engage school students in more dialogue about Big Questions, find ways to build their understanding of different types of disciplinary knowledge and help students to explore ways that areas of knowledge interact to address questions that bridge subjects and disciplines. We believe that the current study, goes a step further and meets a crucial aim of the project which is developing strategies for assessing students’ EI. As the data analysis in the findings section indicated, the suggested model has the criteria to be used for assessing EI.

1. **Moving Forward**

Our data has suggested there is a strong correlation between students with high EI and EI-friendly schools, however, to fully evaluate the utility of the tool we have developed, we need to test it against pre and post survey data. In such a way we can potentially evaluate the impact that our pedagogical tools and interventions are having on students adopting an EI approach to their thinking, especially in schools that have been identified as not being EI-friendly in pre-survey data. The tool itself has the further potential to help inform us of specific deficiencies that may exist, preventing a high EI score for students and schools that we measure, this will prove useful in identifying the range of approaches that can be deployed to achieve the highest return.

Additionally, there is further confirmatory/explanatory research to be undertaken in asking the same/adapted questions that assess constructs 1-4 in relation to the teachers within EI-friendly and less EI-friendly schools. This would enable us to establish whether there are correlations between teacher confidence in and perceived opportunity to address Biq Questions and multidisciplinary issues within their teaching and students' perceptions of the EI friendliness. Thus does an EI friendly learning environment stem from teacher confidence, school ethos and/or their own expectations of delivering a compartmentalised curriculum. Understanding the relationships between teacher perception and student experience has wider implication both for the delivery of further research in this area, but furthermore for the education and continued development of new and existing school teachers.

**Author Contributions:** Conceptualization, B.B.; methodology, M.N.; software, M.N.; validation, M.N. and F.L.; formal analysis, M.N.; investigation, B.B. and M.N..; resources, F.L.; data curation, F.L.; writing—original, B.B. and M.N.; draft preparation, M.N.; writing—review and editing, F.L.; visualization, NA supervision, NA; project administration, B.B. and F.L.; funding acquisition, B.B. and F.L. All authors have read and agreed to the published version of the manuscript.

**Funding:** We are grateful to the Templeton World Charity Foundation for funding this project.

**Data Availability Statement:** Not applicable.

**Conflicts of Interest:** The authors declare no conflict of interest.

1. **References**

1. Organisation for Economic Co-operation and Development (OECD). The future of education and skills: Education 2030. (2018), *OECD Publishing*.

2. Billingsley, B. Teaching and learning about epistemic insight. *Sch. Sci. Rev.,* (2017).

3. Billingsley, B., & Fraser, S. Towards an understanding of epistemic insight: The nature of science in real world contexts and a multidisciplinary arena. *Res. Sci. Educ.*, (2018),*48*(6), 1107-1113.

4. Billingsley, B., Nassaji, M., Fraser, S., & Lawson, F. A framework for teaching epistemic insight in schools. *Res. Sci. Educ.*, (2018), *48*, 1115-1131.

5. Billingsley, B., & Nassaji, M. Exploring secondary school students’ stances on the predictive and explanatory power of science. *Sci.& Educ.*, (2019), *28*, 87-107.

6. Billingsley, B., & Heyes, J. M. Preparing students to engage with science‐and technology‐related misinformation: The role of epistemic insight.  *Curr. J.,* (2022).

7. Miller, H. T. Scientism versus social constructionism in critical policy studies. *Crit. Pol. Stud.*, (2015), *9*(3), 356-360.

8. Stenmark, M. What is scientism? *Rel. Stud.*, (1997), *33*(1), 15-32.

9. Billingsley, B., Taber, K., Riga, F., & Newdick, H. Secondary school students’ epistemic insight into the relationships between science and religion—a preliminary enquiry. *Res. Sci. Educ.*, (2013), *43*, 1715-1732.

10. Konnemann, C., Asshoff, R., & Hammann, M. Insights into the diversity of attitudes concerning evolution and creation: a multidimensional approach. *Sci. Educ.*, (2016),*100*(4), 673-705.

11. Kötter, M., & Hammann, M. Controversy as a blind spot in teaching nature of science: Why the range of different positions concerning nature of science should be an issue in the science classroom. *Sci. & Educ.*, (2017), *26*(5), 451-482.

12. Billingsley, B., Heyes, J. M., & Nassaji, M. Covid-19 as an opportunity to teach epistemic insight: findings from exploratory workshops on Covid-19 and science with students aged 15–17 in England. *SN Soc.Sci.*, (2021), *1*, 1-24.

13. Shipman, H. L., Brickhouse, N. W., Dagher, Z., & Letts IV, W. J. Changes in student views of religion and science in a college astronomy course. *Scie. Educ.*, (2002), *86*(4), 526-547.

14. Billingsley, B., Brock, R., Taber, K. S., & Riga, F. How students view the boundaries between their science and religious education concerning the origins of life and the universe. *Sci. Educ.*, (2016), *100*(3), 459-482.

15. Billingsley, B. A. (2004). *Ways of thinking about the apparent contradictions between science and religion* (Doctoral dissertation, University of Tasmania), (2004).

16. Polkinghorne, J. C. The inbuilt potentiality of creation. *Debating design*, (2004), 246-260.

17. Southgate, C. (Ed.). *God, Humanity and the Cosmos-: A Textbook in Science and Religion*. (2011), Bloomsbury Publishing.

18. Ward, K. (2008), *The big questions in science and religion* (No. 11). Templeton Foundation Press.

19. Guessoum, N. Islam And Science: The next Phase of Debates: with Nidhal Guessoum,“Islam and Science: The Next Phase of the Debates”; and Anindita Niyogi Balslev,“‘Science–Religion Samvada’and the Indian Cultural Heritage.”. *Zygon®*,(2015),*50*(4), 854-876.

20. Polkinghorne, J. *Theology in the Context of Science*. (2014), Yale University Press.

21. Poole, M. W. Science and science education: A Judeo-Christian perspective. *Soc-Cu.l Pers. Sci. Educ.: An Int. Dia.*, (1998), 181-201

22. Fulljames, P. Science, creation and. *Res. Rel. Educ.*, (1996), 257.

23. Reich, K. H. A logic-based typology of science and theology. *J. Int. Stu.*, (1996). *8*(1/2), 149-167.

24. Dillon, S., Personal Communication, 2022

25. Ratcliffe, M. The place of socio-scientific issues in citizenship education. *Hu. Righ. Citi. Educ.*, (2009), 12-16.

26. Tyack, D., & Tobin, W. The “grammar” of schooling: Why has it been so hard to change?. *Amer. Edu.l Res. J.*, (1994), *31*(3), 453-479.

27. Breakstone, J., Smith, M., Ziv, N., & Wineburg, S. Civic preparation for the digital age: How college students evaluate online sources about social and political issues.  *J. High. Educ.*, (2022),*93*(7), 963-988.

28. Kasmo, M. A., Possumah, B. T., Hassan, W. Z. W., Yunos, N., & Mohamad, Z. The Perception on the Relation between Religion and Science: A Cross Culture Study in the Malaysian Society. *Rev. Eur. Stud.*, (2015), *7*, 163.

29. Yasri, P., & Mancy, R. Understanding student approaches to learning evolution in the context of their perceptions of the relationship between science and religion. *International J. Sci. Educ.*, (2014), *36*(1), 24-45.

30. Mujtaba, T., & Reiss, M. (2022). The Development of an ‘Attitudes to Science and Religion’Instrument for Secondary School Students: How Are the Attitudes of Students to Science and Religion Associated with Student Religion and Other Characteristics?. *Educ. Sci.*, *12*(12), 937.

31. Anwar, M., Rehman, A. U., & Shah, S. Z. A. Networking and new venture’s performance: mediating role of competitive advantage. *Int. J. Eme. Mar.*, (2018),*13*(5), 998-1025.