UNIVERSITY OF HULL

Epistemic Insight

Epistemic Insight in Primary Schools

Paul Hopkins - MMXXII

Background

This project took place in four primary schools, three in Hull and one in Lincoln in the Autumn of 2021. The project had been delayed due to issues with the pandemic and there were still some difficulties in accessing schools in the Autumn term. A number of schools were approached via personal contacts of the PI (Hull) Paul HOPKINS [p.hopkins@hull.ac.uk] and six responded that they were interested in taking part in the project. In the end only four or these were able to fit into the timescales and schedules that were available between October and December, 2021. These were:

- Cavendish Primary School, Hull
- Beverley St. Nicks Primary School, Beverley
- Spring Cottage Primary School, Hull
- Monks Abbey Primary School, Lincoln

More details about each school can be found in the relevant section of this report. A materials pack was gathered for each school (see Appendix 1) and professional development (PD) was arranged either in person or via video conferencing. All the schools decided that they preferred to do the activities (Appendix 2) as a 'science day' rather than over a period of sessions and so science days were arranged where the PI could attend if possible (3 schools). The activities were undertaken by the schools and the class teachers two of the schools (Beverley and Monks Abbey) working with Year Six (10-11 year olds) and two of the schools (Cavendish and Spring Cottage) with Year Five (9-10 year olds).

Each school was provided with a pack of materials as well as bags and rulers from the project as a gift. The school were provided with equipment and the activities cards (which were reproduced at the school).

The activities - which can be found on the EI website (https://www.epistemicinsight.com) were:

- **Why do spinners spin**: looking at a paper spinner 'helicopter' with two wings,
- **Why is the sky blue**: Looking at the idea of diffraction,
- **How do clouds stay up**: Exploring the idea of surface tension,
- **In the future will people travel and live in space**: Looking at the size of the universe.

After the PD sessions sessions materials packs were delivered to the school containing all the equipment they would need for the tasks with the exception of paper or photocopying. All sessions took place in December 2021.

Contents

Methodology

The research carried out in the primary schools in Hull followed the pattern set for all the schools in the amended schedule (amended due to the COVID situation).

1. A range of schools were contacted from contacts from the local PI (Paul HOPKINS), from research undertaken by the CCCU RA (Joanne MALONE) or from contacts via the local PSQM contact (Bryony TURFORD),
2. Six schools then agreed to take part in the project but sadly one of those then had to drop out and one was unable to take part due to COVID restrictions,
3. Four schools were left all of whom had pupils in Year 5 or Year 6
4. Professional Development was delivered either face-to-face or online to the participating schools to the Science Lead and to the class teachers who were to be involved in delivery of the project: all the schools decided to deliver the project as a science day,
5. Equipment and support materials were delivered to the schools for the beginning of HT2 and the days agreed. For three of the schools the PI (Paul HOPKINS) was able to attend for one school this was not possible,
6. The schools completed the pre-survey,
7. Three / Four activities were undertaken either in the school or at home,
8. The lessons were observed,
9. The schools completed the post-survey,
10. Teachers were invited for interview,
11. Report was written up.

St. Nicks Primary School, Beverley

The School

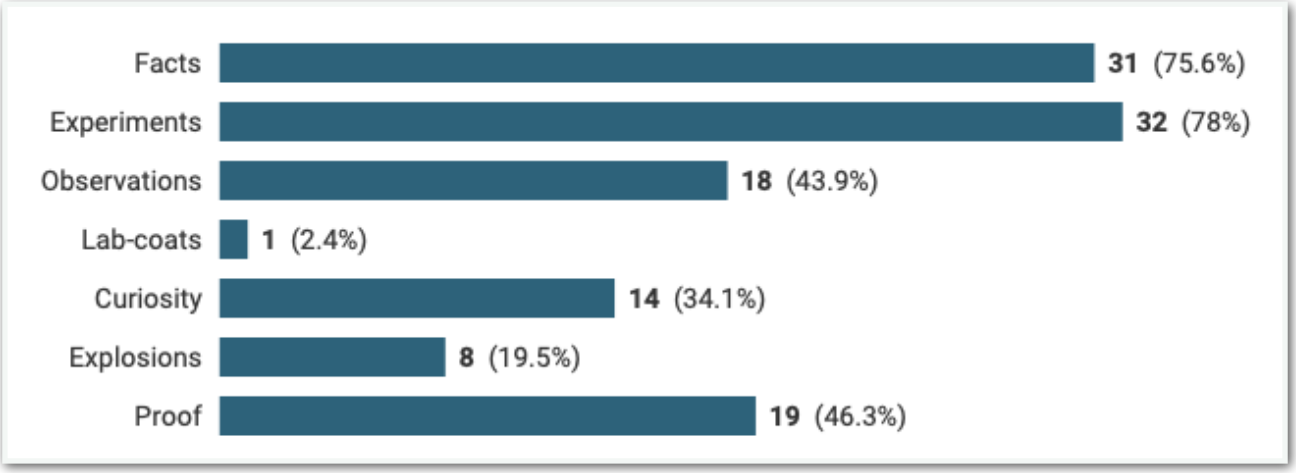
St Nicks Primary School is situated on the East side of Beverley, a small town just north of Kington-upon-Hull in North Yorkshire. The school is a single form entry school with a larger than average number of pupil premium children. The majority of the students are white British heritage. The proportion of children with an identified SEND is also well about the national average. The school is on two sites with the Early Years and Key Stage 1 children on one site and the Key Stage 2 children on another. Science was not mentioned in the 2018 short report from Ofsted or the last full inspection report in 2014.

Pre-Survey Data

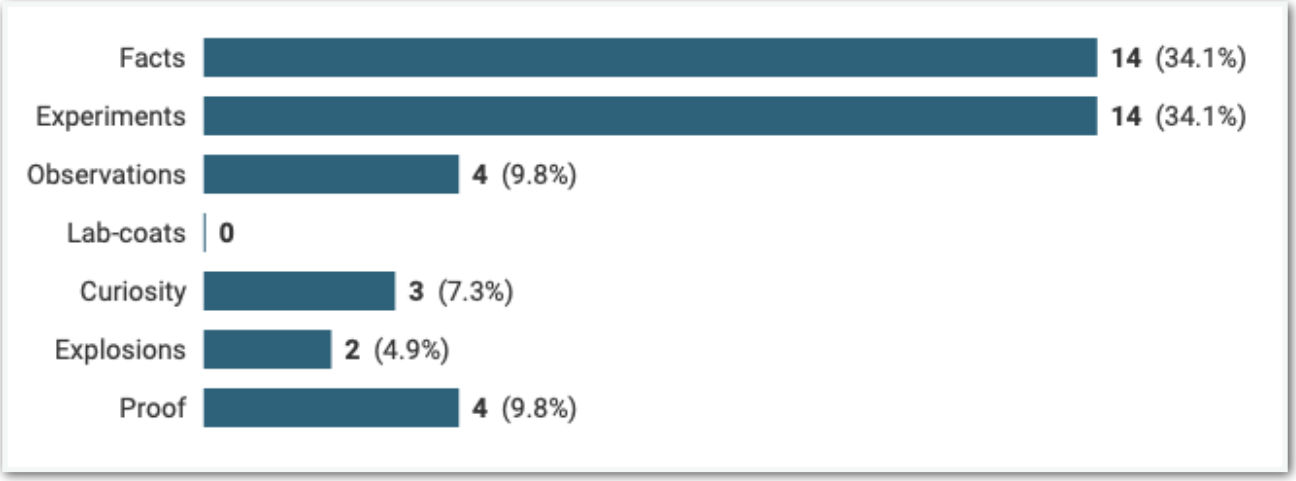
The complete dataset for the pre-survey questions can be found on the online survey website - below are some key highlight taken from the data.

41 children completed the pre-survey **(n=41)**. All of these children were in Year Six.

When asked for three key words about science (Q6) they responded:



Facts (75.6%) and Experiments (78.0%) were given by over three-quarters of the children. These two words also dominated the single word choice (Q6a):



When asked about the term 'discipline' (Q7.1) a significant majority of the children (80.5%) indicated that they had heard the term discipline. A minority (37.5%) reported that they has learnt about this at school (Q7.2) with 42.5% unsure and 20% disagreed.

When asked to give qualitative answers to the question about, 'what is a discipline?' (Q8) there were a range of answers but most falling into the category of behaviour with answers such as:

"A punishment if you have been bad"
"A telling off"
" A discipline is where someone was naughty so you discipline them so they don't do it again"
"When you have been bad and you get disciplined"
"Discipline is where if you are bad you get a bad consequence"
"Where you have been disciplined so you had to stay in at break"

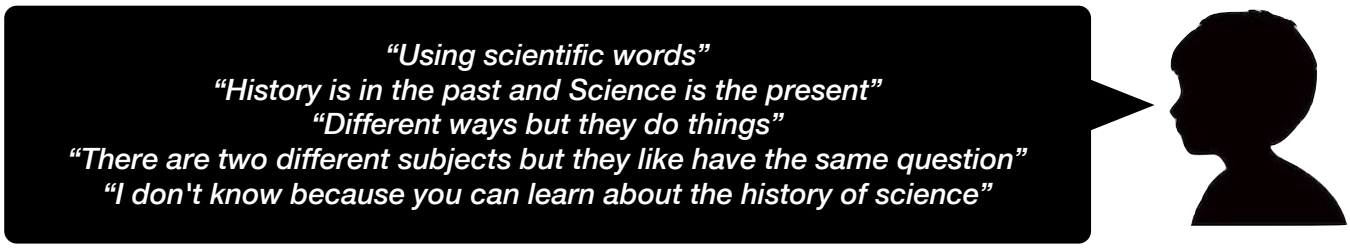
About 40% (15/41) were not able to answer the question. Just under half of children (48.8%) agreed that they know what makes a science question different to a history question (Q9) with a range of answers (Q10), some more 'sciencey' such as:

"History is past and science is evolution in part/present"
"Science is more experimental"
"Science questions have more facts. History questions have dates"
"Science questions are more scientific and history questions are about the history of the past"

Some more focussed on content:

"Science has science words and history has old history"
"Because history is like the ancient Egypt and science chemicals"
"In science they have chemicals. In history they are old"
"Science is about experiments and stuff like that and history is about our country's past and historic things"

and others a little more esoteric!



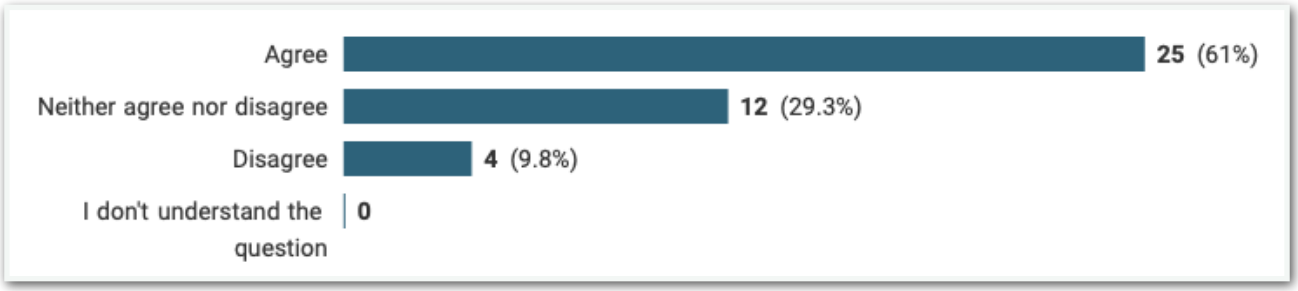
When asked about what makes a question good for science (Q11) 46.3% agreed that they have learnt this in school and the qualitative answers (Q12) gave answers including science content, "Things to do with DNA" or "How space makes people float but not on Earth " or with science processes, "They would use scientific vocabulary", "If you can figure it out"

When asked about topics they would like to investigate as a Big Question (Q13) there were both testable and philosophical questions e.g.:

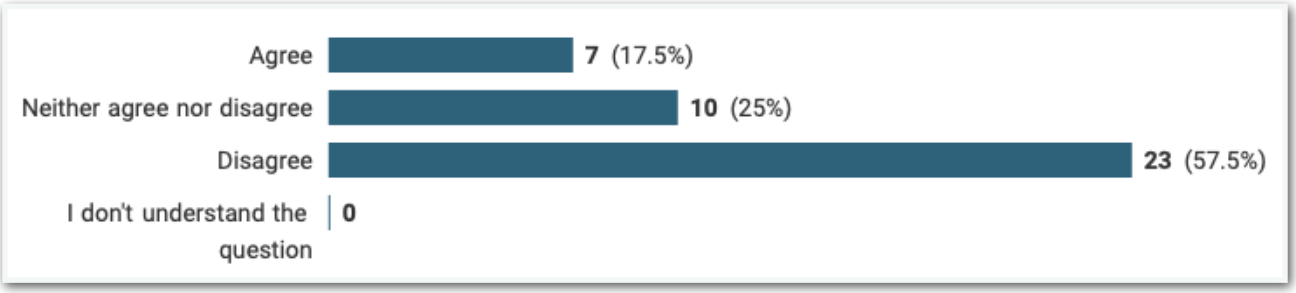
Testable:, "Are there other planets than the eight we know?", "How can we float in space but not on Earth", "Why is the sea blue?", "Can you make a rainbow out of water?", "Can we be invisible?".

Philosophical: ""Why does the universe exist?", "What if we were not humans and a different species", "Who makes words and colours?", "What is at the end of space and everything", "Why can't we think of new colours?".

When asked about big questions like 'whether a robot can be like a person (Q14.1) there was a strong agreement that it could,



but a smaller group of indicated that they had such conversations at home (Q14.2):



When asked if they talk about science at home (Q14.3) then about a third of students (35%) indicated that they did, whilst another third (40%) were neutral and about a fifth (22.25%) saying that they did not.

When asked the more qualitative questions about why humans exist (Q15) there were a range of answers. Again some linked to science ideas, though often showing misconceptions:

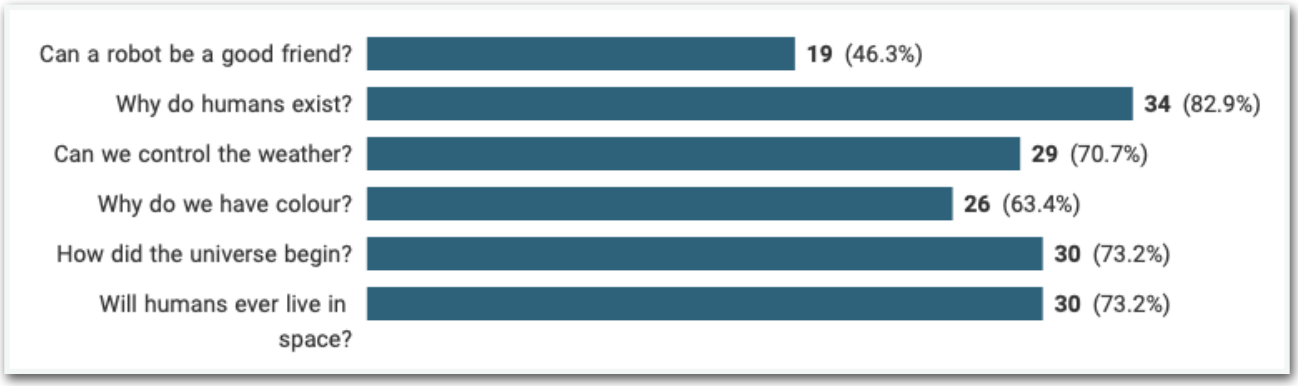
"Humans exist because when the world was made there was animals & humans"
"I think humans don't have a purpose we was just created by something and humans grew smarter over time"
"Maybe because 200 million billion years ago a bang created the universe"
"We are just like animals so to keep the cycle going"
"Because dinosaurs died and now we are here"
"Because the DNA from the dinosaurs have made a human"
"They exist to be like how animals exist because of evolution"
"Because animals have evolved into humans"

Some rooted in more deistic or moralistic reasons:

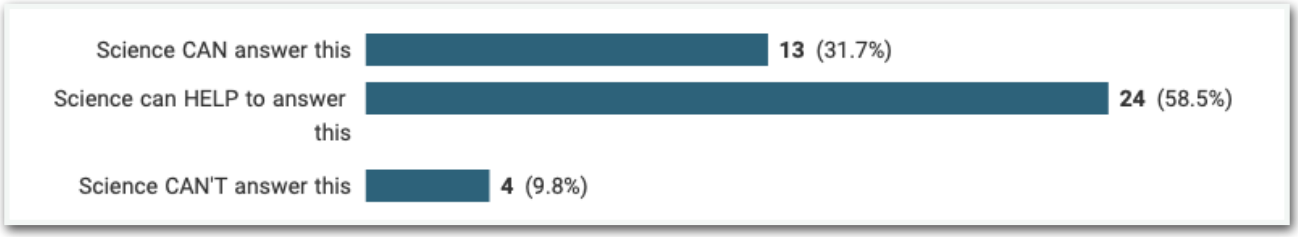
"I think we exist to make the Earth a lot better and to invent stuff"
"Because God created us and the eco-system wouldn't work without us"
"God made them"
"Because God made the first humans and then they made babies"
"Because maybe God made humans"
"To give purpose to the world"
"I think humans exist so the world is a nice fun place"

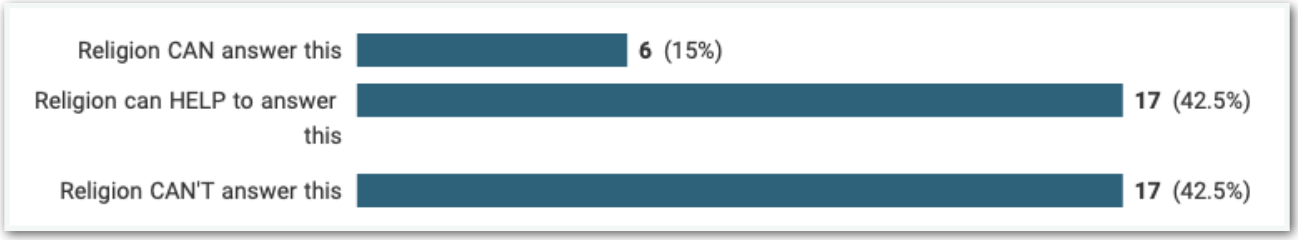
about a quarter (14/41) answers that they did not know or did not answer.

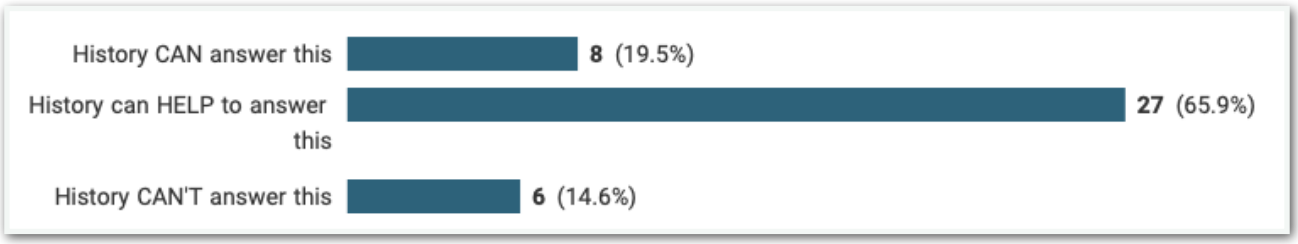
When asked more generally about big questions (Q16) the children were interested in most of the questions - but most in 'why humans exist' (82.9%) and, 'how did the universe begin?' (73.2%), and least in, 'can a robot be a good friend (46.3%).



When considering how the different disciplines of Science, History or RE could answer the question, 'why humans exist' there were a range of answers.

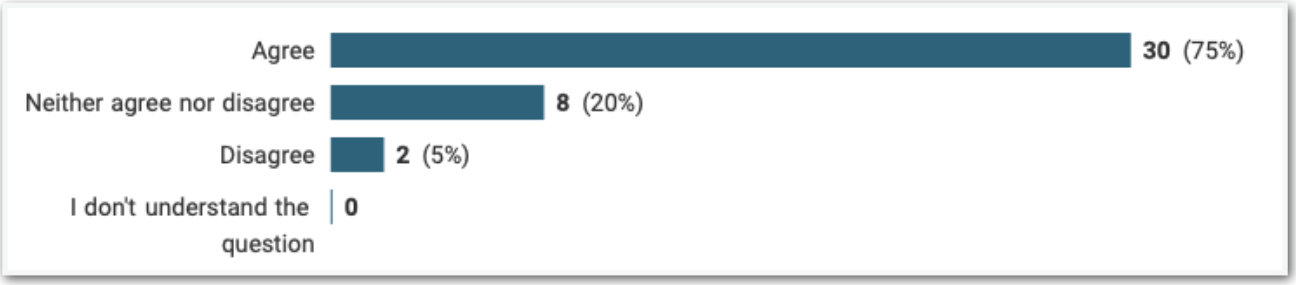






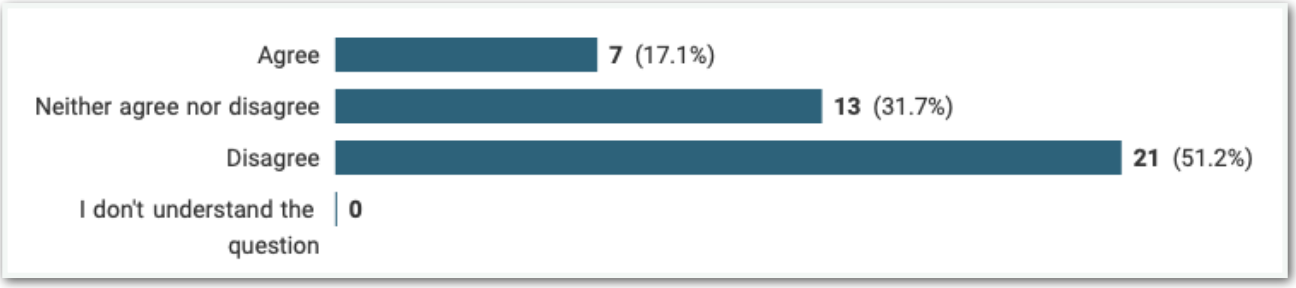
We can see that children felt that science was most likely to be able to answer this (31.7%), with religion least likely (15%) but that all could help. When asked which discipline could NOT answer religion was the highest with nearly half of the children (42.5%) stating that religion could not answer the question.

Children agreed very strongly that they enjoyed science (Q20) with only 5% disagreeing and the vast majority (75%) agreeing.



Coming onto technology and if machines (exemplified by the smartphone) would be smarter then them (Q21.1) there was a division of opinion with equal number (48.8%) thinking there would be and being neutral. When asked if there was already a smartphone cleverer than them 41% agreed but 53.8% were more neutral.

Finally, children were asked about a possible career in science (Q22.1).



About a sixth felt they would but a majority felt they would not (51.2%).

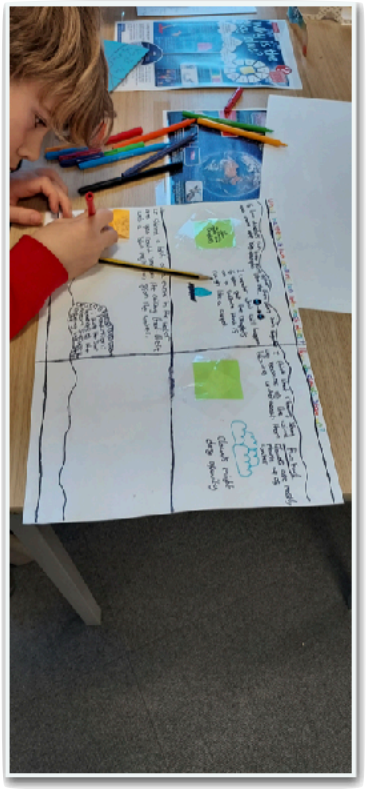
When reasons were given there were a range of reasons.

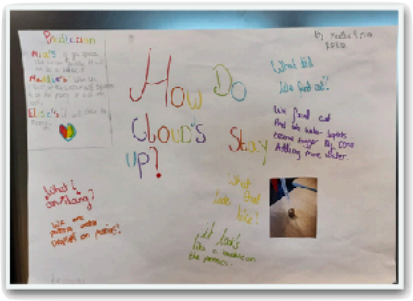
"I don't want to be a scientist because I want to take other jobs"
"No, because I don't want to do experiments that are dangerous, when I am older I want to be an artist"
"It would be very hard and confusing"
"Because I want to be a photographer not a scientist"
"Because I want to be a professional rugby player"
"No because it's too complicated"
"I only like art and science is in it so I guess it could be my future job"
"Because it is a little bit boring and I like sport"

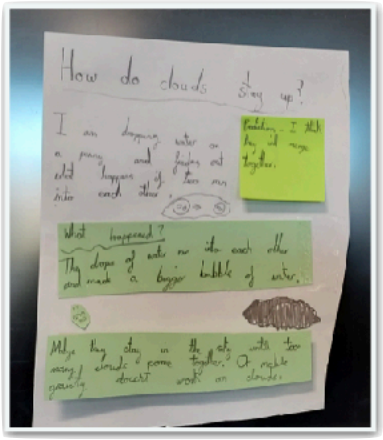
A number of themes emerged from this, small, sample that science not seen as something that applied in wider life, but was often linked to laboratories. There was little understanding of wider disciplines such as sports science, or food science. The second was that science is ‘hard’ or ‘complicated’ and they would not be able to do this and others that they wanted to do something else where science was not seen as relevant.

The Activity Day

The children carried out the activities in a single day with one of the activities being taken home. The PI was not able to be at the school during the activities but the school completed the day and reported that the children were engaged with the activities exploring the key ideas and asking questions about the deeper nature of science and other disciplines. They looked at all the activities and explored some of the big questions looking at the epistemic angles on the questions.







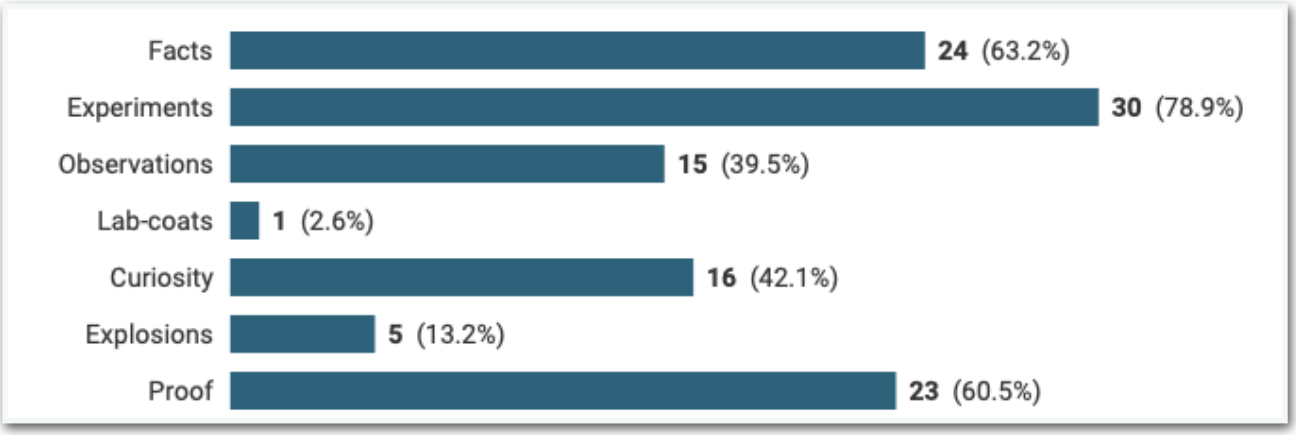
Post-Survey Data

The post-survey questions were carried out at the end of the day, after the activities had been completed.

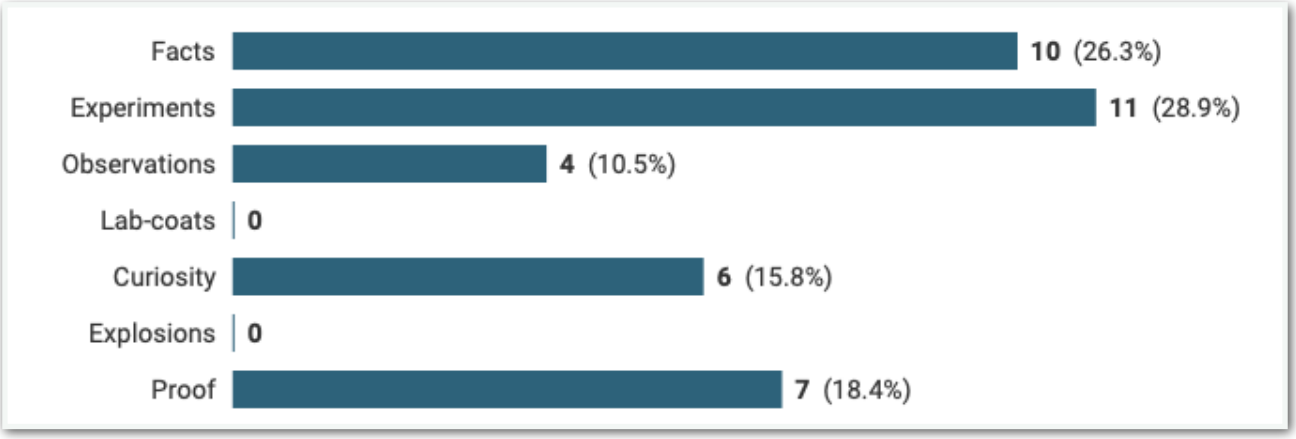
The complete dataset for the post-survey questions can be found on the online survey website - below are some key highlight taken from the data.

38 children completed the post-survey **(n=38)**. All of these children were in Year Six. In the data below the PI picks some key ideas ideas that indicate any changes from the pre-survey data.

Q6a/b asked about key words:



There were some changes from the pre-data with 'Facts' dropping by 12 percentage points (pp), Experiments remaining the same but observations rising 4 percentage points. Facts and observations were still the most popular choice.



When considering just one word (Q6b) again facts fell (8pp), Experiments fell (5pp) and observations (2pp), curiosity (8pp) and proof (8pp) rose.

Interestingly, the rates for knowing about discipline (Q7.2) fell by 18pp to 52.6% and those who disagreed rose slightly by 4pp to 23.7%. Likewise the percentage who said they learning about this at school fell by 11pp to 31.6% and those who disagree rose by 4pp (23.7%). The majority of the qualitative statement were still around punishment or behaviour, though the percentage of those saying, 'do not know' had dropped slightly by 6pp to 34%.

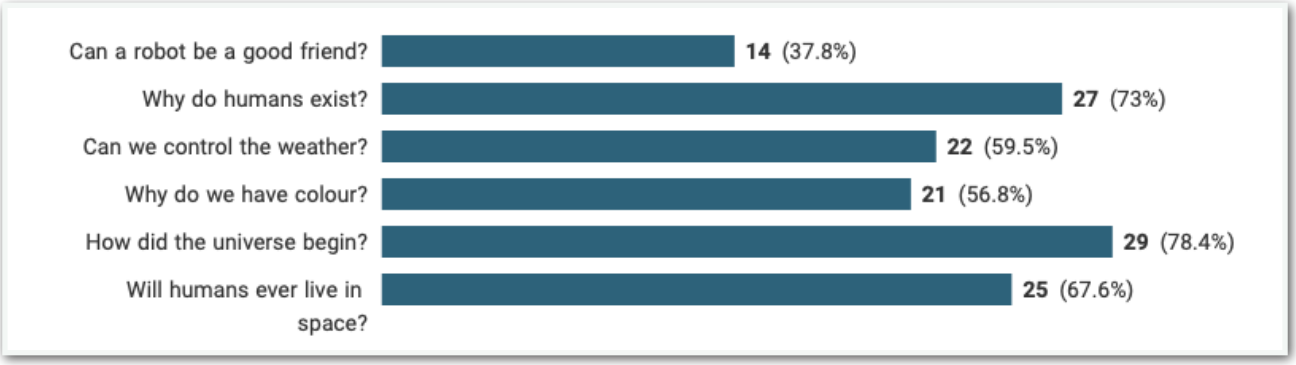
The number of children able to differentiate between a science question and a history question (Q9) rose by 14pp (to 63.2%) with more emphasis in the qualitative answers (Q10) on 'proof' or 'facts' or 'experiments'.

The percentage of children who thought what they had learnt at school make a good science question (Q11) rose significantly by 25pp to 77.1% with again a range of qualitative answers but there was more emphasis on testable questions and fewer more philosophical questions (Q13).

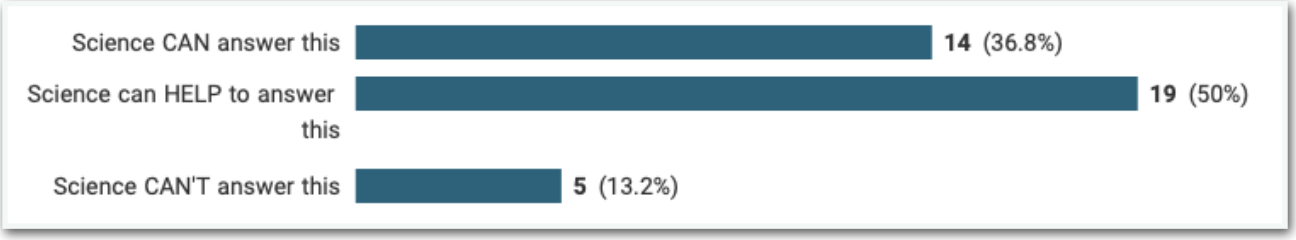
There was a small rise (Q14.1) in children agreeing they like to think about big questions (7pp) and a rise in the percentage who said they talked about science at home (9pp). (Q14.3)

There were similar science, "Because they transformed from monkeys", and philosophical/theological answers, "I think exist because God created us", to Q15 on why humans exist but perhaps a shift towards more science like questions. There was a reduction in the percentage of 'don't knows'.

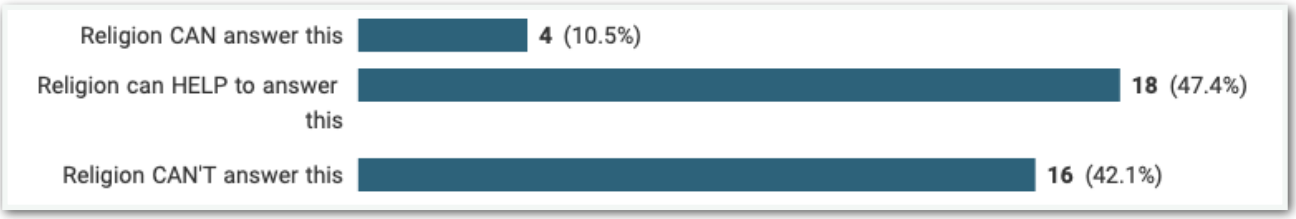
When asked about 'big questions' (Q16) there was a slightly more even spread across the answers:



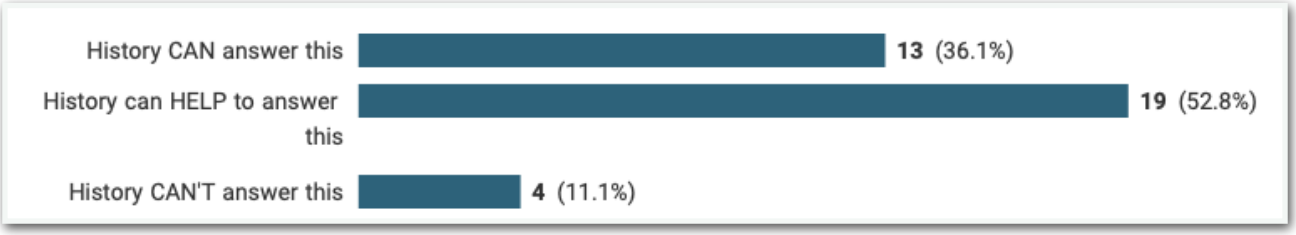
When considering the disciplines' contribute to knowing (Q17) there were some changes:



For science CAN was up 5 pp and religion CAN was down 5pp

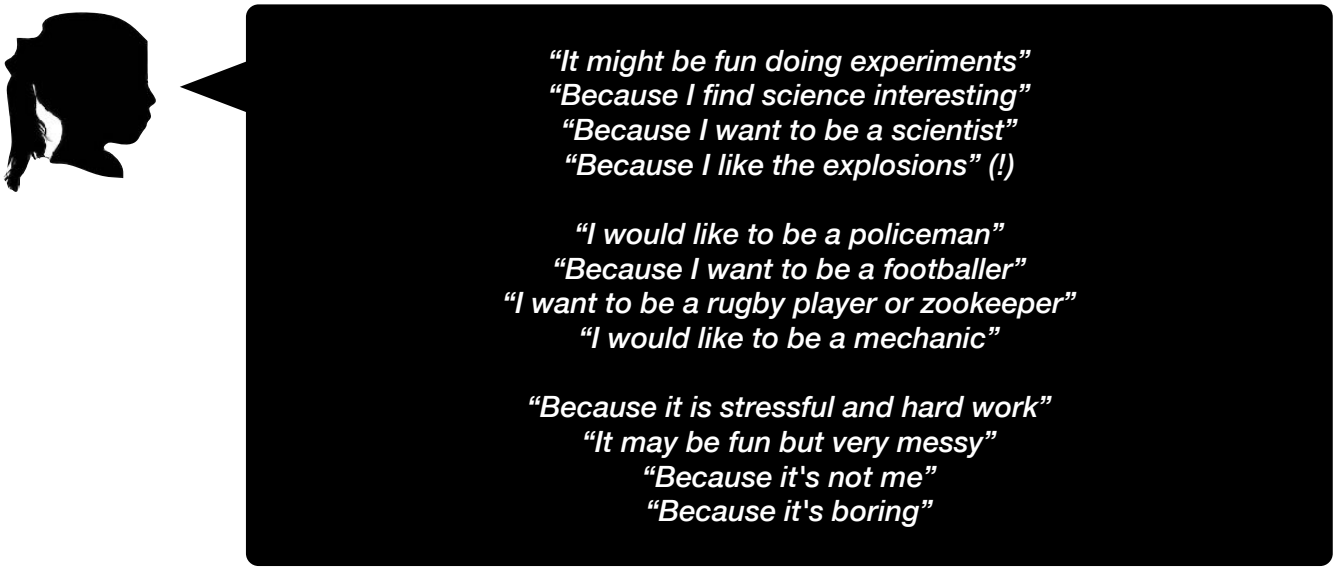


with History CAN was up significantly by 17pp.



More children now stated they liked learning science (Q20) up by 5pp. The number of people who thought there would be a smartphone smarter than them in the future (Q21.2) was up by 5pp though those who thought there was not stayed at 41%.(Q21.2).

When thinking about a career in science that had risen by 5pp to 22.9%, with a range of responses which had similar themes to the pre-survey:



Finally, in the post survey the children were asked which areas they enjoyed most. The children were generally enthusiastic with the majority commenting that they really enjoy doing experiments and investigations – perhaps indicating that this was not a common activity in their normal lessons. Comments included, "Looking at things and looking for investigations", "The experiments because you can find out new things and have fun", "Looking at things and looking for investigations" and "Learning how to answer the big question".

Teacher Interview

A short interview was held with the teacher. The answers below are paraphrased notes on the answers, rather than transcriptions The recorded interviews are available.

How did the activities go?

There was some initial difficulties in that the children did not know what to do. A carousel of activities were set up but the children struggled to understand the instructions and what they had to do. The children were keen to undertake the practical work but without reflecting on the questions being asked or considering the purpose or nature of the activity.

Has this resource helped you to think about the types of questions science asks and how it prefers to investigate them?

They were not making links between the practical activity and the bigger question. The teacher did not give any direct instructions apart from allowing the children to present their findings after they completed all the activities. They were able to choose how they presented these activities. The children struggled to present their ideas, they were able to articulate that they enjoyed the activities but not what they had investigated or discovered. They were able to present some thoughts for example they thought the sky was blue because of the ocean, the teacher said that she thought they had not carefully read the instructions because, "the answers were all on the sheets".

After they had completed the carousel of activities the teacher brought the children together to talk more about the activities. For example, in the space activity they had drawn out the scale but was struggling to relate this to the question about space travel. The teacher then use probing questions, such as, "if this distance take six months then how long would…", The children were then able to start to make inferences and connections. As the teacher said, "it clicked but they needed the input".

What does a normal science lesson look like at your school - how did these activities compare to what normally happens?

We use Snap Science© from Collins Connect. The school is a PSQM (Primary Science Quality Mark) school. One of the things which the school states they got from undertaking this scheme was a more coherent curriculum. Every lesson in the scheme starts with a "big question" - reflecting on the epistemic insight questions the teacher thought that they might need to adapt the way of doing this to you again consider the children undertaking the investigational work and then exploring the big question. The teacher felt there was a lack in the children's investigational skills but this may be linked to the content heavy nature of the curriculum and a large amount of "stuff we have to give them" as part of the curriculum. The teacher is confident that the science of the school is good but thinks there might be some tweaks to undertake having looked at the EI materials.

To what extent were the activities useful for teaching children about the nature of science?

Following on from the EI materials the children had a science based assembly and the teacher feels that the nature of the activities had developed the children's skills in undertaking investigational work and being more self-confidence and self regulated.

Did you notice any difference in engagement in different groups in the class?

The teacher reported that those who are normally the "high flyers" struggled more because they just wanted to, "give the answers". They did not make links between the practical work and answering the questions, whist the more 'middle group' achievers well willing to undertake the investigation work. Again an expectation of wanting the "correct answer" meant that sometimes the higher ability children made it more complicated rather than, "just having a go and enjoying the activities".

Did you notice your students using EI / scientific enquiry language?

The teacher reports that she did, but the students didn't so much. Again after the science assembly a week or so later perhaps a little bit more but not during the activities.

What opportunities, if any, do you usually have for talking about Big Questions in class

The reports that they, "talk about big questions a lot" but we do not investigate them. The RE topic is on big questions so there there is a lot of discussion that takes place but not so much investigation, the teacher reflected that they, "probably do not do enough of this".

Questions arise from work but there is a lack of self regulation, confidence, or independent ability to be able to go away and investigate questions without significant support. The teacher reflects that the school does so much spoon feeding, especially in year six, that these opportunities are rarely available. This can lead to the children wanting binary yes/no answers to questions rather than being willing to have more ambiguous answers. The teacher linked this to the assessment practices in Year Six (SATs).

What impact have using the resources had on you as a teacher

That we really enjoyed this. From the teachers perspectives this was "eye opening" and the process has definitely helped them as teachers in considering how they are approaching the teaching of science (and possibly wider). The teacher commented this is especially true with the use of science and epistemic vocabulary, and that this should lead to some teaching practice.The teacher is keen to encourage the children's interest in science particularly as many seem disillusioned when they reach secondary school. She was keen to give him the idea of potential careers in science and where this may lead. She reflected that many children do not consider how wide the range of careers that involve sciences and that whilst Covid-19 has

highlighted some of these it has also reinforced, to some degree, the idea that scientists are people "in white coats”.

Researcher Reflections and Commentary

There is no doubt that the children engaged and enjoyed the activities but there is still obviously a lack of connection between the practical activities and the wider questions. It is also evident that the current science curriculum in the school is still being seen in a delivery mode and with the idea of exact and correct answers rather than a more investigative mindset.

The children's answers to many of the questions in the surveys indicate again some misunderstanding of the particular nature of science as a testable, and repeatable activity which gathers data in order to answer questions. There is still some misunderstanding and misconceptions between the more historical or philosophical nature of knowledge and the scientific nature of knowledge.

It is interesting that the school has recognised the importance of questions and how these questions can help frame thinking in science, as well as the importance of investigational work in other areas of the curriculum. It is also interesting that they have recognised that an "overstaffed" curriculum can be detrimental to a wider idea of learning.

Cavendish Primary School, Hull

The School

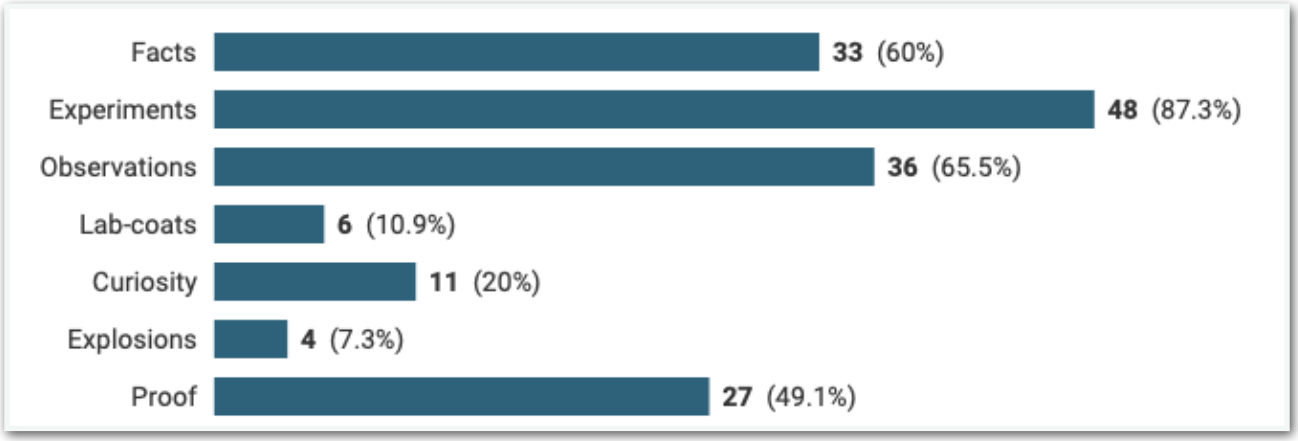
Cavendish is a two form entry school of about 400 children aged 4 to 11, located to the East of the city of Hull. The portion of disadvantage pupils is below the national average whilst the proportion of pupils receiving support for SEND is above average The school website states that, *"we believe that education is about the whole child and we see the children at our school as individuals who all have the potential for excellence"*. Science is well represented and there are colourful and relevant science displays in the corridors. Their last Ofsted report (2018) placed the school in special measures but makes positive comments on the teaching of science, where it comments that, "teachers have been involved in planning topics which link subjects such as history geography and science together to make learning more meaningful to pupils, as a result pupils hold very positive views about their topic work"

Pre-Survey Data

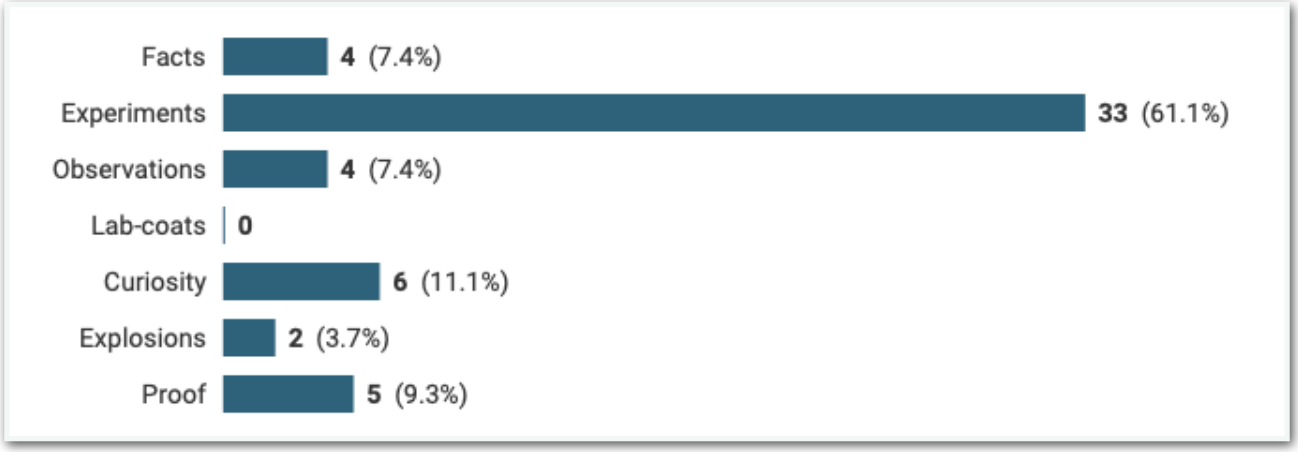
The complete dataset for the pre-survey questions can be found on the online survey website - below are some key highlight taken from the data.

55 children completed the pre-survey **(n=55)**. All of these children were in Year Five.

When asked three keywords about science (Q6a) they responded:



You can see that experiments was the dominant choice (87.3%), with facts and observations chosen by around 2/3rds of the children. When asked to choose a single word (Q6b) again experiments dominated very strongly (with curiosity and proof second and third.



It is noteworthy here that experiments was so dominant having six times as many answers as any other.

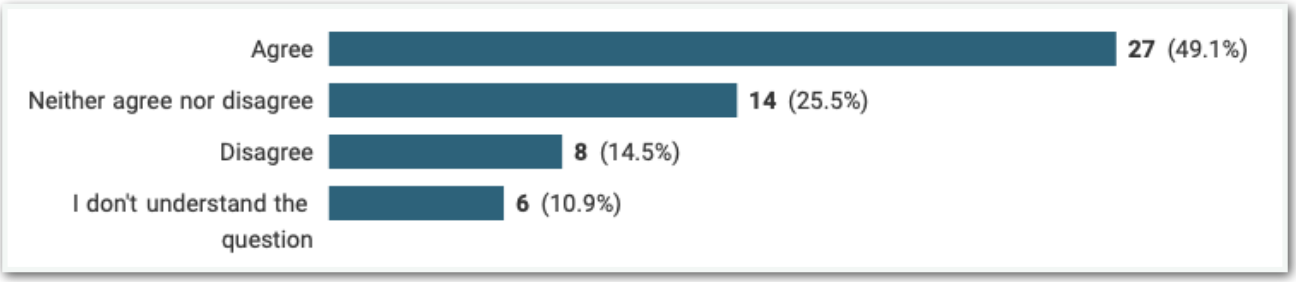
When asked about the term discipline (Q7.1) a small majority of the children (58.2%) indicated that they had heard the term discipline. When asked if they had learnt at school but a discipline is (Q7.2) 29.6% agreed, 31.5% were neutral and 37% disagreed.

When asked to give qualitative answers to the question about, what is the discipline? (Q8) there were a range of answers but a significant number of these were don't know (58%) and the majority of the others were related to behaviour or to punishment:

"I think that discipline is aggressively hurting something"
"say you are being a bit silly and you have to and sit on the stairs"
"It is, if for example you are messing about and you are told to stand outside"
"something you do wrong then you get told off"
"Something happens when you are lazy or angry"
"I think discipline is if you do something wrong you get told off"

Although there were a couple of other responses around the nature of self discipline, "I think discipline is when you are focused on something" and "It is where you have certain standards".

Considering the nature of knowledge, the children were asked what makes the science question different to history question (Q9), just under half agreed they knew the difference whilst a quarter we're not sure and about a seventh disagreed.



When considering qualitative answers to this there were a range of responses some of these were more focused on science type knowledge, whilst others were focused on content and others more philosophical.

"A science question is mostly base off of an experiment you have done. A history question is based off of the past"
"It is different because history is about the world in the past and science is about experiments"
"Because a science question about nature or an element and a history question will be about the past"
"science is doing facts about an experiment and history is facts about the past"
"A history question is about the past and a science question is about discovering something"

"A science question could be "how warm it is?" and a history question could be "what did Columbus find?"
"A science question isn't about like Romans or WW2"

"Well science and history are two different things so you would know for example what did the Germans take over in WW2? and how much atoms make a ball? They sound different, you would know"
"It makes a difference because history the past science the future"
"A science is different to history question is that science is different theory to science theory"
"Some questions are scientific and some questions are historical"

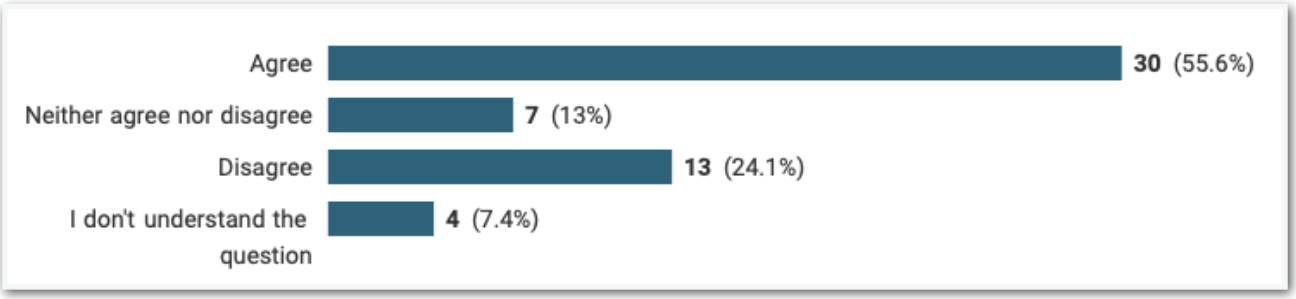
There was a strong thread running through this of history being about 'the past' and science being more about things that are, of the 'now'.

The children were positive that they had learnt what makes a question a good question for science with just over half (54.5%) are green and only about a 10th (9.1%) disagreeing. Whilst again a significant proportion of children gave a, "I don't know" answer (28.5%) to the qualitative question (Q12) there were some thoughtful answers rooted in scientific process e.g. "What have you learned about in this experiment and was your prediction correct", "A good question for science to answer is that science can actually answer it", "A good question would be what is dark matter made of?" and "When the question is observational and based on the experiment", showing and understanding that science must be testable, and a number of answers rooted in scientific knowledge, e.g., "Is it a solid, liquid or gas?".

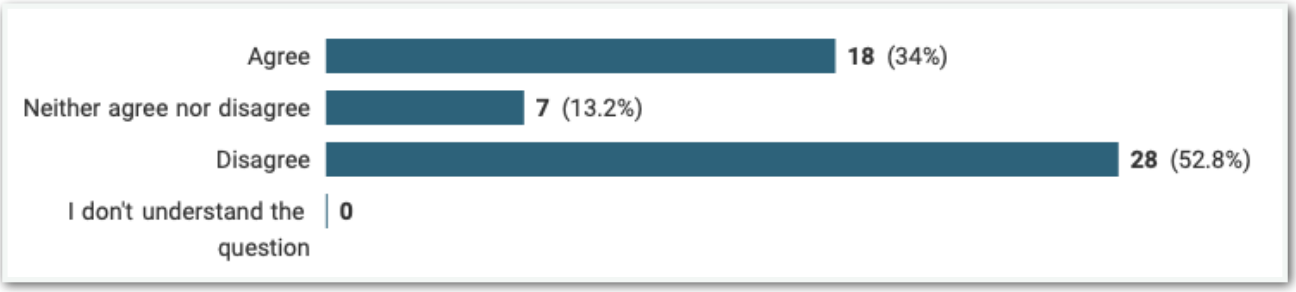
When asked about big questions the answers give were a mix of testable & philosophical questions. Testable Qs included, "Can you make blind people see?", "Can we control the weather?", "Can we survive on different planets?", "Why are

there rainbows in the world?"; and more philosophical questions included, "Why does the universe exist?", "What was the time when time was invented?", "Can a robot be like a human?" and "Can we discover everything from the past?".

When asked about big questions, such as kind of robot to be like a person (Q14.1) they responded:



And if they talk about such questions at home (Q14.2):



And if they talk about science at home (Q14.3):

There is some disjuncture between liking to think about such questions, where just over half agreed (55.6%), whether they talk about such questions, just over a third (34.0%) and if they talk more generally about science, again just under a third (32.1%).

When asked them more qualitative question about why humans exist (Q15) there were a range of answers, including about 28% who did not know. Some of these links to more scientific explanations:

"Humans exist because chemicals and orbs were blasted into space and slowly made planets"
"Humans exist because they formed or evolved from monkeys"
"I think that humens was monkeys and after 1000 years they became humans."
"I think humans exist because radiation from a meteor created an atmosphere and created evolution"
"I think humans exist because we evolved from monkeys and that's nature"
"I think they exist because they are an animal"
"I think humans exist because earth is the only planet fully in the goldy locks zone which is a perfect place to live"

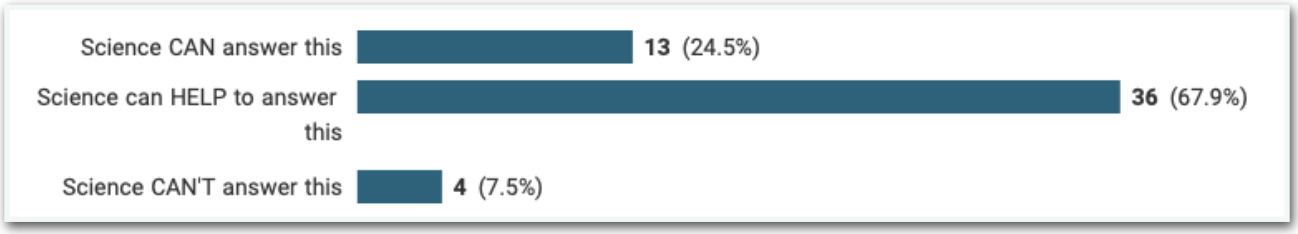
A number of these scientific type explanations indicated some significant scientific misconceptions.

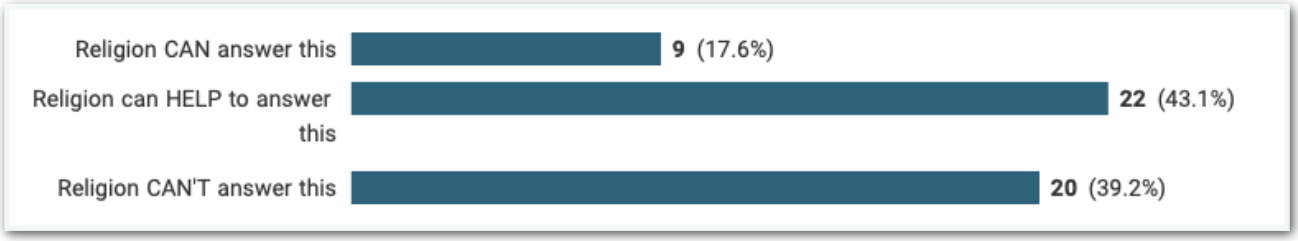
And some more rooted in deistic or moralistic explanations:

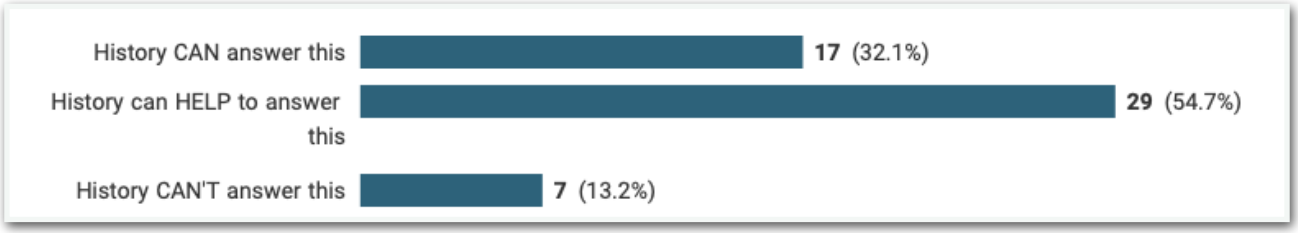
"Humans exist because we can help the plants and trees grow and look after the sea"
"To make the earth make something"
"I think humans exist because then it can make the world a better place"
"Humans exist because Jesus needed someone to protect the world and look after it so that is why humans exist"
"Humans exist because they have to look after the planet"
"I think humans exist to keep everything in order"
"I think humans exist because a long time ago before everyone there was no light at all, then on day god created the world"

When asked more generally about big questions and which questions they are interested (Q16) in children responded positively to most of the answers. The least positives were, 'can a robot be a good friend?' (37.0%), and 'can we control the weather?' (55.6%) and the most positives, 'how did the universe begin?' (77.8%), and 'why do we have colour (74.1%).

When asked to consider why do humans exist (Q17-19) children responded in relation to different disciplines:

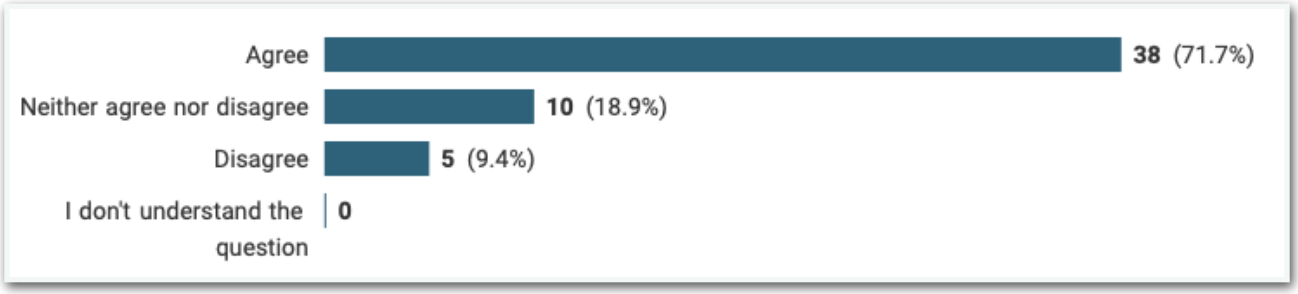






We can say that children felt that history was the most likely to be able to answer this question with about one third of children agreeing (32.1%), Science next with about one quarter of children agreeing (24.5%) and religion last with only about one sixth of children agreeing (17.6%).

Children agreed strongly that they enjoyed learning science (Q20) with almost three quarters agreeing that they did and only about a tenth (9.4%) disagreeing.



Likewise a large majority of children (80.4%) thought that one day there would be a smart phone smart of them themselves (Q21.1), although only 71.4% thought that there currently was (Q21.2).

About a quarter of the children (24.5%) are considering a career in science when they grow up (Q22.1) with another fifth unsure, but a slight majority (55.8%), not currently considering this.

A range of reasons were given for this, some linked to career choice:

"Because I just don't want to be a scientist"
"Because I want to have a different job"
"I would like a different job"
"Maybe. I want to be an actress, but when I was little I wanted to be a scientist, so maybe"
"I like football and I want to be a footballer"
"I would not like a career in science because I want to be a zookeeper"
"I want to be a cook not a scientist"
"I don't want a career in science because I'm more interested in nature and animals and I'd like to be a vet"

Although some of these showed a misunderstanding or limited understanding of the careers that science could impact or be involved in.

Someone more links to a dislike of science, or finding science difficult:

"because I don't like science"
"Because I don't enjoy learning science and I enjoy sports a lot more"
"Because I don't enjoy science and I need a lot of help on it because I don't get all the words"
"Because it will be to hard work"
"Because I don't think I am smart enough"
"Not interested in science that much"
"I wouldn't because it is dangerous, confusing and I don't know much about it"

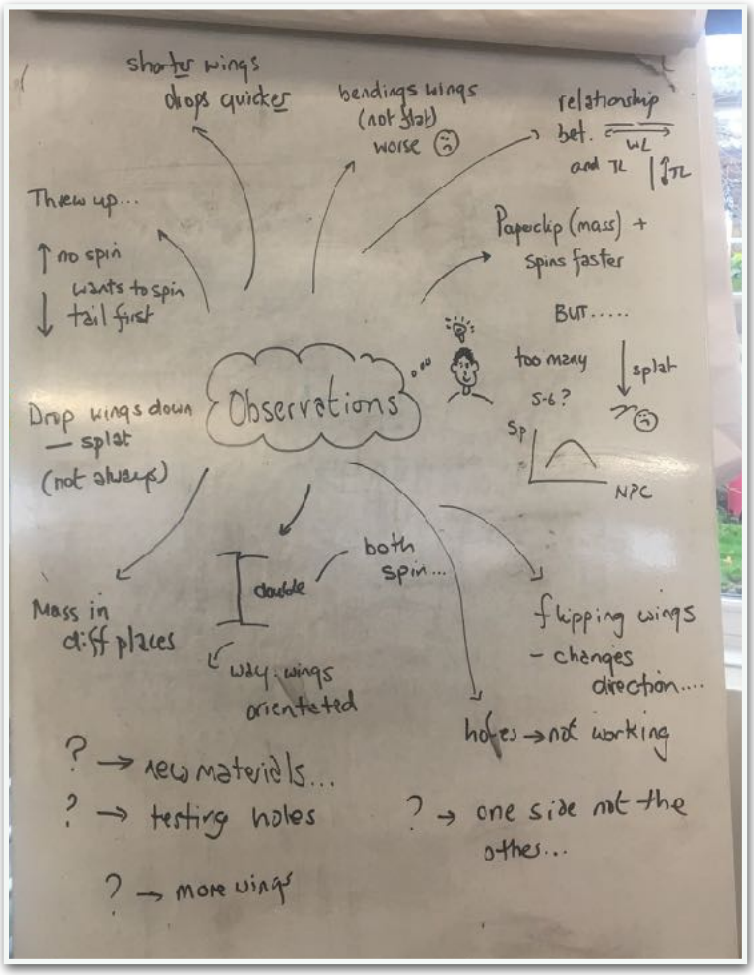
Though some were more positive:

"I love science and space so why not I explore it even more! I could look at samples and do cool stuff so I would like this career"
"I would like a career in science because I would like to advance society and discover the secrets of the universe"
"Because I want to explain and proof big questions"
"I want to have a career in science because I like the experiments and discovering new things"
"I would to have a career of science because it is very interesting"

The Activity Day

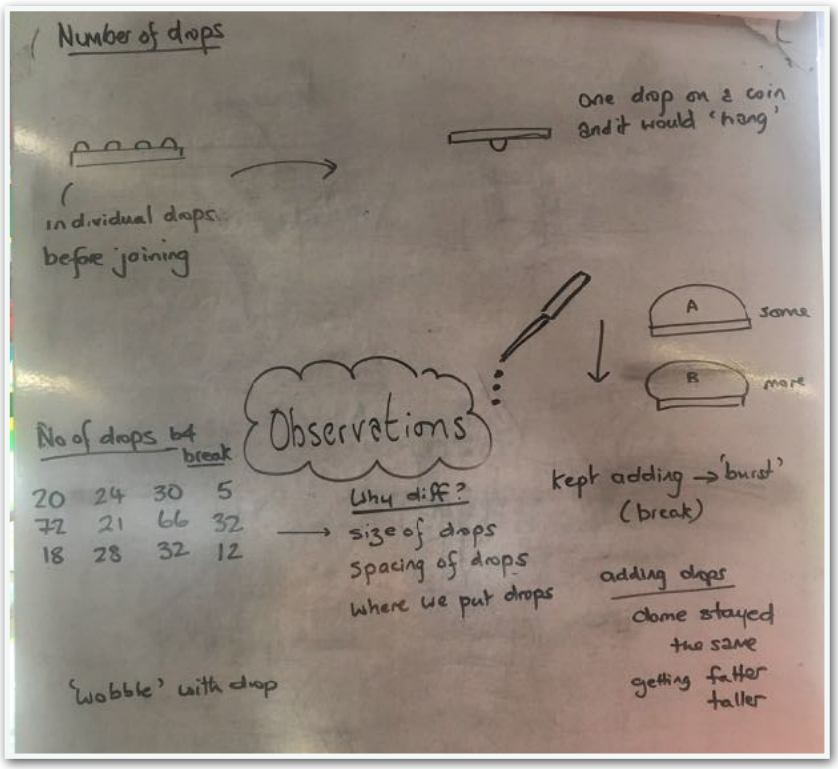
The PI was able to take part in the activity day at Cavendish School. There were two parallel year five classes undertaking the activities and these classrooms were next to each other. The PI introduced the activities for the children in turn and then worked and reflected with each class whilst the class teacher was keeping an eye on activities whilst the researcher was with the other group.

In the morning the classes looked at the spinner activity and the water drop (cloud) activity. In the afternoon the classes looked at the diffraction activity. There was no time during the day for the final travel in space activity but children were given the opportunity to undertake this at home at their own leisure. The day started with the pre-survey and finished with the post survey.



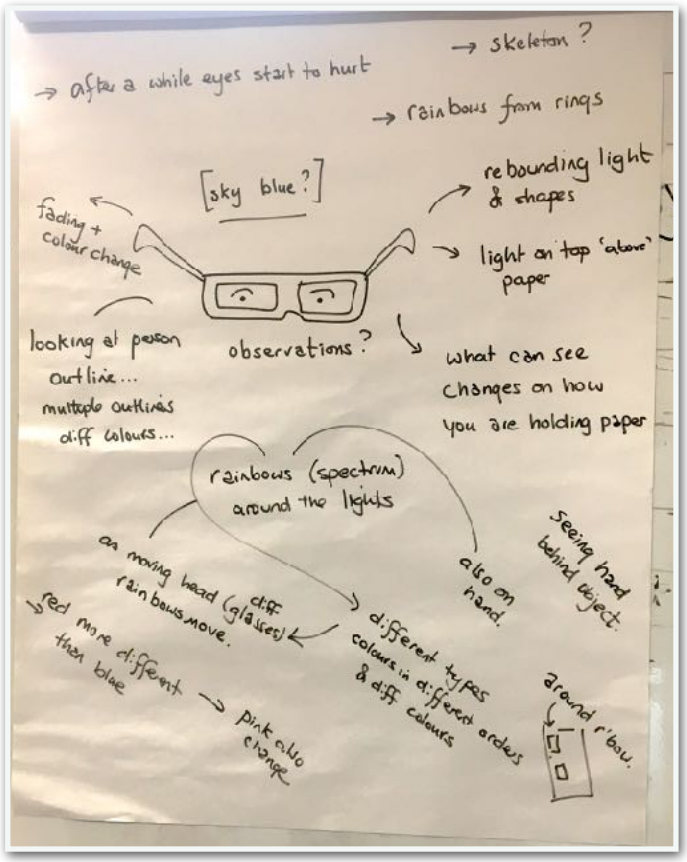
The children were very engaged in the activities and very keen to get involved, but there was a tendency to jump into the practical activity without some reflection on the wider ideas. It was necessary to stop the children on occasions in order to get them to reflect and consider some of the underlying scientific ideas that were being explored. However, when prompted the children were able to expand and explore on the initial activities and to raise subsidiary questions to further explore themselves. As can be seen from the attached image the children were able to observe carefully, consider and hypothesise, and then raise further questions for

exploring, e.g. how would the spinner be affected if it was made from different materials? What would happen if the wings were bent different way? What would happen if we adjusted the relative relationship between the size of the wings and the body? What would happen if we added more mass? Some children also started to develop some systematic thinking, discovering that adding some paperclips improved the spinning of the spinner whilst adding many paperclips made the spinner drop very quickly without spinning, with this group we reflected on the idea of an optimum number of paperclips.



Likewise, when exploring the droplets some the students had a number of very interesting observations over how droplets were placed, the variation in size of droplets, the spacing of the droplets. They were quite systematic in using these observations to reflect on the nature of the investigation and the impact of this on the overall data. When we gathered data on, 'the number of drops until overflow' we found that the number of drops varied hugely between different groups; this engendered a lively conversation around measurement, standardisation, and repeatability as important aspects of scientific process. Similar conversations took place in the afternoon around the nature of light and diffusion.

The PI's observations were that the children did not have a set of fundamental scientific skills which allow them to approach big questions in a confident way. Their normal process of working seem to be much more instrumental in that the teacher would give them instructions which they would follow. There was not a sense of self motivation or self-regulation in order to undertake an exploratory



approach to scientific learning. The children were able to draw on some scientific knowledge, but again we're looking for quite specific answers to questions. However, they were keen when encouraged to develop hypotheses which could then be further tested.

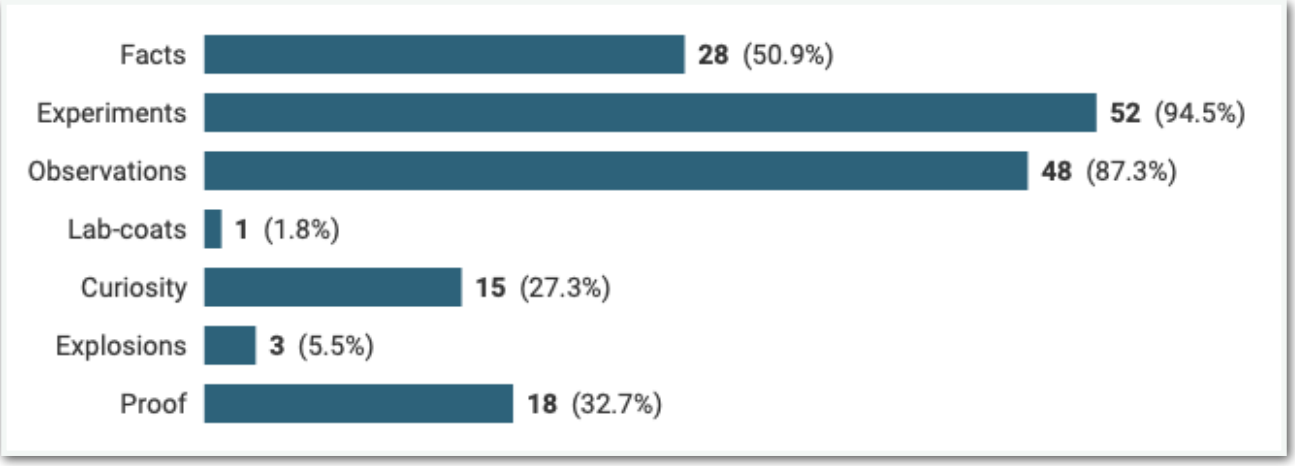
They were also receptive to the idea around testability and repeatability as key ideas within the scientific epistemic paradigm. The the idea of answerable and unanswerable questions and how science could deal with these was discussed.

Post-Survey Data

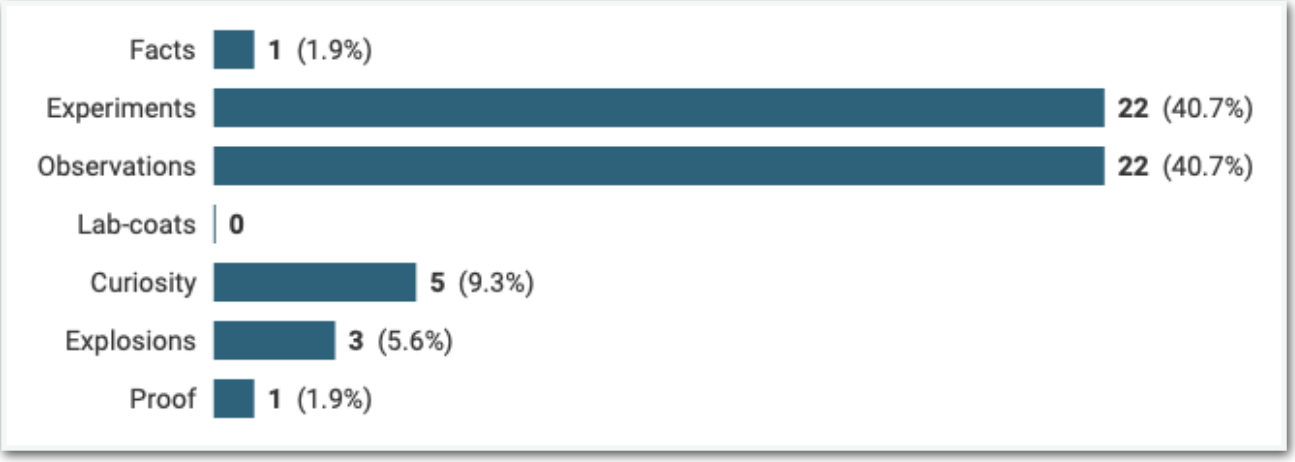
The post-survey was carried out at the end of the activity day, after the activities have been completed. The complete dataset for the post-survey questions can be found on the online survey website - below are some key highlight taken from the data.

55 children completed the post-survey **(n=55)**. All of these children were in Year Five.

Q6a asked about key words:



There were some changes from the pre-data, even more children had chosen experiments as one of their words (94.5% and increase of 7 percentage points (pp)), and observations had also risen by 22pp to 87.3%. Lab coats, explosions, and proof had or decrease significantly well curiosity had risen by seven pp to 27.3%.

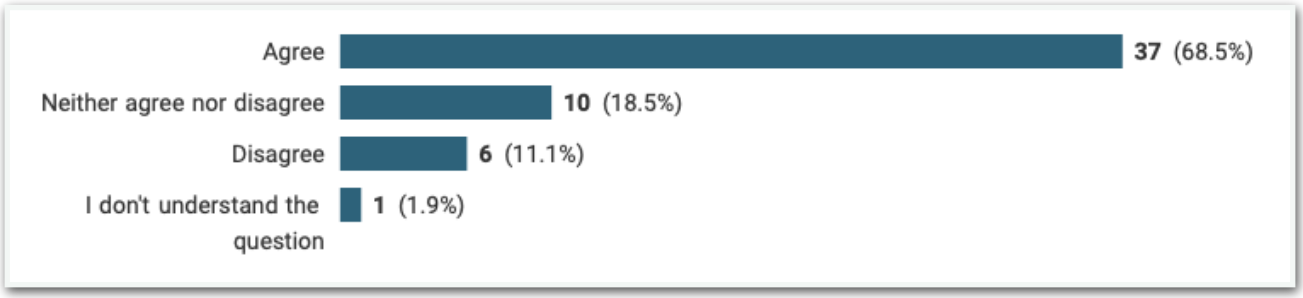


There had been a more significant change in Q6b giving a much more balanced choice between experiments and observations. The really significant change had been in the choice of observation as a single word which had risen by 33pp to 40.7%

In Q7.1 a significantly large number of children have now heard of the term discipline an increase of 12pp to 70.9%, we disagree dropping a corresponding amount to 20%. Likewise in Q7.2 the number of children who now agreed they have learnt what a discipline is at school had risen to 43.6%, a rise of 13pp.

When considering the qualitative answers now in Q8 there were now a number of pupils who replied using a more scientific definition of discipline e.g., “discipline is like Biology an area of science”, “An area of study”, “Biology is a discipline because it is an area of study”, “A discipline is a field of study”. There were still some responses relating to behaviour or punishment but these were considerably fewer than the pre-survey.

Likewise, there were changes in responses to Q9 on the nature of science questions and history questions. Those who now agreed that they knew the difference adoration to 68.5% pay rise of 19pp.



There was more emphasis in the quality of responses to this (Q10). More responses indicated that science was about facts or experiment and that history was about the past or more subjective study.

Children responded more positively about what makes a good questions for science (Q11) with 68.5% agreeing they have learned about this a rise of 14pp. the qualitative answers (Q12) were similar to the protest questions again showing a

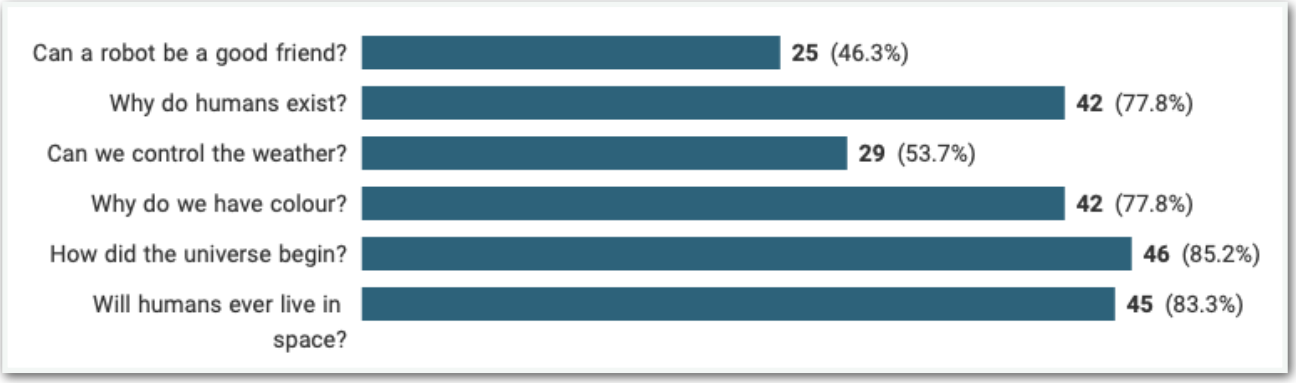
good understanding of the nature of the scientific question - although there were still some more esoteric answers e.g, “something interesting or hard to answer most of the time”. “Being a crazy question”, “You have to learn from the question” and “That it's a curious question” possibly indicating this idea of big open questions being different from factual or closed questions.

The big question is they would like to investigate (Q13) had become more focused on testable and answerable questions with only three children writing, "I don't know" and there being no wider philosophical type questions.

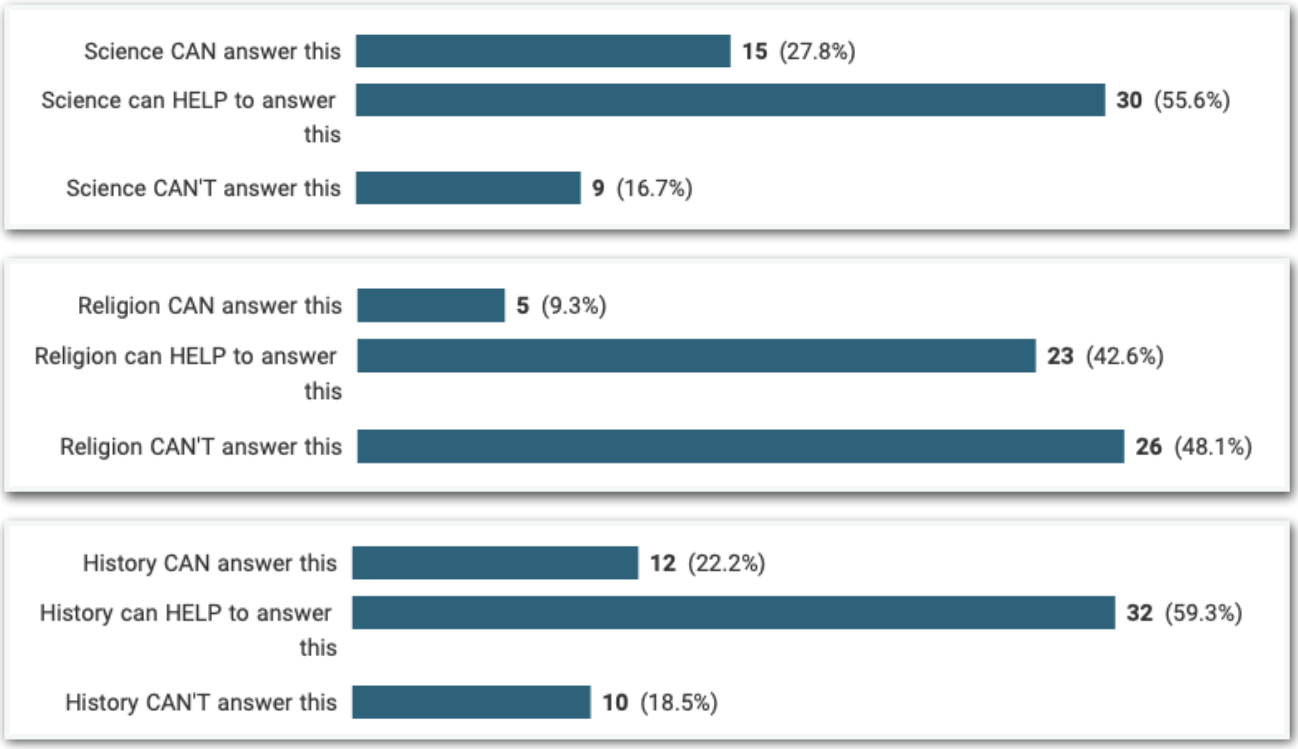
When reflecting on big questions and whether these were discussed at home again there had been a move towards a more positive agree in all of these areas. In Q14.1 there was a 12 pp increase in agree, In Q14.2 a 2pp increase and in Q14.3 (‘I talk about science at home) a 2pp increase - the last two days of course must be questioned and given that the children had not been home in the interim!

Reconsidering the question why do humans exist (Q15), Number of children who still replied "I don't know" was very similar at 27% (-1pp) but there were more children who offered a scientific explanation even if again there was some indication of scientific misconceptions. There were still some children who offered more deistic or moralistic explanations.

In Q16 there were more boxes ticked than in the pre-survey with positive responses to most areas increasing. All questions had an over 50% response rate with three having over 75% interest.



When considering the disciplines and their ability to answer the question, "why do humans exist?" (Q17-19) there were some small changes:



The CAN for science had increased by 3 pp to 27.8% but so had the CAN'T by 9pp (to 17.5%). The CAN for religion had decreased by 8 pp to 9.3% and the CAN'T risen by 9pp to 48.1%. For history the CAN had fallen by 10pp to 22.2% and the CAN'T risen by 5pp to 18.3%. This is a mixed set of results showing a swing towards science as the best answer for this question, away from history, but also showing an increase in the number of people she felt science could not answer the question.

The number of children who said they enjoyed learning science (Q20) had risen very slightly to 75.5%. (4pp), though the percentage who disagreed had remained consistent at 9.4%.

The percentage of children who thought there would be a smart phone smarter than them (Q21.1) had dropped slightly to 75.9% (-5pp), as had the number of children who thought that that was already a smart phone smart of them (Q21.2) by 3pp.

The percentage of children considering a career in science were consistent with the pre-survey at 24.1% agreeing although the number not considering this had risen slightly to 63% (6pp). Similar reasons were given for the choices.

Finally, in the post survey the children were asked which areas they enjoyed most. The children were generally enthusiastic about all the activities, and there was a balance of comments for all the activities undertaken. Most children at Cavendish talked about enjoying a particular investigation although Sam made some wider comments about enjoying investigation and big questions. Comments included, “The helicopter and the glasis (sic) what had rainbows”, “I liked the diffraction glasses and dropping water on coins”, “I like the clouds because we got the pipette and a coin it was really fun”, and “I enjoyed watching the spinners go down when the paper clips were weighing the spinner down because I was interested on the speed”.

Teacher Interview with the two Y6 teachers (Anne and Ricky)

How did the children engage with the activities? Which were most engaged

Ricky: The children were very engaged with all of the activities, but there were particularly engaged with the spinners, as they could experiment with this and take it in a number of different directions. The options with the droplet (cloud) investigation and the glasses (diffusion) investigation were more limited – there were fewer directions in which the children could take the investigation further.

Anne: I agree the spinners did offer the most opportunities from my class and the other activities would've needed more resource to take further.

Do you agree that science in the primary school is seen as 'fun' and facts and that children are less clear on the idea of science as a discipline?

Ricky: It did not change my view, as I had a view of science as an investigative process rather than a collection of facts – I am not sure how much the children have changed as they might well have been engaged without recognising those deeper ideas.

Anne: For me a little, when we teach it is a bit more limited and goes in certain direction and working with certain ideas. I did not think so much as about the idea of opening signs up and asking bigger questions. We focus more on the learning outcomes, the curriculum rather than the bigger areas. I found that is was open and a different way of learning - it has not really changed any idea of science as a discipline but have changed some of my ideas.

What does a 'normal' science lessons look like in your school and how were the activities different?

Ricky: It was very different in the sense that when we do a lesson we have a focus on "this is what the children should walk away knowing, we are teaching to a curriculum so you are directing children towards that outcome knowing what you

want them to leave with". You need to show that they have done something.

Anne: Yes, everything is guided by the national curriculum. The big difference is that the children were able to explore their own ideas, their own investigations. We were talking about with the children should understand how a spinner works by the end of the lesson and how important this was … or that the are working their ways to this.

Ricky: We will often start with an outcome and then leave the children towards that whereas this activity was more starting with a question and seeing where it went. This is not something we normally allow to do.

Anne: One of the biggest things for us, that was different, was that there was no recording which is very time-consuming but which is something that you have to do. They happy writing in their science books and recording all of them done.

Ricky: Yes, they have to be writing explanations and things like that. Whereas, with this we were more having a conversation about things and all the children were dipping in with ideas and it got the same outcomes they were able to explain it but there was no recording.

To what extent were the activities useful for teaching children about the nature of science?

Ricky: it was very useful for encouraging observation, as all the activities were focused on the idea of children observing and then tweaking their ideas, trying to explain their ideas - very observation focussed, good for getting children to see what science is really about. In conversations with children after the activities were over the children were saying that they did not think that science was - science was about looking at books or sitting at tables.

Anne: For me it's about thinking about the nature of science what science really is, so I would say yes there was a focus on the idea of observation. It encouraged them to observe. This is a big thing it's difficult for us to get the children to observe. It's made me think is this more effective? Maybe this is a better way than saying, "here

is ‘so and so’ observe it and write down what you can see”. It’s a different way to develop these skills.

Did you notice any differences in engagement among children in your class who are less confident in science?

Ricky: Definitely. There are children in my class who normally baulk at the idea of science who were very engaged and involved in discussing the activities in ways they would not normally - this pulled them in. This was the nature of the activity, it engaged in a way that it would not normally, in the way that science is taught in the curriculum.

Anne: Nothing especially about less confident but some children were engaged who are often not engaged, across the curriculum, this was the surprise for me in my class.

Would you normally expect children to use the language / vocabulary of investigation?

Ricky: Yes, we would use words like this (hypothesis, observe, investigate etc..) in lessons.

What opportunities, if any, do you usually have for talking about Big Questions in class

Ricky: No, I would say not as the curriculum is normally very geared towards specifications, and the children must walk away know ‘this, this and this’. So, there is very little chance for the children to ask these questions. We need them to know things like, this is the order of the planets, the curriculum is much more fact based than enquiry based,

Anne: This is also effected by assessment - we have assessment in schools and this relates to students doing well in assessments. We have key knowledge, this is what the children need to know by the end of the unit and then we have an assessment

on it. So we are focussed on specific objectives.

Has this had any impact on your confidence to teach science or to explore Big Questions in class?

Ricky: My view of science was already this kind of approach it's that you are geared towards fitting what the system want you to do. So, I do not think it has changed how I view science, or how I would like to teach science.

Anne: On my PGCE course it was promoted this way of learning, it really was and we were all ready to doing this when I came into the job but then it was, 'have to make sure the children have this recorded into their book' and 'you have to make sure they have done this'. I thing we still want to teaching this way and I think we are aware that children want to learn in this way, to direct their own learning. I think have learnt more about the big questions - I think what we do want to do is to let children explore the ideas. I think we are aware of this and do value this and have the opportunity to do this in the classroom.

Ricky: You are also always in the classroom under the impetus of time, you have a certain point in the curriculum by certain time. So you are pushed to 'get through' the materials and this is the way we are held accountable as teachers. There are things about fish that I like, and things I'd like to do more of in school, but you're always aware that there are many things we are required to do as part of the accountability and recording requirements.

Anne: This was of learning is very much how I was taught on my PGCE, I was very inspired by my lecturer and his way of teaching science but then when I came to school it was okay so this is the way you have to do things.

Additional things

Ricky: What there are often not opportunities in class to talk about big questions I will often do this with children out of class, for example this lunchtime I was discussing with a boy in my class about AI, 'will AI overtake humanity?' and this was very interesting.

Researcher Reflections and Commentary

It was really good to be involved in the activities with the children and there was a real sense of both student engagement of students inquiry. The children were able to start off with the core idea but then very quickly offer subsidiary questions, divergent thinking, and bring down ideas to explore future possibilities, undertaking 'possibility thinking' (Cremin, Burnard and Craft, 2006).

The spinner activity seem to be most engaging to the children, as confirmed by the classroom teachers, because this gave the most opportunities for this possibility thinking. It also allows the children to develop more of their own ideas including changing the size, changing the materials, changing the masses attached, and even operating double and upside-down spinners to explore what would happen.

The activities again raised the question about the nature of science in the primary sector and of scientific thinking. Is the journey (exploration) more important than the arrival (answers)? The children were probably not able to fully answer, in a sense of the science physics, how is work but they were able to apply an epistemic approach to scientific investigation. The pre-and post-survey data disco indicates that children's thinking had moved towards a deeper understanding of the epistemology of science.

Finally, the teachers interview particularly highlighted the tension between the aims of the curriculum, as perceived by the teachers of the school, as a deliverer of content and a deliverer of "correct facts" rather than a focus for thinking and working scientifically. The teachers themselves commented on the preference to work in a more open investigatory approach, but that the demands of the curriculum and the system inhibited then in doing this.

Spring Cottage Primary School, Hull

The School

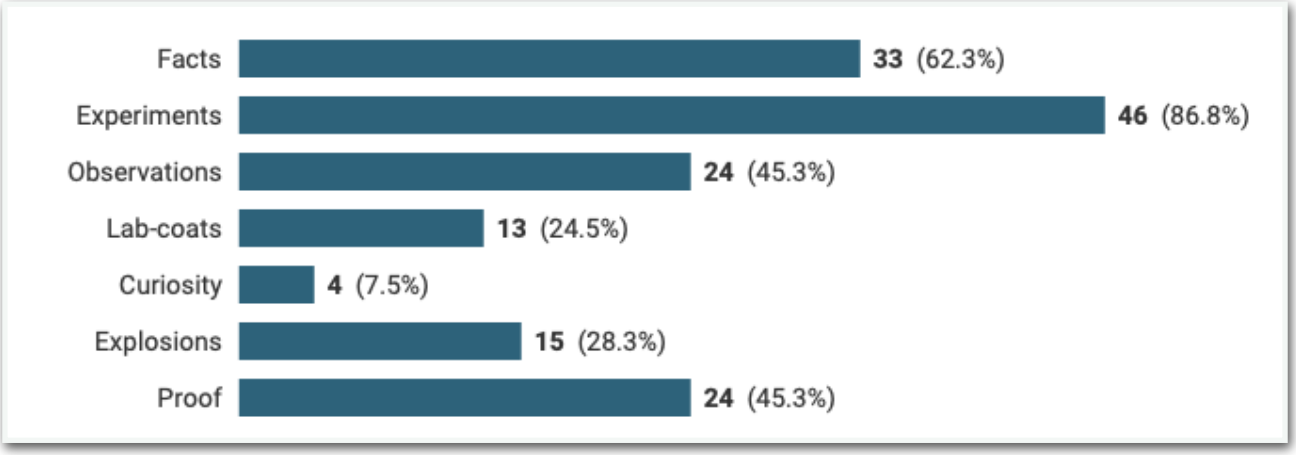
Spring Cottage is a large primary school in the north of Hull. It has a school role of about 500 pupils with charity white British population. The proportion of pupils at the school who are class for disadvantaged is below average as is the proportion of children with learning difficulties and or disabilities. The schools last OFSTED report was 2008 at which time the school was graded as outstanding. Science mentioned in the OFSTED report in that children make significant progress in science at a time at the school. The school motto is, *"Grow together, learn together and make the most of every day"*.

Pre-Survey Data

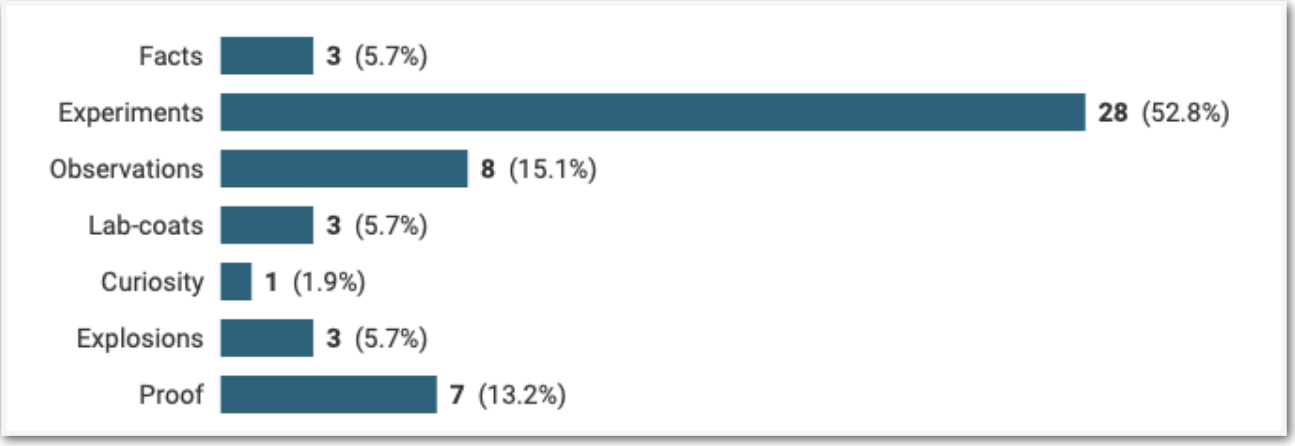
The complete dataset for the pre-survey questions can be found on the online survey website - below are some key highlight taken from the data.

53 children completed the pre-survey **(n=53)**. All of these children were in Year Five.

When asked about three key words for science (Q6) children responded:

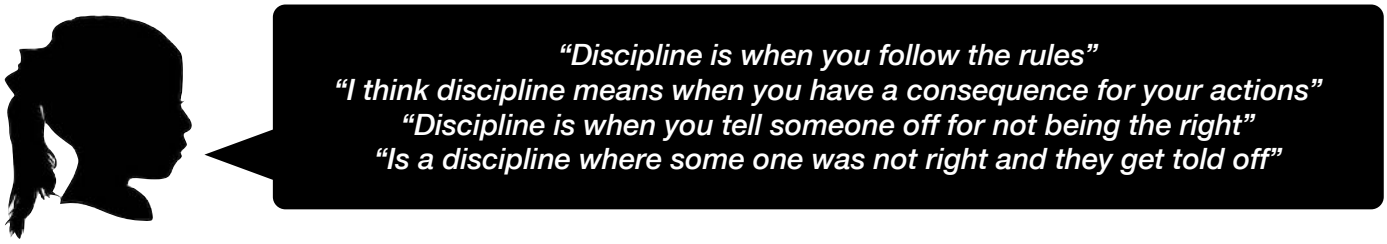


Experiments (86.8%) and Facts (62.3%) come out as over 50% of respondees and Observations and Proof close to half of respondees. When asked to choose only one word:



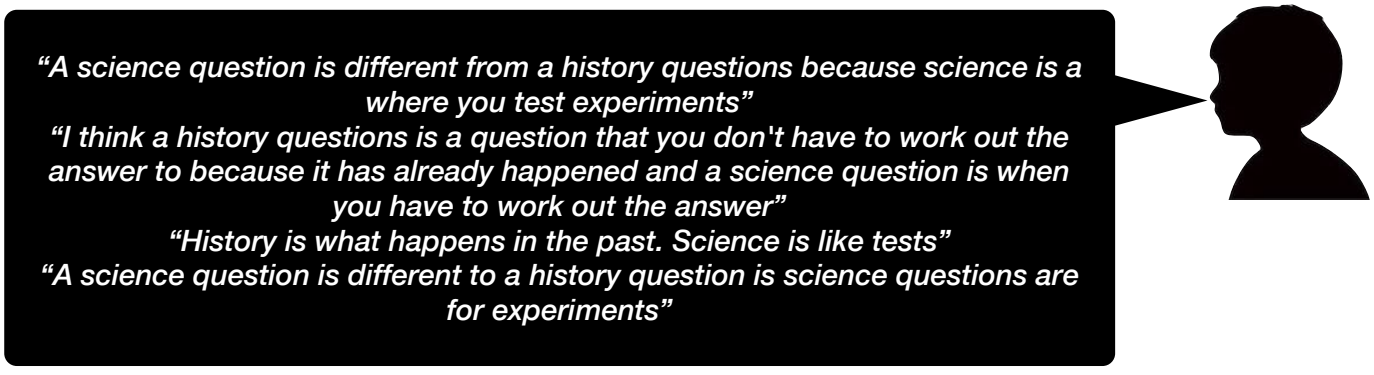
Here 'experiments' is dominant with just over half (52.8%) with other areas much lower with only 'observations' (15.1%) and 'proof' (13.2%) with more than 10%.

When asked about discipline (Q7) a slight majority (52.8%) agreed they has learnt what a discipline was in school, only 11.5% disagreed. When asked for qualitative answers (Q8) a range of answers were given, mostly linked to punishment or behaviour:

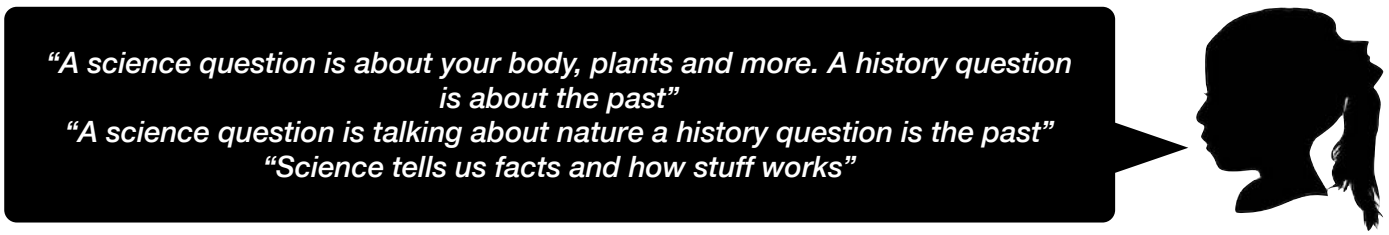


There were some answers which indicated an idea of rule following, "Training to obey rules", "A discipline is training to obey rules", "Discipline is when you follow the rules. If you have discipline you follow the rules" and one answer more linked the to the idea of academic discipline. "A branch of knowledge typically one studied in higher education".

When asked if they knew what makes the science question different to the history question small majority agreed (53.8%) and a small percentage (5.8%) disagreed. The qualitative replies (Q10) some focussed on the procedural,



and some on the content.

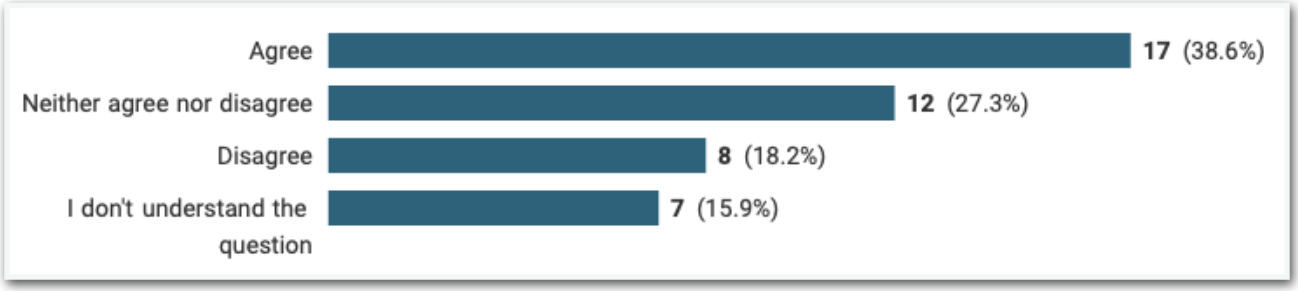


When asked if they had learnt what makes a good question (Q11) under half (39.2%) agreed, 17.6% disagreed but 17.6% also said that they did not understand the question. Looking at the qualitative answers (Q12) there were again answers linked to science process, “A good question foe science is to do an experiment to work it out”, “A good question for science would be one that allows you to work the answer out and experiment on it”, “It could be a question to do with an experiment” and “One that will use factual evidence”; whilst there were also responses that linked directly to science content questions, “It must be a question about specific objects organism or events in the world?”, “Why can axolotls regrow body parts?”, “It must be a question about object events, organism or the world”, “Do you make some flying machines?”, there were indications of misunderstandings for example, “How many Greek gods?”.

When asked about Big Questions (BQs) (Q13) questions came that were both **testable**, e.g. “I would like to look at 'what we have the solar system’”, “Can a person have superpowers?”, “When will the sun explode or stop being hot?”, “I would like to investigate how a plane can fly?”.

and also more **philosophical** responses, “What created the universe?”, “Can a person have superpowers?”, “How many flowers are in England?”, “What is the first colour?” and “why is the sky blue and the grass green?”.

When asked if they like to think about BQs, like ‘can a robot be like a person’ about a third (38.6%) agreed and about a fifth disagreed (18.2%), and 15.9% did not understand the question:



When asked if they talk about BQs at home (Q14.2) most (57.1%) disagreed and

when asked if they talk about science at home a quarter (27.9%) agreed but a third (34.9%) disagreed.

When asked what they think about the BQ, 'why do humans exist' (Q15) there were a range of responses some linked to science ideas, though some of these showed misconceptions:

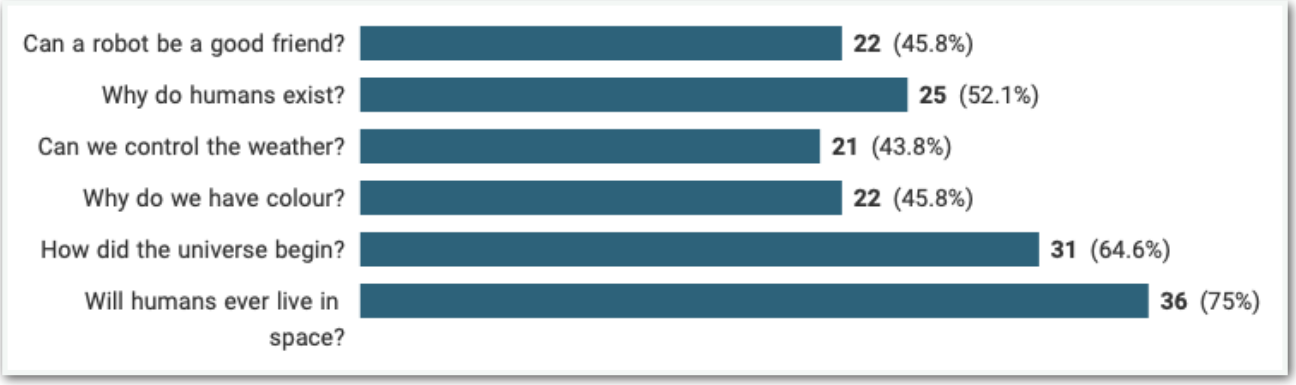
"Humans were first invented by gorillas in the stone ages. There wasn't much humans there were more animal humans than humans"
"I think humans evolved from chimpanzees"
"I think humans are made by monkeys because monkeys re like humans"
"I think humans were accidentally made from the remains of dinosaurs"
"Humans might exist because we were made from monkeys"
"Humans exist because we have water, food and sheller"

Some more rooted in mythological, deistic or moralistic reasons:

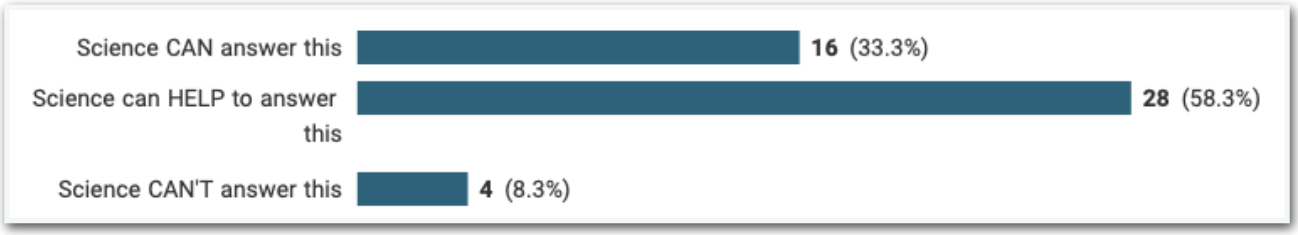
"I think humans exist because god made them"
"humans exist to be the only life in the universe and to keep the planet safe"
"Because god made them and humans are born"
"I think humans exist because so then they can help the world"
"I think humans exist because the world needs friendship"
"If there were no humans the world would be boring"
"To help the world (even though there is litter)"

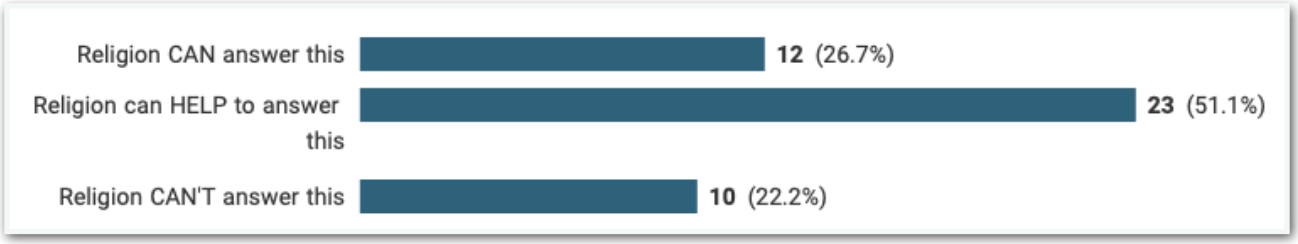
About 27.9% of children responded that they did not know.

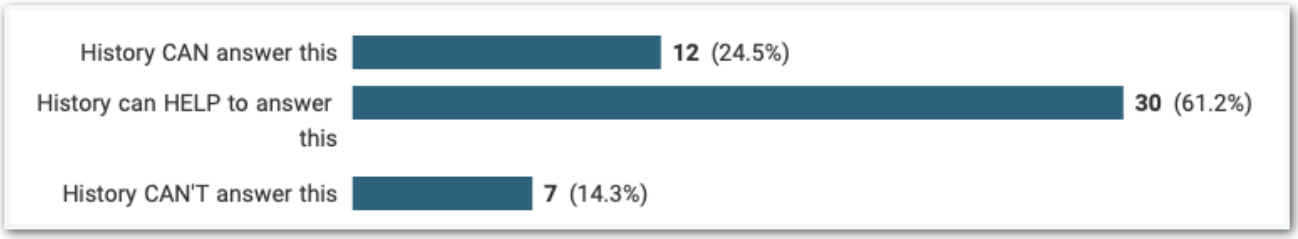
When asked about BQs (Q16) about half of children were interested in the first four questions but the BQs, 'how did the universe begin?" and 'will humans ever live in space?' Had higher responses:



When considering how the different disciplines of Science, History or RE could answer the question, 'why do humans exist' (Q17-19):

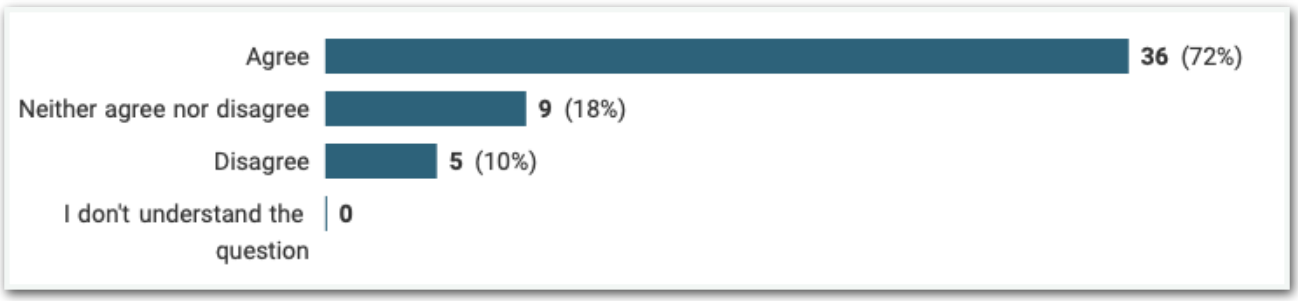






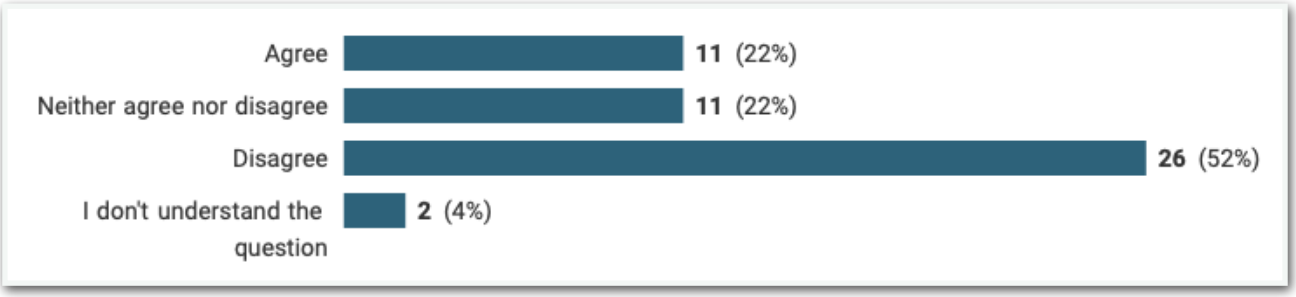
We can see that children felt that science was most likely to be able to answer the question with a third of children saying CAN and 91.6% replying CAN or CAN HELP. The answers for religion are higher than many other schools, but still lower with 26.7% saying CAN and 76.8% CAN or CAN HELP. History has the lowest positive responses with 24.5% saying CAN and 85.7% saying CAN or CAN HELP.

Children are positive about learning science (Q20) with almost three-quarter saying that they agree (72%):



Considering smartphones 72.9% agree that one day there will be a smart phone smarter than them, and 46.3% think that there is a smart phone today that is smarter than them.

Finally children were asked to consider a career in science:



About a quarter thought they would and about half that they would not. Reasons for this were varied but fell into two main groups, linked to dislike or like, difficultly of science or perceptions of use of science for their chosen career:

"When I grow up I want to try experiments only a few people have tried"
"When I am older I would not like to be a scientist I might teach science"
"I wouldn't because I might create something deadly"
"I don't want to have a science career because I want to be a doctor"
"I don't because I do not really like science"
"I don't want to because I want to be an actor and dancer when I grow older"
"I wouldn't because I am better than other things other than science"
"I want to be a footballer because I enjoy sports more than science"
"I would like to do so can help people with questions they do not understand"

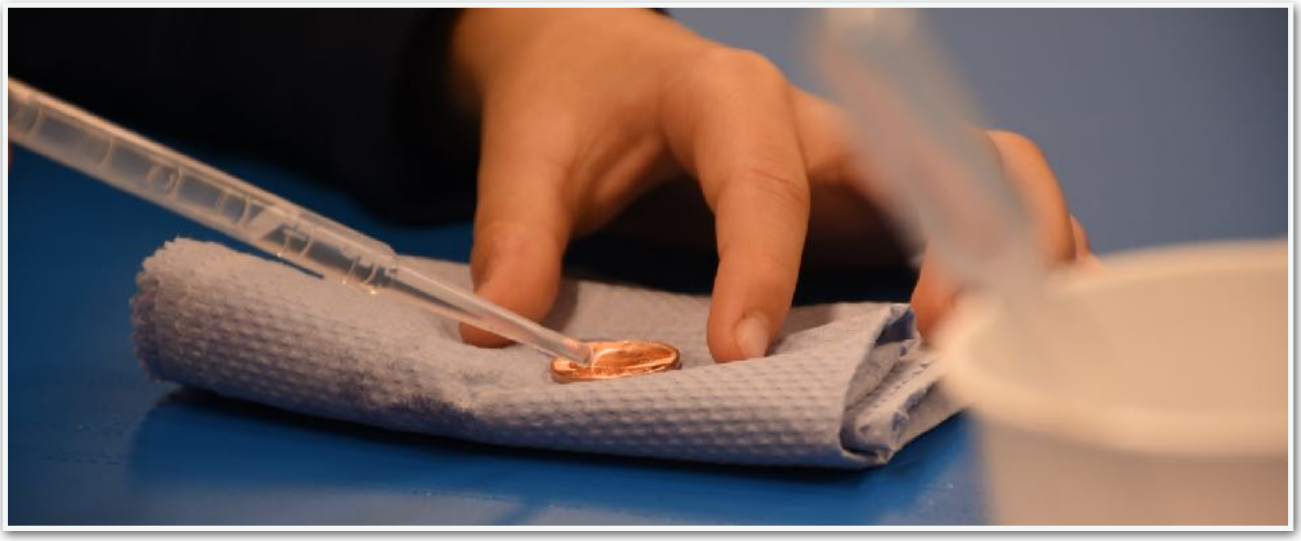
The Activity Day

The PI was able to take part in the activity day at Spring Cottage School. There were two parallel year five classes undertaking the activities and these classrooms were next to each other. The PI introduced the activities for the children in turn and then worked and reflected with each class whilst the class teacher was keeping an eye on activities whilst the researcher was with the other group.

In the morning the classes looked at the spinner activity and the water drop (cloud) activity. In the afternoon the classes looked at the diffraction activity. There was no time during the day for the final travel in space activity but children were given the opportunity to undertake this at home at their own leisure. We started the day with the pre-survey and finished with the post survey.

The children were very engaged in the activities and very keen to both get involved but there was a tendency to jump into the practical activity without some reflection on the wider ideas. At times it was necessary to stop the children in order to get them to reflect and consider some of the underlying scientific ideas that were being explored. The children were able, with some assistance, to self regulate their investigations and to construct and explore sub questions such as: how would the spinner be affected if it was made from different materials? What would happen if the wings were bent different way?

Likewise, when exploring the droplets the students explored a range of divergent approaches to experimentation noting that how your place to drop had an impact on whether they "stuck together or not". Children also noticed that the number of



drops that you could get onto a penny before the, ”bubble broke “ vary quite considerably both between individuals and between attempts. They were able to consider why this was so Andrew consider the importance of measurement and repeatability. There were some similar conversations took place in the afternoon around the nature of light and diffusion but they found this more difficult to explore.

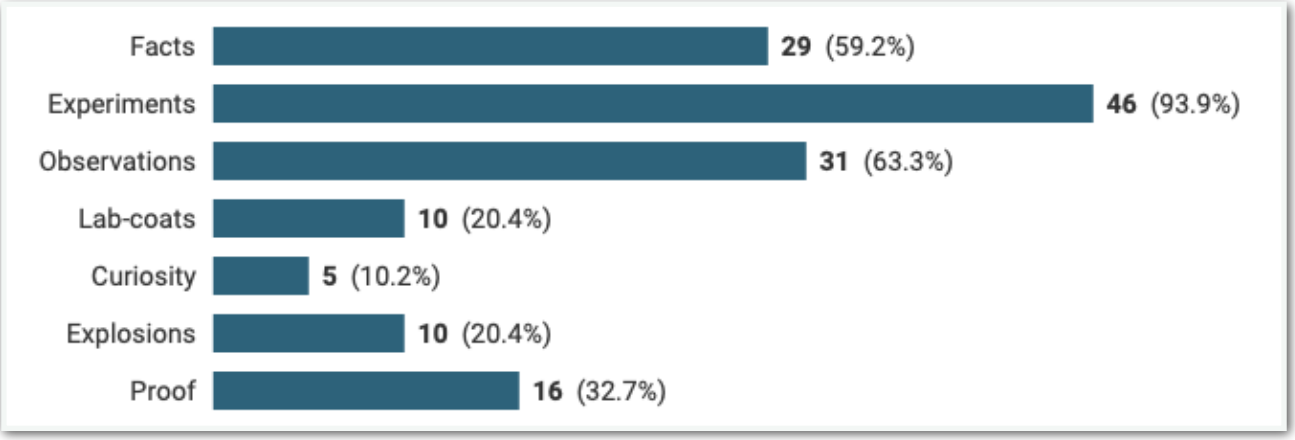
The PI’s observations are that the children did not have a set of fundamental scientific skills which allow them to approach big questions in a confident way. Their normal process of working seem to be much more instrumental in that the teacher would give them instructions which they would follow. There was a low sense of self motivation or self-regulation in order to undertake an exploratory approach to scientific learning. The children were able to draw on some scientific knowledge, but again we're looking for quite specific answers to questions. However, they were keen when encouraged to develop hypotheses which could then be further tested.

Post-Survey Data

The complete dataset for the post-survey questions can be found on the online survey website - below are some key highlight taken from the data.

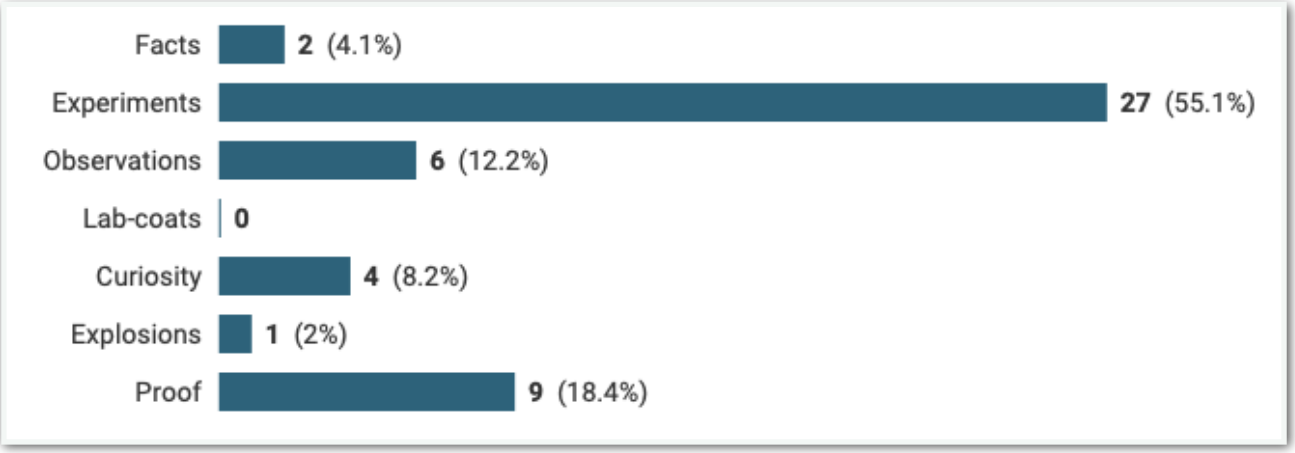
50 children completed the post-survey **(n=50)**. All of these children were in Year Five.

Question 6a asked about key words in science:



There were some changes from the pre-survey. Facts dropped by 3 percentage points (pp), experiments rose by 7pp, observations by 18pp, explosions by 8pp and proof by 12pp.

When asked to choose one work (Q6b):



This was very similar to the pre-survey with only proof showing a significant change up 5pp.

The number of children who had heard of the term discipline (Q7.1) had risen significantly to 75% (+23pp) and the numbers who had learned about this in school had risen by 11pp. In the qualitative replies (Q8) there was a small increase in the number of children who referred to a discipline as a branch of knowledge or study, "A branch of knowledge, typically one studied in higher education", "Is it people practice training - a brach of knowledge", "A branch of knowledge, particularly one studied in higher education", "Discipline is branch of knowledge", "It means a branch of knowledge".

The percentage of children who knew what made a science question different to a history question had risen to 65.3% (+12pp), not as a percentage who disagreed was very similar. The kinds of answers given in the qualitative replies (Q10) what is similar to the pre-survey focusing on either procedural understanding, looking at the different ways of undertaking investigations in science or history, or a content comparison looking at the different kinds of things that you might study in each discipline.

The percentage of children who considered they had learnt what makes a good question for science (Q11) had risen to 54.2% (+15pp) whilst those who said they could not understand the question had dropped slightly to 14.6% (-3pp).

Again, the qualitative answers (Q12) were similar to the pre-survey with some focusing on scientific process, some on specific testable questions for science and some on more general philosophical points, "It has to be a big question", "Why does love exist?". 26.6% of children answered, "I do not know".

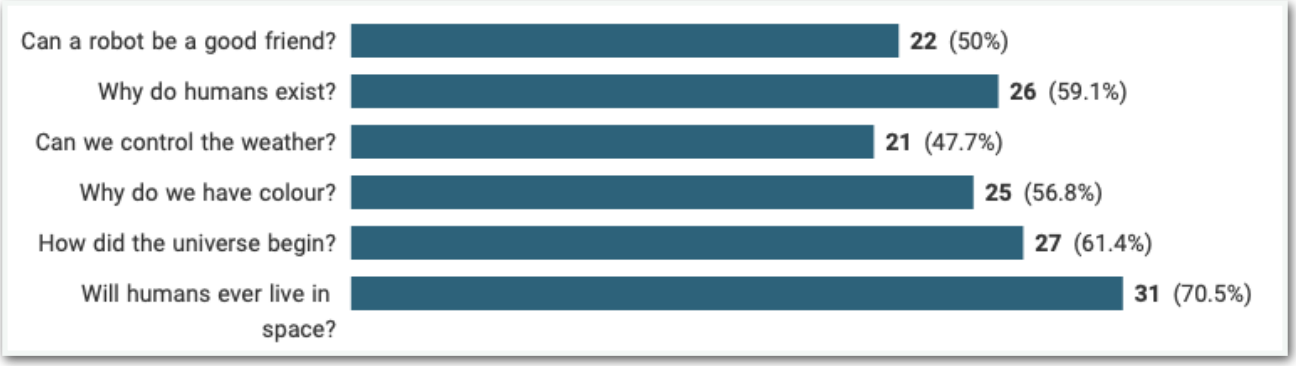
The Big Questions (Q13) were similar to the pre-survey with again testable and philosophical questions. Some of these questions were linked to the activities or discussions undertaken, "Why do spinners spin?", "Can a robot be a nice friend?", "Can we control the weather?", "Why do clouds look yummy?".

When considering how much they might think about big questions (Q14) the number agreeing had risen to 51.1% (+13pp), whilst the number disagreeing had

remained at a similar level (24.4%). However, the number stating they could not understand the question had dropped to 6.7% (-9pp). When after they talk about big questions at home still the largest number was disagree although this had fallen by 16pp. the number who said they talked about science at home had increased to 34.1% (+7pp) the number who disagreed remain similar at 36.6%.

The answer to, why do humans exist, (Q15) what again similar to the pre-survey offering a range of both more scientific, with misconceptions, answers and answers that one more rooted in mythological, deistic on moralistic explanations.

The interest in Big Question (BQs) (Q16) had some changes:



In the pre-survey only, ‘how did the universe begin?” and ‘will humans ever live in space?’, scored over 50% whereas in the post survey only, ‘can we control the weather?’, scored below 50%. The first and second ranked questions remain the same.

When considering which disciplines are best situated to answer the question, ‘why do humans exist?’ (Q17-19) there were some changes. History had overtaken science as the answer with the highest percentage on CAN, at 19.1% although this will still lower than the price of a percentage of 24.5%. The CAN percentage for science had fallen to 16.3% (-17pp), and religion to 9.5% (-17pp). One of the most obvious changes was the percentage of children who said that science can't answer the question which rose to 27.9% (+20pp).

The percentage of children who agreed that they enjoyed learning science (Q20) was similar to pre-survey levels as was the percentage of children agreeing that there will be a smartphone smarter than them (Q21.1) or that there currently is a smartphone smart than them (Q21.2).

Finally the percentage of children who would like a career in science had dropped slightly to 21.3% (-3pp), although those disagreeing had remained similar. The answers given, again fell into three distinct categories: those who like or dislike science, those who found the subject difficult challenging, and those who already had fixed ideas about their future careers and the place of science in these.

Finally, in the post survey the children were asked which areas they enjoyed most. The children were generally enthusiastic about all the activities but the spinner and the penny experiments tended to win out over the diffraction glasses. There were some very positive comments including, “really enjoyed making spinners because it was fun when we started testing them”, “I enjoyed everything that we did”, “I loved trying out the activities for the first time because it is exciting” and, “ I enjoyed doing everything”.

Teacher Interview

The teachers were not available for a spoken interview so below are the responses to the written questions.

How did you find the children engaged with the activities?

The children engaged well, the spinners worked well and allowing the children to come up with their own solutions and investigate independently.

Has this resource helped you to think about the types of questions science asks and how it prefers to investigate them?

Yes it has, as the children were made to think about the process of Science and how they could improve their experiment further.

What does a normal science lesson look like at your school and how did these activities compare to what normally happens?

A normal Science lesson, fits an objective contains key vocabulary and has an investigation aspect to it too. Each unit as a, 'working towards' experiment.

How did you explain the distinctiveness of science in the investigation

It allowed children to think about the 'big questions' of the world, which was great and to differentiate between a Scientific question and a Historic question.

Did you notice any differences in engagement among children in your class who are less confident in science

Allowing the children time on their own to solve things in their own time really helped their confidence levels.

Did you notice if you/your students used EI and scientific enquiry vocabulary?

They used scientific vocabulary such as 'hypothesis'

What opportunities, if any, do you usually have for talking about Big Questions in class?

We have time to discuss big questions as a hook for each lesson related to whatever topic we are doing or when we do our KWL grids.

What impact have using the resources had on you as a teacher?

It has allowed to me to use resources effectively and knowing even little resources can go a long way. I will allow the children more independent time to research moving forward

Focus Group comments

- The spinner- It was fun to try different ideas out.
- There wasn't any writing, which was fun and it allowed us to investigate.
- That Science is everywhere and there are questions science can answer and questions they can't.
- The coin activity with the water.
- Yes we loved thinking about the big questions and it is so exciting to know that science can answer them.
- We think about big questions all the time

Researcher Reflections and Commentary

It was really good to be involved in the activities with the children and there was a real sense of both student engagement of students inquiry. The children were able to start off with the core idea but then very quickly offer subsidiary questions, divergent thinking, and bring down ideas to explore future possibilities, undertaking 'possibility thinking' (Cremin, Burnard and Craft, 2006).

The spinner activity seem to be most engaging to the children, confirmed by the classroom teachers, because this gave the most opportunities for this divergent thinking. It also allows the children to develop more of their own ideas including changing the size, changing the materials, changing the masses attached.

The activities again raised the question about the nature of science in the primary sector and of scientific thinking. Is the journey (exploration) more important than the arrival (answers)? The children struggled to bring subject specific or discipline specific knowledge to their thinking but they were able to apply an epistemic approach to scientific investigation.

The teachers were keen to explore further this idea on investigational approaches and the use of big questions, it might be that the school feels more secure in exploratory work given its Ofsted category. The school science lead is also very active and has started a science club showing that there is stronger activity in science and the school than in many primary schools.

Monks Abbey Primary School, Lincoln

The School

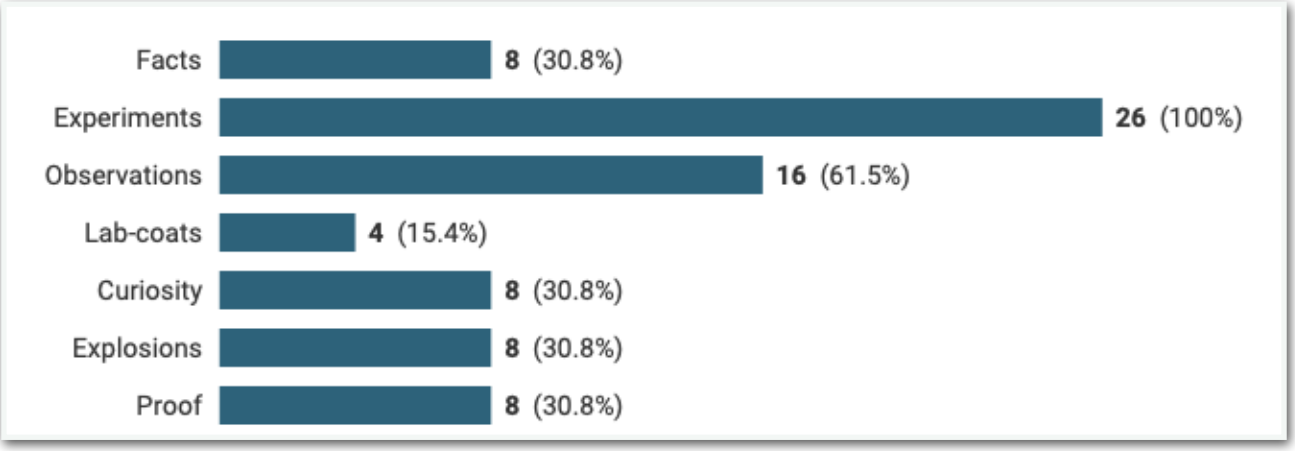
Monks Abbey Primary school is in the third most deprived ward in Lincoln and one of the most deprived in the country. It is a larger primary school (over 400 POR). The last full OFSTED report was in 2018 and a larger than average portion of children are from ethnicities other than white British (40%), the proportion of disadvantaged pupils is above average as is the proportion of children with special educational needs. Science is not mentioned in this OFSTED report. The school was graded good at this Ofsted.

Pre-Survey Data

The complete dataset for the pre-survey questions can be found on the online survey website - below are some key highlight taken from the data.

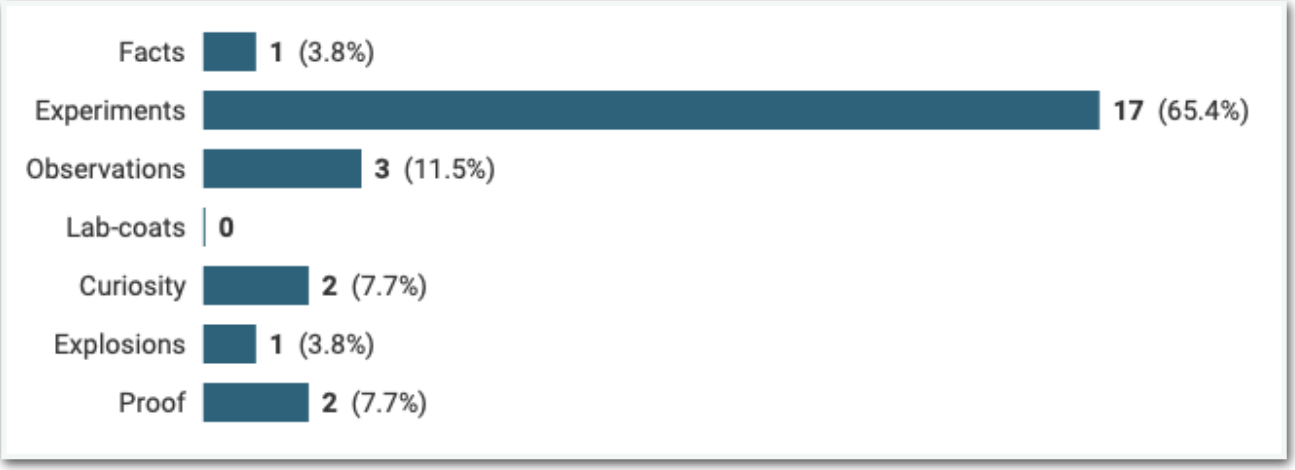
26 children completed the pre-survey **(n=26)**. All of these children were in Year Six.

When asked about three key words about science (Q6a) they responded:



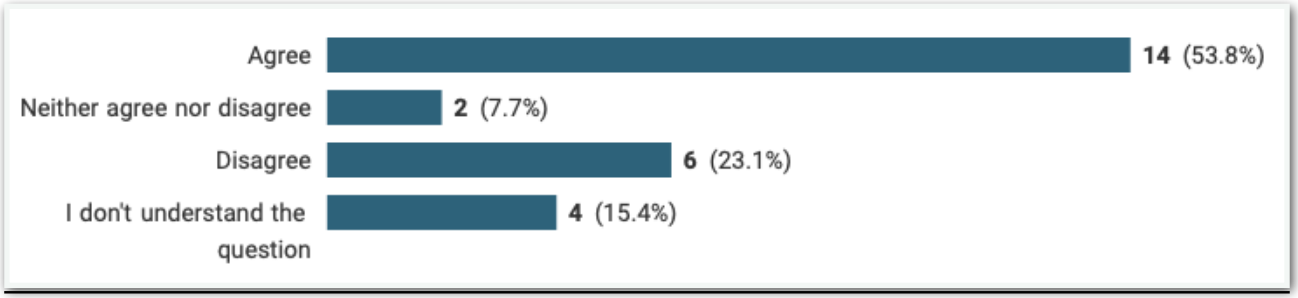
It is very notable that 100% of responders checked 'experiments'. 'Observations' was also high (61.5%) and most others at about a third of responses.

When asked to choose one word (Q6b):



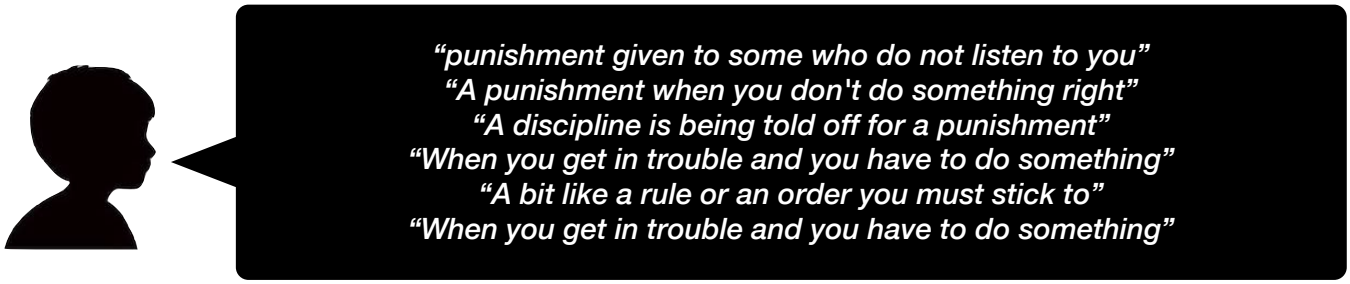
Experiments still dominates with two-thirds choosing this and observations a distant second (11.5%).

When asked about the term discipline (Q7.1)



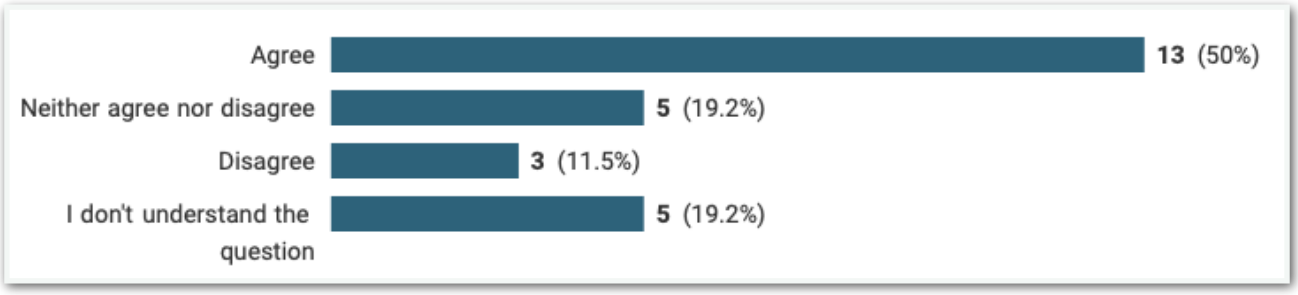
A small majority agree (53.8%) but a significant proportion (23.1%) say they have not heard of the term. When asked if they have learnt about this at school a slight majority (53.8%) disagreed and about a third (30.8%) agreed.

When asked for quantitative descriptions of discipline (Q8) the answers focused on the idea of behaviour and punishment with answers such as:



Though there are some responses more linked to learning, such as: "If you learn something for example Karate you are discipline", and "A discipline is a task or law".

When asked about the difference between a science and a history question (Q9) the children half (50%) agree they know what makes them different, and about a tech (11.5%) disagree.



The qualitative responses varied with some linked to process:

"Science is all about nature and history is all horrible events"
"Because science involves experiments and history doesn't"
"A history question is about the past and science question is about what's happening now or how to improve (experiments)"
"In science you have to find out in history you don't"
"A history question has already happened, yet in science it is usually new"

And some more focussed on content:

"Science is asking questions like what happens if I put this and this to fever but history question is like when was the first rocket to the moon?"
"History is about is about old things like seamans. Science is about experiments"
"It does experiments and history is long times ago stories"

23.1% of children responded with "don't know"

When asked, 'what makes a good question for science to answer' (Q11) 34.6% agreed they had learnt this at school, and 15.4% disagreed. A significant minority (30.8%) said they did not understand the question. Children's qualitative answers (Q12) gave a range of answers. Some of these focussed on science process, "I think that a question you can answer after doing something", "A question that's hard and answerable", "Like when you have a question but you have to experiment to get the answer" and "A good question would be a question with a long answer unlike yes or no", "How do you make an animal" and "An undiscovered thing we need to discover like 'why do llamas sneeze'?". Some focussing on a subject answer, "How much bacteria are ever in a house?" And some more philosophical, "A question that has an answer but maybe no need to explain."

24.0% of the children responded with, "don't know" or "I do not understand the question"

When asked what questions they would like to investigate (Q13) there were a number of testable questions such as, "I'd like to investigate the question 'why does

the universe exist?", "What is outside the universe?", "Can I make an explosion with toothpaste?", "How can scientists make vaccines" and "Why can we see colours".

Whilst some of the questions were more philosophical, "What comes after infinity?", "Can you be friends with a robot?", "Why does the earth exist?", "Is there a reasons why humans exist?" and "Can a robot be like a person?".

When asked about Big Questions (BQs) (Q14) just over half (53.8%) agreed they liked to think about BQs, but a significant majority said they did not talk about such things at home (69.2%). When asked more widely about talking about science at home about a third (34.6%) said they did but over half (53.8%) say they did not.

Thinking about, 'why humans exist?' (Q15) some of the questions were linked to scientific explanations, though some of these displaying misconceptions:

"Our planet has perfect living conditions for life and apes evolved into humans"
"Because they are cleverer than animals"
"Atoms merged together on the earth and made apes then we evolved to what we are now"
"I think that humans exist because the universe decided to create them"
"I think humans exist because of the Big Bang which made the universe"

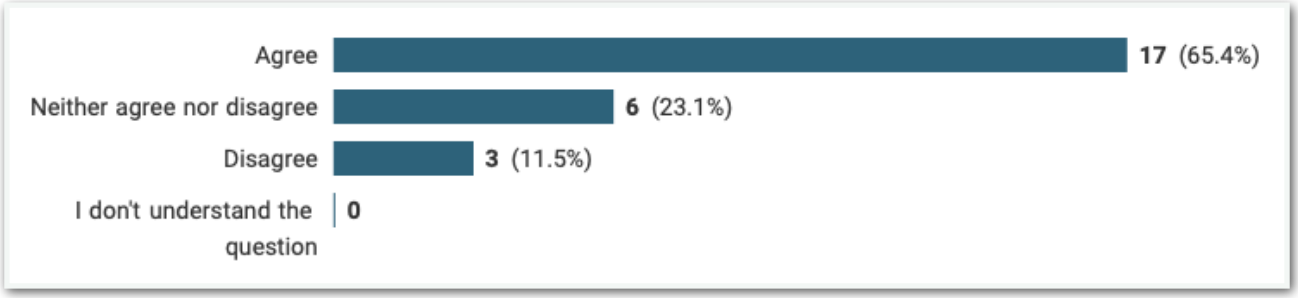
And some rooted in more deistic or moralistic explanations:

"Because we're made out of life and clay"
"Because we're created with air, water and warmth"
"God created humans so the world could be a better place"
"God creates them to play, cook, exercise and pray for god"
"So people go to heaven and there's some kind of lives on earth is useful"

When asked about BQs more generally (Q16) they were interested in most of the questions. The most popular was 'how did the universe begin?' (84%) and 'will humans ever live in space?' (68%) but the only BQ below 50% was 'can we control the weather' (48%).

When they were asked to consider the disciplines and their impact on the question, 'why do humans exist' (Q18-20) there was a significant bias towards scientific explanations with 76.9% thinking science CAN or CAN HELP with the answer, compared to 42.3% who thought religion CAN or CAN HELP and 69.2% for history (though only 3.8% thought history CAN rather CAN HELP).

About two-thirds of the children agreed that they enjoyed learning science (Q20):



When thinking about smartphones (Q21) 56% thought there would be a smartphone cleverer than them in the future, and 61.5% that there is currently a smartphone clever than them - a dichotomy in thinking!

Considering a career in science just under a quarter (23.1%) agreed whilst two thirds (65.4%) disagreed, when reasons were given these varied, those who disagreed either did not like science or had other plans:

"Because I'm not interested in science as much as I am in other things"
"Because I already have a good job as a footballer"
"I do not want to be a scientist because I would like to be a part of the army"
"Because I am not really interested in science that much"
"Because I don't like science"
"I don't want to work in science because I'm not that interested in science"
"It's a bit too hard"
"Because I do't really like researching and stuff like that because when you do since you have to write a lot"

Those who were considering a career in science also had a range of reasons:

"Because I love experiments and explosions"
"I want to be a doctor so I can help so I can help people with issues. A doctor is a career in science"
"Because I want to be a doctor and being scientists is a lot of work and explosions"
"Because I want to build rockets. When I was younger I would draw all the parts of a rocket and name them"

The Activity Day (researcher present)

The children had already undertaken the spinner investigation and the clouds investigation before the researcher was able to come to the classroom. During the morning whilst the PI was present we looked at the, “why is the sky blue?" Investigation. The children were set off on the activity and then after a little while the children were brought back together and there was some discussion before the children again took investigation further.

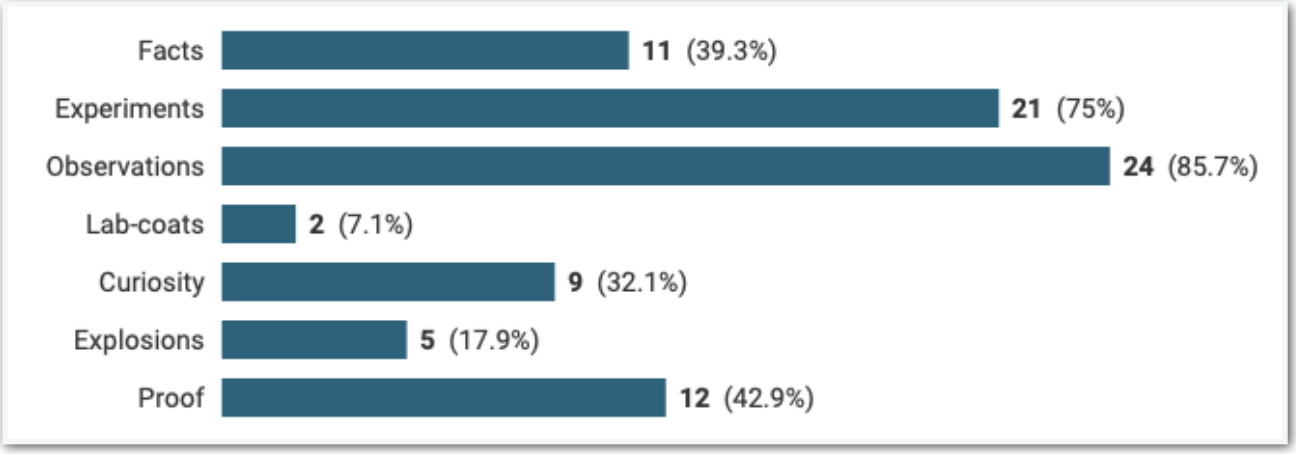
When undertaking the investigation, ‘why is the sky blue’ the children were very positive in exploring the idea is that the question presented and very self directed in exploring how the diffraction glasses worked. As well as looking at direct light sources they were also interested in looking at reflected light sources and discussing and exploring any differences that took place. So they would look at different colour papers as well as the red paper and one was very interested in looking at the water bottle which had some higher reflective surfaces and some lower reflective surfaces. This generated a significant number of sub questions which the children were then keen to explore. There was still a degree of wanting to know "the answers" but they did understand that observation and question generation was quite key to scientific investigation. They also understood the need for a systematic recording of data and this to be an iterative process where the evidence builds up over repeated observations.

Post-Survey Data

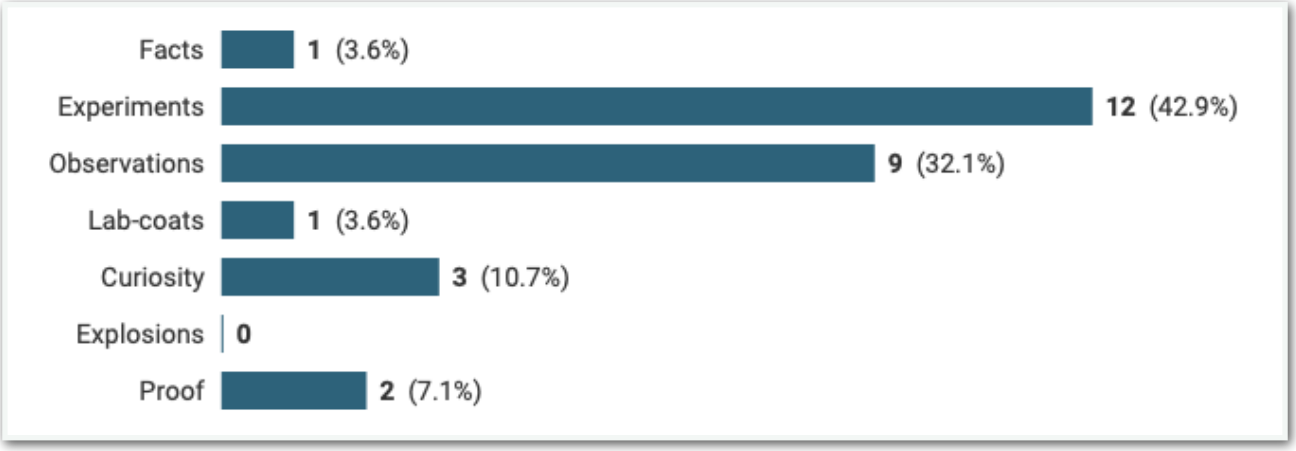
The complete dataset for the post-survey questions can be found on the online survey website - below are some key highlight taken from the data.

28 children completed the post-survey **(n=28)**. All of these children were in Year Six. The post survey was taken at the end of the day the research it was in the classroom the pre-survey had been done a couple of day later. It is to be noted that there are two more responses in the post survey than in the pre-survey.

Question 6a asked about key words (Q6a):



There were some changes from the pre-survey with facts rising by 9 percentage points (pp) and experiments dropping by 25pp. Curiosity and proof also showed small increases (2pp and 12pp respectively).



The one-word choice also showed a decrease in the choice of experiments by 23pp and an increase in the choice of observations by 21pp.

The rate for having heard about discipline (Q8) rose by 4pp (to 57.1%) though those who disagreed stayed at a similar level at 25% (from 23% in the pre-survey). There was however a significant decrease in those who said they had learnt was a discipline was at school dropping by 12pp from 30.8% to 17.9%. They majority of the quantitative responses were still around punishment or behaviour.

When looking at the difference between science and history questions (Q9) the responses were similar with no change in the agree (50%) and a slight decrease in the disagree (by 4pp). There were similar qualitative answers (Q10) to the pre-survey either linked to science process, “A history question is about the past and science question it's about what you think and you have to observe and experiment it” or content “Science question are like why can't we live for ever but history question who invented the language”.

When thinking about a ‘good question for science to answer’ (Q11) the percentage who agreed they had been taught about this was similar (-1pp) but those who disagreed has dropped (-12pp) as had those who did not understand the question (-15pp) leaving almost half now unsure (48.1%) a change of +28pp.

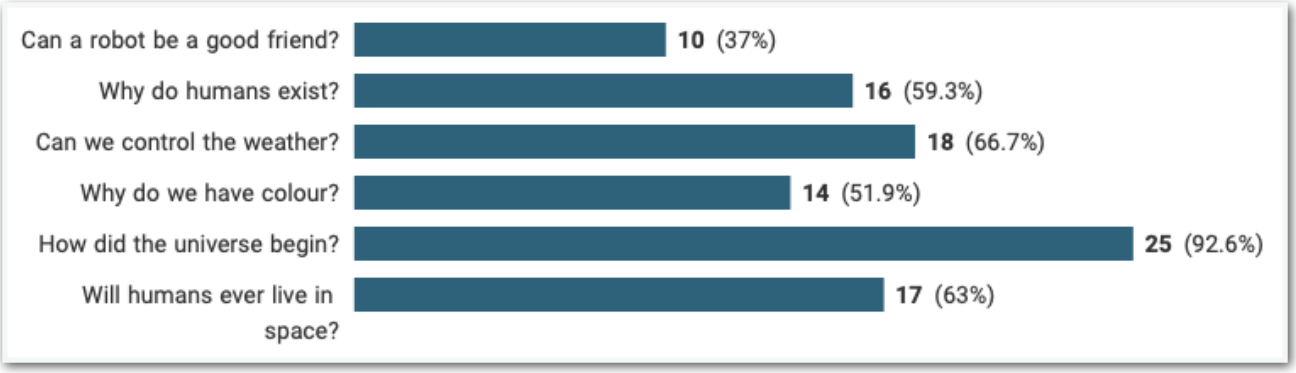
The qualitative answers (Q12) were similar to the pre-survey with some answers on science process, “A good question is a question that is big and takes a lot of time to answer and a lot of proof and experiments have to be done” and some more philosophical, “It being a big unanswerable question”.

Likewise the questions the would like to ask (Q13) were similar with a mix of testable and philosophical questions.

Numbers dropped slightly for wanting to think about Big Questions (BQs) (Q14) from 53.8% to 48.1% (-5pp) but so had the number who said they did not talk about this at home from 53.8% to 48.1% (-5pp) and the number of children who said they did not talk about science at home had also dropped from 53.4% to 37% (-17pp).

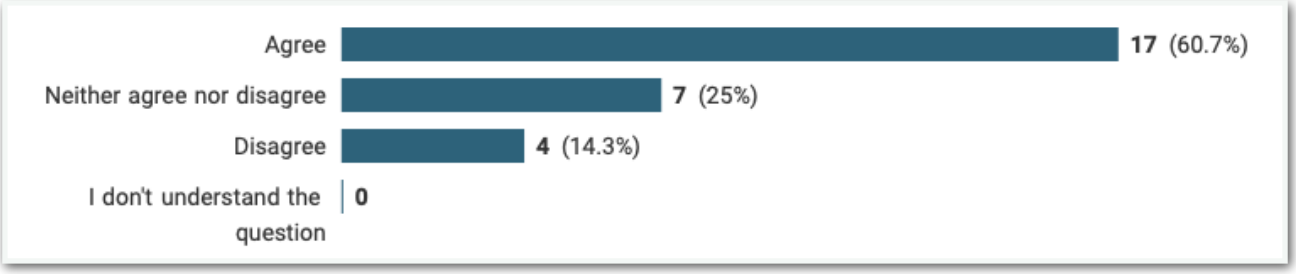
Thinking about 'why humans exist' the qualitative answers (Q15) were again similar to the pre-survey with some scientific explanations rooted in, sometimes misunderstood or misconceived, ideas about evolution, "Earth has the perfect conditions for life and we just happened to evolve", "I think they exist because of the big bang", and "Genetic evolution" and some more mystical and theistic, "Because the universe decided to create them", "I think god created everything and also created humans", "I think that humans exist because we can protect some endangered animals", my favourite was a combination of both science and theology, "They are made form clay and water and DNA".

Q16 on interesting in BQs offering a similar spread to the pre-survey:



The exception was the change in the question, 'can we control the weather' which rose from 48% to 66.7% a rise of 19pp - possibly as a results of the investigation on clouds?

A little shift in the thinking about disciplines (Q18-20) with a drop in Science CAN to 7.4% but a rise in CAN and CAN HELP to 92.6% (+16pp), religion staying the same but history gaining on CAN (from 3.8% to 18.5%) and CAN and CAN HELP to 58.7% (+16pp). The percentage enjoying science dropped slightly to 60.7% (-4pp).



The reflections on smartphones (Q21) changed a little with rise to 67.9% (+12pp) in those who thought there would be a smarter smartphone and drop to 53.8% (-8pp) of those who thought there currently was one.

There was small increase in those considering science as a career (+2pp), and a small corresponding drop in those not considering (-12pp). The reasons given for positive, “Because science is fun and it can help people”, “Because I want to be a doctor and a doctor is to do with science”, “I would like to be a scientist or engineer because it is really interesting” and those who were negative, “I don't want to be a scientist because I hate science”, “Cause I already chose my job”, “No because I'm not that interested in science” similar. Some children still did not have the wider conception of science viz. “because I want to be a doctor and I don't know how t make science experiment”.

Finally, in the post survey the children were asked which areas they enjoyed most. The children were generally enthusiastic, a significant number talked about enjoying the investigation experimental work with some mentioning the spinners and the penny (water drop) experiment. Comments included, “Learning new things and asking new questions”, “Finding different ways to make it better or easier to do”, “I like doing experiments and finding proof of things” and “I enjoy learning things and testing experiments”.

Teacher Interview

Teachers were not available for an interview.

Researcher Reflections and Commentary

The school is in a deprived area and the range of children's abilities, even in Year Six, was apparent from the handwriting and comments on the surveys. There are a significant number of the children working at a level below national expectations for year six and the class teacher was not overly secure in her science knowledge. The children were generally keen and enthusiastic with the activities and offered some thoughtful responses but there was some significant confusion on some of the core ideas. The children reported on liking the activities and the open-ended and discursive nature of these and in conversation with the teacher she agreed that these were useful and different to the 'normal' ways of working. She alas said that the children were not so used to science activities in year six as this was year normally geared towards SATs in May.

Some children's work was offered by the teacher, who has carried out two of the investigations (the spinner and the water drops) before the researcher was able to come into the class. The children's work indicated that they had reflected thoughtfully on the questions and were able to generate both their own questions and recognise the nature and process of scientific enquiry.

Conclusions and Wider Reflections

Drawing together data from the pre- and post-survey data; the responses from the teachers and the responses from children in the classroom leads to a number of reflections on the research:

1. **Children's engagement for open activities**

Children were generally enthused about undertaking investigational work and really enjoyed the opportunity to undertake these open investigations. They were good at exploring the initial ideas and then throwing off sub questions and new hypotheses to explore and test further. This idea of probability thinking was something which the activities encourage them to do. Some children did struggle a little with the reflection and discussion but it was also evident that lower ability children, or children who normally struggled with the scientific activities, were able to engage in a way that was not normal in their everyday practice.

2. **The paradox of structure, boundaries and freedom to explore**

Children really enjoyed the freedom to take their investigations in directions which they chose. There was some hesitancy and it was obvious that this was not normal in the practice, but they like the opportunity to do this although occasionally frustrated when resource was not available. The removal of the barriers of an instructional technique meant that students were able to exercise curiosity and creativity. However, they also did need some,"nudging" and well-scaffolded discussions in order to keep some sense of order.

3. **The opportunity for divergent thinking / possibility thinking**

As mentioned above a real takeaway is the opportunity for children to undertake this divergent thinking, this was evidenced in most of the activities but particularly in the spinner activity.

4. The importance of epistemic clarity

What's the children engaged very well with the activities there is a need to be careful and be stink about the use of language and scientific terminology in order to ensure that children have a grip on this important common language. Also linking investigational work, and the exploration of the big questions, back to science discipline knowledge and science procedural knowledge. Whilst children were able to grasp the ideas of testability, observation, and replication these are concepts that need to be carefully stressed and carefully structured in the activities.

5. The perceived restrictions of the curriculum

Most of the teachers commented on how these activities went down well because they were, "not the normal curriculum" and that they were not hampered by the need to, “fulfil particular learning objectives”.

6. Systemic restrictions

Most of the teachers commented on the systemic restrictions of the curriculum and the amount of knowledge that needed to be transmitted to children, and the expectation that children would know a certain amount of knowledge that could be tested and replicated. This led to investigational work but tend to be very highly structured and where children follow instructions rather than having any self-direction or agency. There is a growing tendency for the push of this "slow practical" approach where the teaching model is an activity and the children then mimic it. It was particularly interesting that one of the teachers talked about this way of learning being promoted on her teacher education course but being restricted once that she was in an institution.