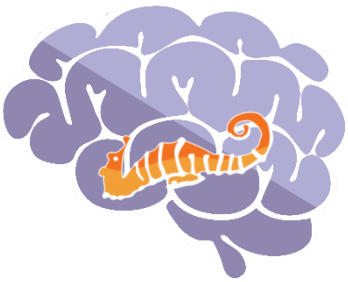

# The Curious Brain

# Evaluation Report

Public engagement pilot on curiosity and curiosity-based learning in primary schools. A coproduction involving neuroscience researchers, science communicators, teachers and primary school pupils.

**NOVEMBER 2024**

**Sophie Bartlett, Wendy Sadler, Rachel Mason and Matthias Gruber**

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# Abstract

Curiosity plays a pivotal role in enhancing learning and memory, making it a focal interest for educators. The Curious Brain project was established to align neuroscience research on curiosity with the learner-centred principles of the new Curriculum for Wales. The project sought to transfer neuroscience research to a primary school classroom context. Through an external evaluator, the Curious Brain was independently evaluated to explore the application of curiosity-based learning in classroom settings and the value of the collaborative process among neuroscience researchers, science communicators and teachers. Data were collected from pupils, teachers, neuroscience researchers, and science communicators to provide a holistic and comprehensive review of the project's implementation and impact.

Key findings highlighted the transformative effect of curiosity on pupil engagement and thinking. Curiosity was regarded to function as both an initial "spark" and a sustained process that fostered deeper inquiry. Pupils demonstrated independence and creativity in their learning and learning about the neuroscience behind curiosity enhanced pupils' awareness of the cognitive processes behind their thinking and equipped them with the appropriate language to communicate their own curiosity. Questioning emerged as both a central driver and indicator of curiosity, paralleling the "trivia paradigm" commonly used in neuroscience to evoke curiosity.

Pupils generally associated curiosity with positive feelings of excitement and fun, however some expressed frustrated when they did not know the answers to their own questions or how to find out. Challenges were also recognised among pupils of lower ability, limited cultural capital and who were non-native English speakers. This finding underscored the need for tailored differentiation to ensure inclusivity.

Collaboration between neuroscience researchers, science communicators, and teachers yielded key learning for all groups. This interdisciplinary partnership successfully translated complex scientific concepts into actionable classroom strategies, enriching teaching practices and fostering a deeper understanding of curiosity's role in learning. Teachers gained valuable insights into the science of curiosity, which informed their pedagogical approaches and encouraged reflective practice.

Overall, the Curious Brain project demonstrated that curiosity-driven learning can enhance engagement and cognitive development in primary education settings. By integrating neuroscience research with classroom practice, the project highlighted the potential of curiosity as a cornerstone of effective teaching and learning. The findings underscore the importance of tailored strategies to address diverse pupil needs and promote equitable access to curiosity-driven learning opportunities. We hope to explore scalable approaches to embedding this project on a larger scale and measuring longer-term impact.

# Acknowledgements



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The Curious Brain team would like to send a big thank you to the teachers, researchers and science communicators who kindly consented to take part in the evaluation of the Curious Brain project and gave up their time in interviews or feedback surveys.

# Author Contributions

S.B., W.J.S. and M.J.G. contributed to the conceptualisation and methodology of the evaluation. S.B. carried out the evaluation: data collection and full analysis. Funding acquisition was secured by M.J.G. with support from R.M. Project administration was managed by W.J.S., R.M. and M.J.G., under the supervision of M.J.G. In this report, the Evaluation Method, Evaluation Results and Summary and Conclusion sections were written by S.B. The Introduction section was written by M.J.G., and The Curious Brain section was written by W.J.S. and R.M. All authors participated in the review and editing of the report.

### Competing Interests

Note that M.J.G is an author but also was part of the researchers interviewed for this evaluation. All data collection and analysis for the evaluation conducted independently by S.B. as an independent evaluator.

# Contents

# 1. Introduction

Curiosity is believed to have a crucial influence on learning and memory, making it a central topic of interest for educators (Gruber et al., 2019; Jirout et al., 2024; Oosterwijk et al., 2024).

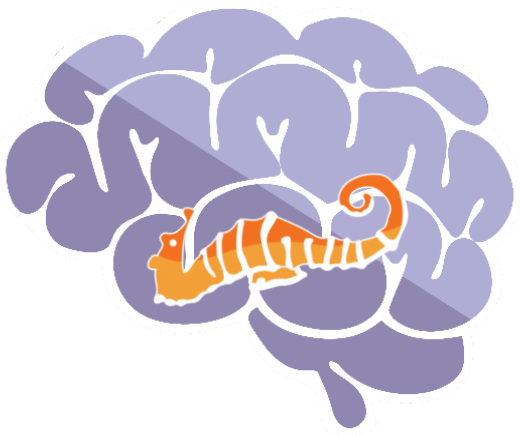
While early studies on curiosity primarily emphasised curiosity as a stable personality characteristic (i.e., trait curiosity; Grossnickle, 2016), research in the last decade has focused on understanding curiosity as a temporary cognitive state (i.e., state curiosity; Kang et al., 2009; Marvin & Shohamy, 2016; Gruber et al., 2014; van Lieshout et al., 2018).

State curiosity is generally defined as a motivational state that drives exploration and information-seeking behaviour aimed at reducing uncertainty (Litman et al., 2005; Gottlieb & Oudeyer, 2018; Kidd & Hayden, 2015; Berlyne, 1966).

Recent studies have shown that curiosity significantly enhances both learning and long-term retention of information. Many studies investigating the relationship between curiosity and memory have used a trivia paradigm (Kang et al., 2009), in which participants are tested on their memory for trivia answers that provoke varying levels of curiosity. These studies consistently demonstrated that participants exhibit better memory for answers to trivia questions that evoked higher levels of curiosity (Kang et al., 2009; Marvin & Shohamy, 2016; Gruber et al., 2014; Stare et al., 2018; Wade & Kidd, 2019; Murphy et al., 2021; Murayama, 2021; Erdemli et al., 2024).

Importantly, curiosity has also been shown to benefit real-world academic outcomes (independent of intelligence and conscientiousness) (von Stumm et al., 2011), with even larger effects on academic outcomes for children from socio-economically disadvantaged families (Shah et al., 2018). Curiosity also enhances well-being (Li et al., 2023; Kashdan et al., 2018). However, research findings also indicate that curiosity diminishes as pupils progress through the mainstream school system (Engel, 2009, 2011) with academic performance pressure rising. Academic performance pressure creates a less effective learning environment and is associated with mental health problems (Steare et al., 2023; Kodal et al., 2017; Fitzgerald et al., 2024).

Although new school curricula encourage sparking pupils' curiosity (Welsh Government, 2022) to harness the positive effects of curiosity and well-being, little is known about how to effectively support curiosity-based learning in schools.



Therefore, we designed the co-production project The Curious Brain to explore between researchers, science communicators, teachers, and their pupils how to best harness curiosity-based learning in upper key-stage 2 classrooms (year 5-6) in Wales.

# 2. The Curious Brain

The Curious Brain was designed to encourage the use of curiosity in line with the new Curriculum for Wales[1] which has an emphasis on learner-centred exploration. In this co-production pilot, we aimed to collaborate with researchers, science communicators, teachers and primary school pupils to:

- share knowledge about what researchers know about curiosity and the brain
- work alongside teachers to provide supporting resources and activities to facilitate curiosity-based learning
- give freedom for schools and pupils to choose how they wanted to explore curiosity
- evaluate which aspects of the co-production pilot could be helpful to other schools in delivering aspects of the Curriculum for Wales goals

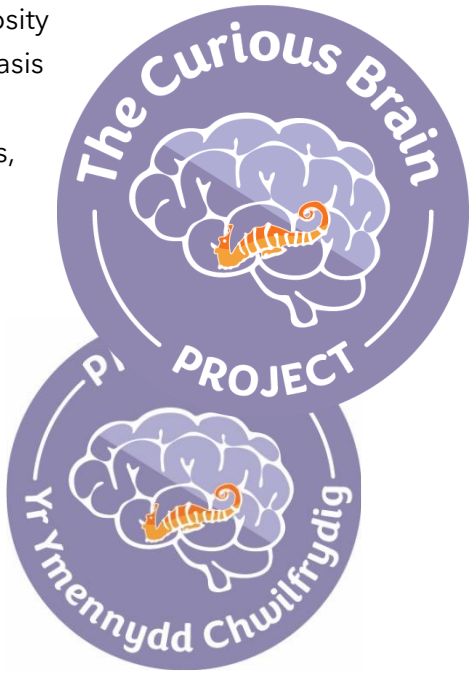



**Figure 1- Curious Brain project branding for schools**

The 3-step public engagement activity on curiosity and curiosity-based learning targets upper primary school children in five primary schools across Cardiff. There were multiple interactions with the schools which gave a framework and a timeline for the project whilst still allowing flexibility for how each school wanted to use the project.

At the start of the project a sandpit event was held with researchers and teachers exchanging research expertise and teaching expertise to explore what kind of content and support would be beneficial for both parties.

From the findings of this event, a plan of visits and activities were developed and a selection of 10 curiosity-based lesson plans were developed using themes suggested by the pilot schools and then these were developed by the science communication team. See Appendix 1 for pupil lesson plans and teacher notes.

These activities were designed to align with the CREST[2] awards to allow schools to gain accreditation for the projects they took up.

[1] The new Curriculum for Wales - introduced in September 2022. hwb.gov.wales/curriculum-for-wales

[2] CREST is a nationally recognised scheme (managed by the British Science Association) for student-led project work in the STEM subjects. Funding from the Welsh Government allows all schools in Wales to take part in this scheme at no cost. crestawards.org

Prior to the official start of delivery in schools a 'Curiosity Corner' was set up in each school with mystery items hanging from a tree and facilities for pupils to write about things they found curious (a photographic image of the complete curiosity tree is displayed in Figure 2). Four photos of objects related to the neuroscience research were planted in this corner of the classroom and pupils were invited to become 'curiosity detectives' to think about what might connect the clues.


**Figure 2 – Curiosity Corner in school**

Each school then received a class presentation about the brain from the science communicators and neuroscientists together to introduce some of the science and research of what we know about curiosity. This also included discussions and group work on how curiosity makes the pupils feel. The presentation used a selection of curiosity-inducing science demonstrations that were used to trigger questions and discussions.

The concept of the hippocampus (where curiosity-based learning occurs in the brain) and how MRI machines work to show us what is happening were covered at an appropriate level. The connection between curiosity and the release of the reward chemical dopamine was also introduced, and how dopamine is important for learning and memory.


**Figure 3 – Mini-research project planning in class**

After this visit, teachers decided with their class what they would work on for a mini-research project connected in some way to the concept of curiosity (see Figure 3).

Schools had around 8-10 weeks to work on this content and each received 1 or 2 further visits from the researchers and science communicators to help them develop their ideas and to answer questions.

Finally, the schools were asked to prepare a display about their work to exhibit at the celebration event held at Techniquest Science Discovery Centre, Cardiff in July 2024. This event allowed schools to see what the other teachers and pupils on the project had done. Science Rapper Jon Chase (MC Oort Kuiper) created a bespoke rap about curiosity and the brain that was performed and groups received prizes and certificates for taking part.

# 3. Evaluation Method

An independent evaluator was commissioned to evaluate the implementation and impact of the Curious Brain project. The aim of this evaluation was to investigate how findings from curiosity neuroscience research could be applied to primary school classroom settings. As the project involved collaboration across neuroscience researchers, science communicators and teachers, it was important to explore how each of these groups interpreted the concept of curiosity-based learning and their experiences of the project's implementation. The key questions this evaluation sought to address were fivefold:

1. What are young people's views on and experiences of curiosity?
2. How can teachers apply neuroscience research on curiosity to their classroom practice?
3. What does curiosity look like in the classroom environment?
    a. What are indicators of curiosity?
    b. How is curiosity stimulated?
4. What are the benefits of applying curiosity in the classroom?
5. What lessons can be learnt from collaboration among researchers, science communicators, and teachers?

These questions were addressed through mixed method data collection from pupils, teachers, neuroscience researchers and science communicators. All data collection took place after the implementation of the Curious Brain project or in the case of pupils, at the final celebration event at Techniquest.

Data collection from pupils involved their contribution to a 'curiosity tree' (a photographic image of the complete curiosity tree is displayed in Figure 4).

Four questions were posed to pupils, who had autonomy in which questions they answered.

They contributed their answers in either written or drawn formats and placed their answers on the curiosity tree which presented pupils' contributions on cards as the leaves (blank pupils response cards can be seen in Figure 5).

**Figure 4 – Pupils' Curiosity Tree**

The four questions were as follows:

**How does curiosity make you feel?** This question was intended to explore the emotions pupils attribute to curiosity and how they feel when they are being curious.

**What are you curious about?** This question was designed to gauge what pupils think about when they are curious about and to explore any common patterns across pupils in terms of the focus of their curiosity.

**How would you describe curiosity to a friend?** This was designed to gauge pupils' interpretation of and understanding of what the term 'curiosity' means.

**Being curious is [select from brilliant, good, bad, awful], because...** - this question was intended to uncover whether pupils regard curiosity as a positive or negative construct and the reasons for this association.

Data were collected from teachers via one-to-one interviews either via Microsoft Teams or telephone. One teacher was unable to commit to this method so contributed via a feedback form that provided a condensed version of the interview question schedule. Group interviews were conducted in-person with the neuroscience researchers, and online with the science communicators. All interview discussions were recorded, transcribed and transferred into the qualitative data analysis software, NVivo, for pattern coding and thematic analysis according to the protocol set out by Braun and Clarke (2006).

To protect the identity of participants, data has been anonymised and quotes are only labelled according to role (pupil, teacher, neuroscience researcher, science communicator). The evaluation was granted a favourable ethical opinion by the Cardiff University School of Psychology Research Ethics Committee.

# 4. Evaluation Results

## Data Collected

A total of 101 responses were received across all four questions posed to the pupils. It is not possible to deduce the total number of pupils who provided data as their contributions were anonymous and they responded to a different number of each of the four questions (that is, some only responded to one question, some to two, three, or all four).

All responses provided by pupils to these questions are provided in Appendix 2.

A total of 3 hours 50 minutes of conversation data were collected from interviews with teachers, neuroscience researchers and science communicators. Total data collection is summarised in Table 1.


**Figure 5 – Pupils' response cards**

***Table 1 – Total Data Collected***

| Participant | Number of participants | Data |
|---|---|---|
| Pupils | Unknown | ***How does curiosity make you feel?*** 20 responses<br>***What are you curious about?*** 20 responses<br>***How would you describe curiosity to a friend?*** 19 responses<br>***Being curious is brilliant/good/bad/awful because...*** 42 responses |
| Teachers | 5 | 1:58:51 conversation data |
| Neuroscience researchers | 3 | 1:09:33 conversation data |
| Science Communicators | 2 | 00:41:08 conversation data |

The subsequent sections detail the results from the thematic analysis of transcripts from interviews with the neuroscience researchers, science communicators and teachers. These results are then mapped against the evaluation objectives in the final conclusion section.

# Defining Curiosity: in the Lab and in Practice

The Curious Brain project was designed to translate lab-based research on curiosity and its connection to memory and information retention into the real-world scenario of primary school classrooms. The project involved four key groups: the neuroscience researchers engaged in curiosity research, science communicators, teachers, and pupils. To provide a context for the wider results of the implementation of the project, the evaluation protocol sought to identify each group's perspective on curiosity and how they defined it.

The neuroscience researchers highlighted the challenges in defining curiosity. While there is a broad definition used in psychology that describes an individual's desire to acquire new information, there are other less agreed upon definitions, such as the role of extrinsic and intrinsic factors.

> *There are so many definitions. There's no specific definition that everybody would agree on, the most general definition would be the desire to acquire novel information. The intrinsic motivation to get somewhere, to get a new piece of information.*
>
> ***(Neuroscience Researcher)***

> *I also tend to go with the really general definition, looking for information when it doesn't have any extrinsic reward attached to it. But I think even that is not generally agreed upon and you can still be curious when extrinsic reward is there.*
>
> ***(Neuroscience Researcher)***

One researcher highlighted the importance of exploring how researchers' definitions compare to education practitioners' definitions, particularly in the context of whether curiosity is always a positive attribute or if it can induce negative effects on individuals.

> *I think it's an interesting question worth exploring... how much that aligns with practicing educators' definition and how they see it happen in the wild. Maybe we never admit this, but I think we implicitly always assumed that this always goes in a positive direction. And I think we might touch a little bit upon the question of what if that's not the case? And what should we do with that in science communication settings and more broadly, maybe psychology needs to look into that other angle.*
>
> ***(Neuroscience Researcher)***

From the perspective of the science communicators, while they did not have explicit understanding of the science of curiosity, they felt they had implicitly used curiosity in their personal or professional experiences of teaching and learning.

> *This project was my first time hearing about it, but as soon as I heard it, it was like 'yeah, that that makes sense'. Personally, I find it really hard to focus on stuff that I'm not interested in or curious about, so it made a lot of sense to me.*
>
> ***(Science Communicator)***

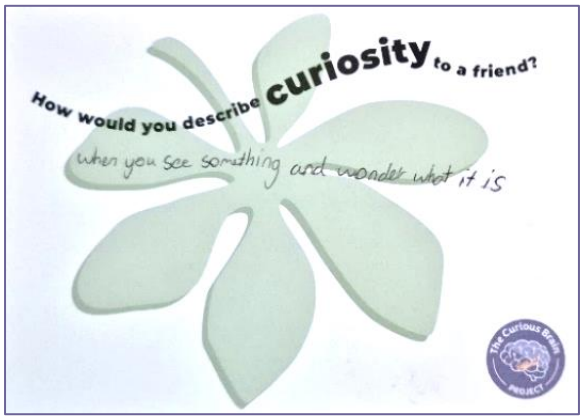
> *I worked as a teacher for 23 years beforehand and the teaching methodology that I came to prefer over the years was project based learning and guided discovery, and at the end of the day there are so many crossovers with curiosity-based learning. So, it's just giving it a slightly different focus, a slightly different title.*
>
> ***(Science Communicator)***

Reflections of the science communicators were similar to those of the teachers. Teachers reflected that while they knew the term 'curiosity', they were unfamiliar with the science behind it or its explicit relevance to the classroom. Nonetheless, some reflected on experiences of implementing similar pedagogical styles such as 'thinking and learning questions' and inquiry-based learning.

*It was something that I've kind of never really read about or like, read any literature and based around it. But yeah, I've always kind of known the importance of curiosity.*
***(Teacher)***

*We use something called at TLQ, which is a thinking and learning question and we use it instead of a title. So, we've always had a question to begin with and then they answer it with the work that we give them to do.*
***(Teacher)***

Pupils were also asked about their understanding and experience of curiosity. When posed the question, 'how would you describe curiosity to a friend?' pupils gave insightful responses. Some described curiosity as a desire to learn something or question something, others specifically described that curiosity comes from the hippocampus in your brain.




*It makes you want to know what something is.*
***(Pupil)***

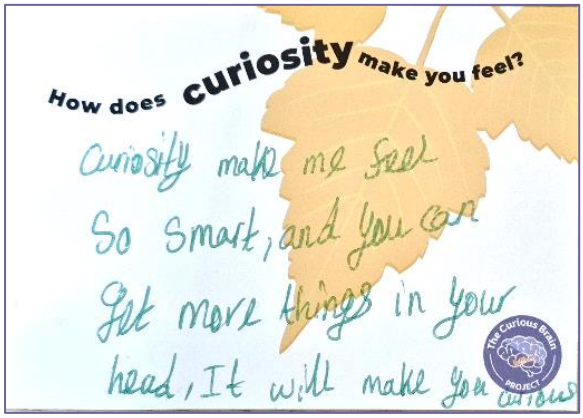
*When you see something and wonder what it is.*
***(Pupil)***

*I would say it's something that makes you interested about something.*
***(Pupil)***

*It is the hippocampus that makes you curious about different stuff or items.*
***(Pupil)***

# Pupils' Experience of Curiosity

When asked how they would describe curiosity, some pupils attributed particular emotions to curiosity. Some described curiosity as 'really fun', or that it 'makes you feel happy', or said it was 'a feeling or emotion that happens from time to time'. Similarly, the separate question, 'how does curiosity make you feel?' prompted generally positive responses from pupils who reflected that curiosity made them happy and excited:




*Curiosity makes me feel excited to ask questions.*
***(Pupil)***

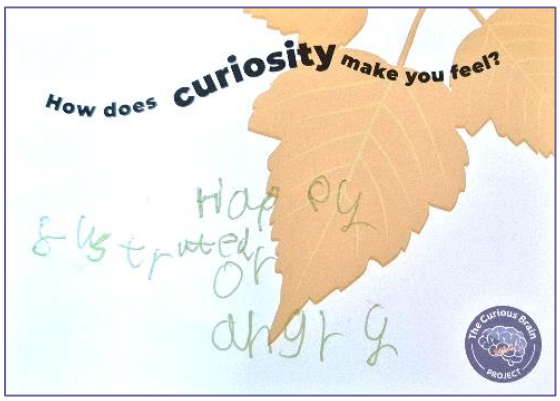
*It makes me feel happy and weird inside.*
***(Pupil)***

*Curiosity makes me feel so smart, and you can get more things in your head, it will make you curious.*
***(Pupil)***

Teachers also commented on the positive responses they had observed among their pupils. They reported that some pupils had even described that the dopamine release felt like their brain was rewarding them for their learning.

*Some of them were saying 'I think I've just had a dopamine hit.' 'I think my brain's giving me a reward' and coming out with these things. It's really nice to see.*
***(Teacher)***

However, some pupils attributed negative connotations to how curiosity made them feel, describing feelings of frustration or annoyance. It is noteworthy that these were typically combined with positive feelings and were rarely used solely to describe their feelings.




*Happy, frustrated or angry.*
***(Pupil)***

*Happy and sometimes sad.*
***(Pupil)***

*Mae chwifryddedd yn gweneud i fi teimlon counfused!*
*[curiosity makes me feel confused!].*
***(Pupil)***

Those who expressed frustration or confusion conveyed feeling like this when they didn't know the answer or couldn't find an answer to their questions. To ensure that curiosity-based learning induced positive experiences, teachers and science communicators stressed the importance of creating a safe and suitable environment to empower pupils to ask questions without fear of asking 'wrong' questions. One teacher explicitly described how they structured their lessons to ensure curiosity was contained to the capabilities of the pupils and what could realistically be achieved in the classroom.

> *I want to make sure that I close that unknowing and that loop of never really get into an endpoint. It could be quite frustrating for them and I would worry that they thought they were doing it wrong. Like if they were kind of asking the wrong questions and stuff.*
>
> ***(Teacher)***

It was apparent in discussions with the researchers that these emotional responses from pupils had parallels with two types of curiosity traits they observe in the lab – interest-based curiosity and deprivation-based curiosity. They stressed the value in seeing how these traits manifested in real-world scenarios and the effects they induced.

> *When SMS [Science Made Simple] talked about the different feelings and something like oh, it's a happy feeling or it's an annoying feeling like oh, we could see this maps exactly to the two types of trait curiosity, deprivation based, which is more associated with negative affect and then the positive one that's more interest based or joyous exploration curiosity that's more associated with positive affect. So, it was good for us to see this panning out.*
>
> ***(Neuroscience Researcher)***

Despite these parallels, the role of emotions in curiosity was described by the neuroscience researchers as something they actively aim to reduce in their experiments so that it does not cloud how the brain mapping presents cognitive information. They recognised this as a key difference in the priority of what researchers' need to achieve in the laboratory and what teachers need to achieve in the classroom.

> *It's so interesting because ironically, when you talk to the public, the full definition of curiosity involves emotion or some kind of emotional valence or description. In our experiments we actually try to tame that part in order to focus on more cognitive information aspects, but actually for teachers, they might have their priorities different. And so, I would say that there's a question of how emotional is the curiosity that you're trying to elicit? And I think we differ in the lab to that of in the wild.*
>
> ***(Neuroscience Researcher)***

# Curiosity in the Classroom

Much of the discussions with teachers explored how they had implemented the Curious Brain project and the concept of curiosity-based learning in their classroom. Teachers were asked about the techniques they use to stimulate curiosity among their pupils and any barriers they perceived in terms of pupils being curious but also using curiosity-based learning in the classroom setting.

## Implementing the Curious Brain Project

In terms of embedding curiosity in the classroom, while teachers took different approaches, most implemented the project over an intense timeframe. Some did this by applying curiosity to a topic they had already scheduled in their teaching timetable for this period. In such circumstances, teachers taught the same subject matter but altered their pedagogical approach to include a curiosity focus.

> *It wasn't exactly the same as what we would normally do. The asking questions actually did come in and lend itself quite well to our curriculum. Which is what they wanted us to do at the start of each of the lessons was, 'right, we're going to do a lesson about solids, liquids and gases', which is what we were doing, 'what questions do you have? What are you interested in?' The idea that that spurs on their curiosity.*
>
> ***(Teacher)***

One teacher described how positively their pupils responded to this approach. They were impressed by the ideas that pupils came up with that went beyond what they as the teacher would have thought of.

> *The things we did for the curiosity project was 'what is beauty?' So, looked at beauty and music, we looked at inner beauty and outer beauty, we looked at plastic surgery and changing the way you look. We look beauty in different cultures, [...] they looked at the stars, so one of them is doing about the solar system and why people find beauty in astronomy, in the weather, why people are obsessed with the weather and look all day. In feelings and why people are more attracted to people who are happy. I would never have thought to do that, it's a nice way to do it.*
>
> ***(Teacher)***

Other teachers applied the Curious Brain project to a designated themed week they had at school, or applied curiosity to extra-curricular activities that the school sets aside time for in the school timetable. Teachers envisaged that this approach would promote more self-directed learning among their pupils and would introduce them to topics they would not usually encounter in the classroom. One teacher even described allowing the pupils to contribute to this decision by sharing the topics they would be interested in.

> *We decided not to link it to the theme we were doing in school at the time, just because we'd been doing the theme for quite a while, and they had quite a bit of background information, and we wanted them going in with no idea, so there was more scope and more curiosity there behind them. So, we normally have a STEM[3] week, so we used the Curious Brain project as our STEM, so we decided to give them a theme, like a scientific theme to look into and make mini projects themselves.*
>
> ***(Teacher)***

[3] STEM – Science, Technology, Engineering and Maths

*It's like a new curriculum approach where we utilise the strengths of the staff in school to produce an afternoon, every half term where we have extracurricular activities running. So I do things like coding or cycling clubs, that kind of thing. So I was looking for something to do with Curious Brain with that. And when I spoke to the children, they were very keen to go down the video games [route].*

***(Teacher)***

## Stimulating Curiosity

In terms of stimulating pupils' curiosity, it was apparent that a common approach among teachers was to pose questions to the pupils. Researchers and science communicators perceived this to be valuable modelling behaviour that helped guide the pupils in forming their own questions and ensuring the openness of curiosity was controlled sufficiently to remain appropriate for the curriculum content.

*In terms of asking them questions, I think that was probably the most consistent across schools, [teachers] just helping the students to generate questions, writing the questions, collecting the questions on the board to find out what they're interested in, just to see, 'OK, Can we find anything?', adding new questions, guiding them towards thinking about it in a slightly different way.*

***(Neuroscience Researcher)***

*I remember one of the teachers, I always thought he was brilliant every time because whenever we were talking in front of his class, he would input anecdotes, he would have his hand up and ask questions as well. And I just think modelling that behaviour to the students, they can see their teacher is paying attention and their teacher is engaging, that makes them more likely to do that.*

***(Science Communicator)***

Researchers highlighted parallels in how teachers triggered pupils' curiosity with the trivia paradigm they use to elicit curiosity in their experiments. They regarded posing trivia questions to participants to pique their curiosity as akin to teachers posing questions to pupils about the topic they were going to be learning about.

*The working horse in curiosity research is the trivia paradigm which basically uses trivia questions to illicit different levels of curiosity. But I think it's quite similar to in the classroom because we use trivia questions, science related, could be any subject related, there's some other, music and sports in there that might be less school related, but it is quite school related.*

***(Neuroscience Researcher)***

Alternatively, one teacher used a technique of providing limited information to pupils to stimulate their curiosity and cause them to wonder what they were engaging with and what information they were missing. In recognising the different learning preferences of pupils, the teacher experimented with different senses: using images, audio and video clips to prompt curiosity across different individuals in their class.

*I would often give them a blue picture of a video game which they could make out minute details of. It wasn't evident what it was and that would then spark the curiosity and get the conversations flowing. Some children were able to run with their ideas and really go to town with it. Some children really struggled with that element. And then following on from that, we played a small audio clip whether it be like a sound effect or whether it be the soundtrack of the game or even just the title music and things like that. That spread different learners to be curious about different things. So the ones who maybe were less vocal during the picture side of it then becoming more vocal during the audio side of it when they were listening to the parts aspects of the game.*

***(Teacher)***

## Barriers to Pupils' Curiosity

Teachers were forthcoming in highlighting some of the barriers to fostering curiosity, emphasising the need for key components to implement it effectively. Many stressed the importance of ensuring the pupils had a degree of baseline knowledge – not only of the subject, but also what curiosity is, how to be curious and how it can help their learning. The knowledge of how to be curious was seen as effective in helping pupils to feel confident in engaging with this way of learning and in framing their questions to make them more specific and manageable. For example, in one school, pupils were studying evaporation and condensation. At the beginning, the teacher reported that their only questions were 'what is evaporation?' and 'what is condensation?', but as their learning progressed and they acquired more understanding, pupils were able to formulate more focused and specific questions.

*We've spoken about how you need information to become curious, it's very rare that you become curious about something that you know nothing about. You need something to spark it.*

***(Teacher)***

*They struggled a little bit with asking the questions because they didn't have much background knowledge on it... They can't talk and write about stuff until they've learned it. So, at the start of a lesson, when you're saying, right, we're going to do condensation and evaporation. Have you got any questions on that? Apart from what is condensation? And what is evaporation? [...] So we found that when we got talking about and explaining it, then the questions will come in.*

***(Teacher)***

The challenge of baseline knowledge and appropriate language was particularly evident for the less able pupils. Teachers reflected how these pupils required additional structure and scaffolds to support their learning and consequently found the openness of curiosity and increased agency it gave them, a challenge.

*I definitely think the less able children, or who aren't as academically confident, I think they find it a little bit harder. Just because they're used to structured learning and using scaffolds to help them within their work and things and then you open this up to them this idea of curiosity, and they can dig into things how they want to, but I definitely think that they seem to find it slightly harder.*

***(Teacher)***

*My top group, they're very good at articulating, 'we're curious about this because we didn't know this before' or 'we're using prior knowledge'. So I think with my more able group, that's working really, really well. My less able group need a lot of support and a lot of guidance with the vocabulary to manage that and to almost unpick what they're doing.*

***(Teacher)***

Several teachers reported on the mixed demographic of their pupil population and felt that pupils who frequently engaged in activities and learning opportunities outside of school with their parents, benefited from these experiences and were able to draw on these in the classroom. These differences were most apparent in terms of pupils' vocabulary and were suggestive of a discrepancy in the value of curiosity-based learning across pupils with different levels of cultural capital. Teachers were concerned that some pupils, and those for whom English was not their first language, did not have sufficient language, communication skills or experience to convey their curiosity and construct appropriate questions.

*We've got a very mixed demographic and background of the children here. Maybe three quarters of them get a lot of experiences outside the classroom, at home with their parents, going here, going there, and some of them just go home and don't leave the house until the next morning and come back to school. [...] And it lends itself into the classroom. The ones who can who have been, can speak about it, have more of a vocabulary, they're writing, they can draw on experiences that they've had.*

***(Teacher)***

*Some children didn't speak much English when they first came to our school. There was a child with additional needs in the group as well, so he did need a little bit of extra support just to kind of grasp some of the initial concepts.*

***(Teacher)***

## Barriers to Curiosity in the Classroom

As well as highlighting the barriers to pupils' ability to use curiosity, teachers also conveyed the more practical barriers to embedding curiosity in the school setting. These largely related to time restrictions and curriculum constraints. Nonetheless, teachers commented that while these presented a challenge, they recognised the benefits of finding time for curiosity-based learning. One teacher also urged the increased feasibility of embedding elements of curiosity into existing teaching content and adapting the start of the lesson to allow pupils to pose questions, rather than trying to find additional time to apply curiosity.

*I wouldn't say you have to plan for it, but you do have to give up time for it. You do have to give up time to say 'this isn't what I planned, but this is more beneficial' and I know a lot of teachers find it quite hard to let go because they have their ideas of what's structured, what they need to do, what they need to cover.* ***(Teacher)***

*I think adding things in is always difficult. But putting it into something else is not so difficult... where you can slide it in something as a technique. Because the time and the restrictions with curriculum, and what you have to cover is so tight already, putting in a whole lesson on curiosity, you wouldn't have a chance. But sliding it into a topic lesson, like a science lesson or history, geography lesson... I think there's potential for that, where you can at the start of the lesson for ten minutes, talk about it, talk about questions, talk about answers, I think that's more plausible than something totally new.*

***(Teacher)***

# Indicators of Curiosity

The neuroscience researchers use brain imaging and mapping techniques to recognise active curiosity among individuals. However, as brain scanning technology is not available in primary schools, the evaluation sought to explore how teachers recognised curiosity among their pupils in the classroom environment.

The commonly cited indicator of curiosity, as described by teachers, science communicators and researchers were pupils asking questions. Teachers observed that this behaviour signalled a desire to learn and was often accompanied by increased engagement, focus, enthusiasm and effort in lessons – and sometimes, even outside the classroom.

> *Questions being the biggest thing. Sometimes if we're doing a topic that they really think is key, constantly they're like 'what about this?' 'What about that?' They're wanting to find out more. The effort is usually pretty good, you tend to find their enthusiasm towards it is higher as well when they find themselves being more curious.*
>
> ***(Teacher)***

> *Engagement, participation and focus in lessons. Going home to research further learning (for some). Asking questions of interest based on learning.*
>
> ***(Teacher)***

Some teachers also described how learning about the science of curiosity from the neuroscience researchers had made pupils more equipped to articulate when they were feeling curious. This provided explicit evidence of their pupils' curiosity and meant the teacher was less reliant of identifying indirect indicators of curiosity. Pupils were not only able to express when they were feeling curious, they also voiced when they were not.

> *You can hear it around the room as they're working, that they'll say, 'oh, I'm curious about this', or 'my hippocampus is working' and just that general awareness that something is happening in their brain as they're doing it. [...] Then there was the negative, it's 'I've got no dopamine at all. It's really low'.*
>
> ***(Teacher)***

However, it was apparent that teachers sometimes struggled to recognise indicators of curiosity when teaching so many pupils together. Pupils display individual differences in terms of their behaviour and engagement, which leads them to express curiosity in different ways. One of the neuroscientist researchers acknowledged the challenge that arises from attempting to identify curiosity as a behaviour among large groups in an educational setting compared to brain mapping on a single individual in laboratory conditions.

> *So many different ways with this group because they're all so different in the way they learn. Some of them was just questions, questions, questions, and then other ones were happy just to crack on and find out things themselves. And then they come up to me and be like, 'oh, do you know this? Do you know that?' So some of them will be quite reliant on asking questions [to me], and other ones would just go out their way independently, find out what they wanted to know, learn some new facts and then take it upon themselves, to be curious.*
>
> ***(Teacher)***

*I do remember talking to one teacher who said that she was really looking for the behavioural markers. And I think asking questions is the big one and kind of said that was what sort of she found tricky about inspiring curiosity was in some ways, It's hard to tell, especially when you've got thirty kids in a room, how everybody is feeling. So for her, she said 'I'm looking for question asking as a big indicator that these are the kids who are feeling curious and want to know something more'.*

***(Neuroscience Researcher)***

# The Role of Curiosity in Learning

While the neuroscience researchers had experimental evidence of how curiosity can benefit memory and information retention, the Curious Brain project demonstrated how pupils themselves also recognised this benefit. When posed the statement 'curiosity is brilliant/good/bad/awful' because…' all pupils, who provided responses, marked curiosity as either 'good' or 'brilliant' with common justifications being that it had helped their learning, helped them to think, and helped their brain. Some even connected curiosity with the hippocampus in their brain, and one even connected curiosity and memory.

*Being curious is brilliant/good because it helps your memory to adapt to what you are thinking.*

***(Pupil)***

*Being curious is good because it helps you learn more stuff and helps your brain develop.*

***(Pupil)***

*Being curious is brilliant because it makes me ask questions and it uses my brain power which helps me learning.*

***(Pupil)***

*Being curious is brilliant because being curious gets your hippocampus working and you'll learn more.*

***(Pupil)***

Interviews with teachers, neuroscience researchers and science communicators explored their views on the role of curiosity and its place either as a trigger for learning or a vehicle and process for learning. The researchers again emphasised the broad and various definitions of curiosity that are employed in neuroscience research. While simplistically, curiosity is described as a desire to acquire new information, some researchers maintain that the process of exploring, and information seeking is also part of curiosity.

*The broad definition we gave, the desire to acquire new information, is just the spark, but then other definitions would say it's all the processes associated with it. So, you have the spark, but then everything else you do, the exploration, the information seeking, that's also part of curiosity.*

***(Neuroscience Researcher)***

One science communicator and teacher signalled that while pupils' initial curiosity prompted a search for more information, acquisition of this additional information triggered further curiosity. This process might suggest that curiosity was embedded in the process of learning and helped sustain the learning process, rather than acting merely as an initial trigger. One science communicator described this process as "*curiosity in motion*".

> *With the Curious Brain project, the more they asked, the more curious they became, and it tumbleweed-ed into becoming more and more curious the whole way through it. So instead of, I guess, collecting ideas at the start and learning the facts about those things, we just had them be curious about the whole thing, so that their learning was always developing in regards to their curiosity.*
>
> ***(Teacher)***

> *The projects done by [school name] really stood out as giving the children the opportunity to follow their curiosity because they all started with the same subject which was 'beauty' but they [pupils] went off at completely different angles and then they got curious about plastic in the oceans and then they investigated this, and someone else has started investigating something else. So, it was really nice to see their curiosity in motion.*
>
> ***(Science Communicator)***

Another science communicator commented on their view of curiosity as not only a desire for information, but a process that readies your mind to accept and store that new information. They saw this as the connection with memory and retention, not simply a desire to learn, but a psychological ability to.

> *I think curiosity is when you want to know information, but it means you're really ready to accept that information.*
>
> ***(Science Communicator)***

Conversely, some teachers viewed curiosity as the trigger for learning rather than the process. Nonetheless, they expressed the importance of curiosity as an essential foundation for learning to take place. One teacher coined curiosity as a "*spark*" for learning and used the analogy of a campfire with their pupils. The need for fuel and heat to make fire was seen as analogous to the need for curiosity as a vital pre-requisite for effective learning.

> *We looked at a visual of a campfire, we looked at the learning behind getting that 'boom'. You're not going to ignite your fire without those sticks, those underneath things, you're not going to get anything without them. We looked at that and that's why they call it spark because they get there.*
>
> ***(Teacher)***

> *Personally, I think it's that spark. Whenever they have that new information about new things, that new resource, that new teacher, whatever it might be. I think that curiosity, that spark is what plays the most vital role in their education. When I was training, it was always you want to try and have a hook, something to get them really excited, that was always the word, something to get them excited, but actually now, we want something to get them curious. We want to get them thinking, discussing.*
>
> ***(Teacher)***

# Curiosity Across Different School Subjects

Interviews with teachers also explored the applicability of curiosity to different school subjects. While teachers felt curiosity could be applied to other school subjects, they expressed a view that some subjects could embed curiosity more readily than other subjects. English was used by several teachers as an example where curiosity could be naturally woven into the curriculum.

> *If you're teaching English, if you're starting to read a book in class, the first thing you tend to do is look at the cover and start asking questions about, what do you think it's going to be about? What can you deduce from the picture on the front, let's read the blurb, what do you think might happen? All of that comes with curiosity, so I think there is a place.*
>
> ***(Teacher)***

Alternatively, maths was commonly cited as a subject that lacked natural excitement and curiosity and would be harder to teach through a curiosity-based approach. Nonetheless, one of the science communicators emphasised the potential of using curiosity to contextualise any subject and framing subject matter within more stimulating and interesting real-world contexts or scenarios.

> *I think maybe teachers have go to work with their curriculum, 'okay, we're still doing the maths, we're still doing this, but we're flavouring it with something' that the kids have chosen. Like the kids wanted to learn about the sea, so we're going to calculate how deep this part of the ocean is, and that'll be your maths. I feel like there could be potential to look into flavouring lessons around stuff that the children have voted on or chosen.*
>
> ***(Science Communicator)***

One teacher also emphasised the importance that regardless of subject, pupils should be encouraged to recognise and reflect on their thinking and their curiosity so that their thinking can continue to develop. This reflected the previous comments about how ongoing curiosity leads to ongoing learning.

> *I think for English, they do ask a lot of questions when we're reading. We've been reading goodnight, Mr. Tom. And we stop quite a lot because they have a lot of questions about why did he do that? Or why did that happen, more for themselves to think, oh, actually why did that happen? Or why has he done that? Or even, what does that mean? Or what does that word mean? You know, so they are constantly asking questions, it's just bringing them into focus, thinking about why they're asking the question.*
>
> ***(Teacher)***

# Benefits of Curiosity

While memory retention was the focus of the neuroscience research and was emphasised to the teachers as a key potential benefit from embedding curiosity in their classroom, feedback from the teachers demonstrated there had been additional benefits of curiosity to pupils beyond retention.

## Independence and Creativity

A key benefit of implementing curiosity-based learning was seen in its ability to foster pupils' agency, and independent thinking and working. One teacher felt this was particularly valuable in the context of constraints of the curriculum and tight teaching time which stifled opportunities for pupils to explore their own thinking and ideas. Teachers felt the Curious Brain project had created more opportunities than what is typically granted by traditional teaching for pupils to become more independent learners.

> *I think that was really nice about the project, it gave them that opportunity to find out the questions that they wanted to know and be curious about, which is quite different to school when we're learning about something specific, they can't really go down those routes and be as independent or as curious.*
>
> ***(Teacher)***

There was also a sense that this space for independent thinking encouraged the pupils to be more creative, being guided by their imagination and interests rather than following didactic instructions. One pupil even commented on how curiosity allowed them to "*be more creative*".

> *I think it allows them to be really creative as well. Because people can be curious in different ways. And I think we definitely saw that in the project. It definitely brought out and showed the creativity in some of the children. And I think it just opens up their imagination.*
>
> ***(Teacher)***

## Self-Awareness and Reflective Thinking

Teachers also described how learning about the science of curiosity and what it does to your brain and your thinking had encouraged pupils to be more self-aware and reflective of their own thinking and how they can use their thinking effectively to acquire information. Teachers felt this was not only beneficial for the pupils but was valuable understanding for the teachers in guiding their lessons and encouraging pupils to reflect on how they felt about their learning.

> *We have noticed that the way they engage has improved slightly because they're thinking more about how they're thinking, and we've done a lot of talking about what happens when you're starting to learn. So they're almost practiced in what you do to start thinking [...] thinking about how they're going to get started with something. I'm less involved in starting work with them. [...] So it's always been, we know curious means we want to find out more, but they kind of progressed into 'how are we going to find out?' and 'how are we going to keep it going?'*
>
> ***(Teacher)***

*They feel more comfortable, their thinking has changed, their language has maybe changed slightly. I think they've got that core knowledge of curiosity and I think it's changed the way that they receive new things. Whenever we've had anything new going on, I'd imagine that it's the thought process going on 'well, I'm excited about this because I'm curious about it, I want to find out more because I am curious'. So yeah, I think there's definitely been a change.*

***(Teacher)***

## Improved Language and Communication Skills

While teachers commented on the importance of language in curiosity-based learning and how this presented challenges for some pupils, they also reflected that engagement with the Curious Brain project had helped in developing the pupils' language and communication skills. They commented that pupils were using language that they would never had been subject to without the project.

*My top groups were often saying 'I think my hippocampus is working extra hard', 'I think I've got extra dopamine' and really using the language that I would never have ever taught them, I would never have said... I would never have used that vocabulary with them. It's not something that was ever taught and it's now something that gets used a lot around the classroom.*

***(Teacher)***

*We've never delved into the hippocampus, the dopamine response system, that's something that we would never touch in primary school normally, but actually they've coped really well with it. I think they've got a pretty solid understanding. I had a few people coming in to observe, we had inspectors come in and they were asking the children questions and they were blown away by what they'd be learning about, they couldn't believe that we were [doing] all this neurological science.*

***(Teacher)***

One teacher described the celebration event where pupils presented their work to judges and to pupils from other schools as a valuable opportunity for pupils to recognise the importance and ways of communicating and sharing their ideas.

*I think it's important to teach the children as well that it's all well and good knowing these ideas and having this information, but it's very important as well, to be able to communicate it to others and share and present ideas. I think yesterday [celebration event] was really successful, and they got to see other schools sharing their ideas, too, communicating with the scientists and other people. I think that was really nice*

***(Teacher)***.

# Looking to the Future

Given the finite timescale of the Curious Brain project, a key component of conversations with teachers was to gain insight into their expectations of the legacy of the project in terms of their own classroom practices. In terms of looking to the future of the Curious Brain project and potential extension or follow-on stages, teachers' views of potential improvements were also explored as well as all participants' views on the value of the collaborative component among teachers, neuroscience researchers and science communicators.

## Improvements to the Curious Brain Project

While the teachers spoke positively of the Curious Brain project, they expressed some suggestions for how it could be improved in the future. One teacher expressed a desire for greater interaction with other schools involved in the project, to share and learn from different techniques for implementing curiosity.

> *We had a very brief opportunity to speak with the other schools who were involved. And I think, it's all time and unfortunately, we're all very busy as teachers. But having that opportunity to network and to find out what are they doing in that in [school name] primary, what they're doing here and how are they doing it differently? Having that discussion would help support everyone.*
>
> ***(Teacher)***

Some teachers also suggested providing opportunities for the pupils to use scientific equipment or even to visit the neuroscience researchers at work to see what it's like in the day of a scientist and see the instruments and equipment they use to conduct their research.

> *It would've been nice to visit the research team in their place of work and do something 'sciencey' in the university maybe? An added experience? Not a criticism, but a nice add on if they were to run the project again.*
>
> ***(Teacher)***

> *The lesson on the particles that were too small to be seen, we chatted about it after and said, 'oh, we could have used some of the microscopes' and things like that.*
>
> ***(Teacher)***

## Teachers' Ongoing Practice

One teacher reported that they had begun to thread curiosity-based learning throughout all their teaching topics and in their day-to-day teaching. Each time a new topic was introduced in the classroom, the teacher would begin with an inquiry activity, introducing the topic and then allowing pupils to pose questions they wanted to learn about, the teacher would then incorporate these questions into their lessons over the next few weeks to allow pupils to pursue avenues for answering them.

> *So what we've started doing in our inquiry, the children stick up questions, so we've pinned up their questions on the wall, and if they're not already in my planning, then I'll take that as part of my planning and try and answer those questions, either directly answer them or give them opportunity to find out... I would never have thought of the questions that are up there right now, but I'll give*

*them the opportunity to find out and present back to people because that's what they're interested in. It's that they'll remember, it's not what I teach, it's that.*

***(Teacher)***

Some teachers had kept the materials that formed the Curiosity Corner. One had kept hold of the toy brain and seahorse that represented the hippocampus and described how this provided a useful visual aid to encourage pupils to stop and reflect on their thinking and their learning.

*I kept the hippocampus and the brain and use them as resources for my children. So, something that you'll get out and say, 'right, it's hippocampus time, it's curious time, let's have a think' because I really like the way that the children were able to speak about what was happening when they were learning. It's not something I've ever found a way to articulate before, was how they're learning.*

***(Teacher)***

Others had maintained the concept of Curiosity Corner, an area in their classroom where a number of prompts related to the particular topic the pupils would be learning about to prompt their interest and curiosity in what they were going to be learning about. One teacher was keen to try and implement a Curiosity Corner in every classroom in their school and explore how it could be differentiated to make it suitable for all pupils and learning needs.

*I'm just in the process now of setting up my new classroom, and I'm going to be having a curiosity corner using a lot of resources that [science communicator] provided us with to keep the children engaged with it as long as possible, really. This is so important. [...] hopefully we can potentially roll out across the school have a curiosity corner in every classroom, and how we can differentiate to make sure it is accessible to different people, to different learning needs.*

***(Teacher)***

Teachers were forthcoming in expressing their optimism for how curiosity would naturally lend itself to the new curriculum in Wales. Their view was that this revised curriculum allowed for more openness and exploration in the classroom and freedom for pupils and teachers to be more creative.

*I think the vision now for this new curriculum is that the children can have a bit more independence, a bit more freedom to choose what they want to do, so that naturally will lend itself to curiosity. We can set things up in the classroom, hopefully gravitate towards becoming curious and lead their own learning. I think it'll pay dividends in the end.*

***(Teacher)***

## Lessons Learned from Collaboration

An important uniqueness of the Curious Brain project was how it brought together different experts. Neuroscience researchers, science communicators and teachers all contributed to how the project evolved and implemented into the classroom.

Overall, the teachers, neuroscience researchers and science communicators reflected positively on the experience of working with each other. Science communicators and neuroscience researchers felt everyone had worked as a team, offering different insights and contributions.

*It did feel like teamwork, with the teachers as well. Everyone has very different perspectives and needs and interests. I thought it was really interesting and useful.*

***(Science Communicator)***

In particular, the researchers valued the opportunity to 'get out of the lab' and see how their research applies to real-world scenarios. They felt this offered additional insight they could not gain from lab-based experiments and reassured them about the ecological validity of their research methods.

*Think it was amazing. We learned so much from it, and probably our time, we learned much more than just compared to running another experiment.*

***(Neuroscience Researcher)***

*We think a lot about how to increase the ecological validity of the work we're doing, of course we would have been doing it retrospective, but of course this helps. I think that it helps in having more courage in working with younger demographics than what we normally work with in the lab.*

***(Neuroscience Researcher)***

The neuroscience researchers also felt this real-world application was important for demonstrating the value of their work and extending their impact beyond merely academic channels. They reported a desire to continue exploring co-production opportunities in the future.

*It's terribly exciting. I haven't seen anything like this before so I do think that this will have to be crucial going forward because we're entering a time of probably more limited resources and I think the research that psychologists contribute might have to be a bit more tailored to apply to settings, maybe going forward. And so what better way to do it than through these co-developments?*

***(Neuroscience Researcher)***

*Before, we were in our ivory tower and thinking 'yeah, I can imagine curiosity might be used in the classroom but it's not that important', but just having this from five teachers, knowing how they used it before and what changed, I think that it's a game changer, and it really helped our group to really appreciate the value of co-production, so we're trying to get that into our future projects now.*

***(Neuroscience Researcher)***

## Contribution of Teachers

Teachers were asked what contribution they felt they were able to offer to the Curious Brain project. Their responses largely centred around demonstrating how to manage a classroom environment and how to work with, talk to, and interact with children to maximise engagement and apply appropriate teaching strategies.

*I think it's that experience in schools of how to work with children. The researchers weren't sure how to come in, how to talk to the children, what they needed. And it's just that saying 'we need this, this and this, this needs to happen. You have to do it a certain way because this is how we do it as a school or this is how Year Five children need to learn'. Because they've [the researchers] got so much knowledge, they know so much, but it's very different disseminating that to somebody who's wrapping their legs around the chair and trying to hit someone else with a ruler.*

***(Teacher)***

*Whenever they came into school, they stayed for the duration of the session, so they were able to see my teaching strategies, my classroom provision and what I set up in the classroom, how I manage the pupils and that kind of thing.*

***(Teacher)***

Indeed, the neuroscience researchers were forthcoming in expressing their admiration of how teachers were able to recognise and adapt to the needs of their pupils and find the "*sweet spot*" to stimulate enough excitement to engage the pupils but not too much that it detracted from their learning and focus. This approach was unfamiliar to the lab setting where they typically only work with one participant at a time, and all variables are controlled and comparable across participants. The researchers were intrigued how this could be understood scientifically.

*It's finding that sweet spot, surely there's a point where you over-excite children, and it actually harms how much you can work with them and convey messages. And I really don't know enough. That's probably a hallmark of a good teacher is to for them to intuitively know and average out the excitement dynamics of each child and find the optimum class level group average point of what is the good energy level for this classroom. It's incredibly amazing that a lot of teachers are able to find this intuitively, it would be amazing to understand that scientifically, how if I give you 20 different people, how can you find that group level sweet spot? I think that would be a big contribution of psychology to education research or education practice.*

***(Neuroscience Researcher)***

*Working with the teachers who work with these kids day-to-day... they of course know a lot about the practicalities and the challenges they're facing in these real-world classroom environments that we don't need to consider having one undergraduate student in the lab at a time in this very controlled environment. It is completely different than when you get thirty kids who all want to go off and do different things. It was just so valuable to get inside at different steps of that process.*

***(Neuroscience Researcher)***

## Contribution of Science Communicators

In terms of the science communicators, their role appeared to offer different contributions to that of the teachers and to the neuroscience researchers. From the researchers' perspectives, they valued how the science communicators were able to translate the scientific research into something tangible and meaningful for primary school pupils and teachers. While the researchers recognised the potential educational value of their own work, they did not feel they had the expertise to apply it. The science communicators therefore provided a means of adapting the research to be suitable to a classroom environment and were recognisant of the needs of and demands on teachers.

*Obviously, when you're doing any kind of science, your hope is that somewhere down the line, it's going to be useful outside of the lab, but there are so many missing links to get to that point. So, working with the science communicators who know how to present the science in a way that's effective but also engaging and can target different audiences, that's so valuable.*

***(Neuroscience researchers)***

Alternatively, the teachers welcomed how the science communicators were able to excite the pupils about the project as well as helping the teachers to generate ideas for implementation and ensuring they could adopt the project whilst not deterring from the curriculum or the expectations on the school.

> *The group that came in at the start to introduce the Curious Brain Project, that was fantastic, it grabbed the kids' attention straightaway, and really got them excited about the program. So that was really, really nice.*
>
> ***(Teacher)***

> *We are very knowledge-heavy, that's what our Head[teacher] was worried about initially, about how it would be different. But when they came in and explained it, they said, 'oh, no, no, no, we'll tailor it towards your curriculum, it's just more about the asking questions', which is what they were pushing [...] they said, 'we're not coming in to tell you how to do it, we want to tailor it around what you're already doing' so that worked well.*
>
> ***(Teacher)***

> *[science communicator name] was brilliant in terms of giving me ideas of what to do, coming in and setting up various things. [...] Having the team in from Science Made Simple, with some of their contraptions, it was really, really exciting for the children to see because they sparked their interest and there was a general buzz in the room, it wasn't just me hopping on about curiosity every week.*
>
> ***(Teacher)***

## Contribution of Neuroscience Researchers

Teachers described the value of engaging with the neuroscience researchers at the start to learn and ask questions about their research and its implications for learning. They valued the opportunity to understand more about what curiosity can do to your brain, how it has potential to improve learning and understand its value in the classroom.

> *The one psychologist came in to talk about the science side of the research behind it and met with our headteacher, and they talked about curiosity and how it works. It was interesting to hear the research behind that. She went into far, far more detail into the science and how the brain works and why it's important, which is good to hear, actually.*
>
> ***(Teacher)***

> *It's new to me from a science point of view. We've always looked at how you learn, at different roles for learning. We do a lot of cooperative learning, so we've always looked at the roles of the learner, the thinker and the leader and thought about why you would do each role, why you need each role. But we've never did the science behind it, and what your brain needs for thinking and what happens when you think. So, that's been really interesting for the staff, for the children.*
>
> ***(Teacher)***

In addition to this information sharing, teachers felt the researchers presented as valuable role models for the pupils, giving them an opportunity to learn more about what a career in science involves and to interact with "*real scientists*" who they looked up to and admired.

*It was sold to them as you're meeting real scientists. So they've had this big thing: the scientists are coming. It's been really nice for them because it doesn't matter how much I teach them, these people are real scientists, so whatever they say is law, so they were really engaged from the word go, which is really nice.*

***(Teacher)***

*Doctor Gruber and his team came in and gave a lot of the kind of the research-based findings and talked about their own research and what they did. And I mean, the children were fascinated by the MRI scanner. The fact that they could track what their brains were doing, it did blow their minds. So that was a really nice element of it.*

***(Teacher)***

The researchers themselves hoped that their presence in the schools and interaction with the pupils would encourage some to consider a career in science or prompt a teacher to explore curiosity-based learning opportunities and implement these with additional pupil cohorts or share with their colleagues. The researchers were encouraged by the comments they'd received from some of the pupils who implied the project had helped them to recognise the value of the topics they learn in school and how they might use these skills in their own future.

*For the kids, I hope it was fun to have us come in. I think scientist is a weird job and I remember at one school I was getting a lot of really good questions like, 'so where do you actually work?' and 'what do you actually do?' And at one point I was saying, 'we have experiments, and we do a bunch of math' and a kid at the back was like 'oh, is that why we have to learn math?'*

***(Neuroscience Researcher)***

*I think kids appreciate people coming in and spending some time with them and I would like to think that it makes them feel valued and important, and I hope that we just provided that experience for them. And maybe if every tenth or thirtieth or one hundredth student thinks 'yeah, the brain is cool', or they're interested in neuroscience or physics because of what gets embedded with it, that's worth it, absolutely worth thirty minutes of our time, no doubt. That's the micro view of it and maybe the macro view is if the teacher decides to read a paper on curiosity-based learning and maybe they try it out when they have time, embrace it between the other teachers, I think that that has ripple effects.*

***(Neuroscience Researcher)***

## Neuroscience Researchers' Future Practices

The neuroscience researchers reported on some of the future work that has already begun in response to the implementation of the Curious Brain project. They reflected on their observations of the primary school pupils' engagement in the project compared to what they had observed in other separate engagements with secondary schools and colleges. They observed that the level of engagement and natural curiosity among young people appeared to drop between these different stages of education and were interested in exploring why this happens and how their research could explore ways to mitigate it.

*The one thing that was really striking for me too, was the kids seemed so curious and so engaged, versus when I did a co-production event at a local college and the level of curiosity had gone way down and the level of stress had gone way up, which makes sense, but it really got me thinking about what's happening in between there and is there anything that we as researchers can do to help understand that or maybe help mitigate that?*

***(Neuroscience Researcher)***

It was apparent that some of these efforts were already in motion and engagement has begun with secondary schools. There was also a desire to explore how the Curious Brain project could be upscaled for implementation across a wider number of schools and as a more formally embedded component of the new Curriculum for Wales.

*We started already co-production with a secondary school that came out of this, because we presented the Curious Brain at the Science Festival, 'to be a scientist', so that was already one spin out of that, where we're doing co-production and working closer with the schools. The Curious Brain project itself, I think, we'll see based on the evaluation as well, I would be quite keen to translate that to bigger classrooms across Wales, across other schools to see whether this could be produced as a kids' activity booklet and so on, yeah. Whether this could be upscaling it, whether this could be part of something like a project within the new Curriculum for Wales.*

***(Neuroscience Researcher)***

# 5.Summary and Conclusion

The Curious Brain project was an iterative co-production project between teachers, neuroscience researchers, and science communicators, yielding valuable insights for all groups into how curiosity can be effectively integrated into primary school settings and induce valuable learning experiences for pupils. It was apparent from implementation that curiosity was successful in sparking engagement and learning among pupils whilst also sustaining it.

Teachers observed that curiosity-based learning promoted pupils' independent thinking, creativity, and self-awareness, and provided more opportunities for them to become independent learners compared to traditional teaching methods. While some teachers faced challenges in recognising indicators of curiosity in large class sizes, the process of asking questions and pupils' increased engagement were commonly perceived indicators.

However, curiosity-based learning was not without its challenges. Teachers described how pupils of lower ability and language proficiency sometimes struggled to engage in this learning approach. Conversely, the more able learners picked it up quickly and flourished. This is an important consideration in the context of the learning gap between pupils of different characteristics, such as socioeconomic status and implies curiosity-based learning needs to be carefully differentiated to ensure suitability and benefits for all learners.

Neuroscience researchers valued the chance to see their work applied in real-world settings. This reassured them of the ecological validity of their methods and highlighted the impact of their research beyond the lab. Science communicators were key in translating complex research into tangible classroom practices, enthusing pupils, and helping teachers align curiosity-based learning with the curriculum. Teachers also appreciated learning the science behind curiosity and understanding empirically, its contribution to memory and information retention. The key findings from the evaluation have been mapped against the evaluation objectives in Table 2.

***Table 2 – Evaluation Results Mapped to Evaluation Objectives***

| **What are young people's views on and experiences of curiosity?** |
| --- |
| • When asked to define curiosity, pupils described a desire to learn, and a sense of wonder and interest in something. Some also explicitly referred to the role of the hippocampus in curiosity.<br>• Every pupil who participated in the evaluation described curiosity as 'good' or 'brilliant'. Their justifications for this positivity included its ability to help their learning, help them to think, and help their brain.<br>• Most pupils associated curiosity with positive emotions, such as fun and happiness, though some also mentioned feelings of frustration, annoyance, or confusion.<br>• Neuroscience researchers noted that these emotional responses reflect the two types of curiosity they observe in their research: interest-based curiosity and deprivation-based curiosity. |

## How can teachers apply neuroscience research on curiosity to their classroom practice?

- Teachers adopted various approaches to embedding curiosity in the classroom. Some integrated curiosity-driven learning into their existing lesson plans, while others dedicated themed weeks for more extracurricular style activities focused around curiosity.
- A common practice among all teachers was posing thought-provoking questions to spark pupils' curiosity. Researchers and science communicators perceived this to be valuable modelling behaviour, helping guide the pupils in forming their own questions while ensuring the openness of curiosity was controlled sufficiently to remain appropriate for the curriculum content.
- Neuroscience researchers noted that the technique of posing questions mirrored the trivia paradigm, a common experimental method used to stimulate curiosity in psychological studies.
- One teacher experimented by providing pupils with partial information to pique their curiosity. Recognising different learning preferences, they also explored engaging multiple senses to enhance curiosity.
- Teachers faced some barriers in implementing curiosity-based learning, both in terms of pupil engagement and practical classroom constraints. They emphasised the importance of pupils having a foundational understanding—not only of the subject matter but also of what curiosity is and how to cultivate it. This challenge was particularly evident with less able pupils, those with lower cultural capital, and those for whom language was a barrier. This could suggest that curiosity-based learning, if not suitably differentiated to different groups, risks expanding the gap between pupils according to characteristics such as socioeconomic status and language.
- Regarding classroom limitations, teachers noted challenges with time constraints and the demands of the curriculum. Nevertheless, they viewed curiosity-based learning as valuable and found it more feasible to integrate elements of curiosity into existing lessons rather than creating additional time for it.

## What does curiosity look like in the classroom environment?

- Teachers commonly identified pupils' curiosity through their tendency to ask questions, viewing this behaviour as a key indicator of a desire to learn. They observed that curiosity often coincided with increased engagement, focus, enthusiasm, and effort during lessons.
- Some teachers also noted that, after learning about the science behind curiosity, pupils were able to explicitly express when they felt curious and when they did not.
- Nonetheless, some teachers were expressive of the challenges in recognising indicators of curiosity in large class sizes. Pupils display individual differences in terms of their behaviour and engagement which in turn, leads them to express curiosity in different ways.
- Neuroscience researchers acknowledged the complexity of identifying curiosity as a behavioural marker in real-world settings, especially with large groups, compared to tracking psychological markers in a single individual in controlled laboratory conditions.
- In terms of the role of curiosity, some teachers described it as a "spark" for learning and other described it as an ongoing process, where their initial curiosity led pupils to acquire new information, and this information prompted further curiosity.

## What are the benefits of applying curiosity in the classroom?

- Teachers highlighted several benefits of incorporating curiosity-based learning in the classroom. They noted that it fostered pupils' agency, encouraging independent thinking and self-directed learning. Many felt that the Curious Brain project provided more opportunities for independence than traditional teaching methods typically allow.
- Some teachers also observed that creating space for independence nurtured pupils' creativity, allowing them to be guided by their imagination.
- Additionally, learning about the science behind curiosity and how it affects the brain helped pupils become more self-aware and reflective about their own thinking processes (i.e., meta-cognition). It also equipped them with the language to better express their thoughts and emotions.

## What lessons can be learnt from collaboration among researchers, science communicators, and teachers?

- Overall, teachers, neuroscience researchers and science communicators reflected positively on the experience of working with each other throughout the project. Nonetheless, teachers expressed a desire for greater interaction with other schools involved in the project, to share and learn from each other.
- The neuroscience researchers described efforts that were already in motion for further collaborative projects on curiosity with secondary schools in response to the Curious Brain project.
- Neuroscience researchers appreciated the opportunity to see how their findings apply in real-world classroom settings, providing insights beyond what could be gained in lab-based experiments. This experience reassured them about the ecological validity of their research and highlighted the broader value of their work outside academia.
- Researchers appreciated how science communicators effectively translated complex research into tangible, meaningful concepts for primary schools and teachers.
- Teachers welcomed the contributions of science communicators, particularly in helping them develop practical ideas for implementing the project in ways that aligned with their school's needs. They also valued the way science communicators enthused the pupils.
- Teachers found the collaboration with neuroscience researchers beneficial in deepening their understanding of how curiosity influences the brain and its potential to enhance learning. They also saw the researchers as valuable role models for their pupils.
- In terms of ongoing practices, teachers conveyed how they were now threading curiosity-based learning in all their teaching topics. Some also retained the materials from the 'Curiosity Corner' either to use as visual aids to encourage pupils to stop and reflect on their thinking and learning, or to adapt each time they introduced a new topic in lessons.

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# 7. Appendices

## Appendix 1 – Support Resources for Teachers and Pupils

The Curious Brain Project Teacher Guide, Teacher Activity Booklet and Pupil Activity Sheets can be downloaded from a dedicated project page on Science Made Simple's website as English or Welsh materials. www.sciencemadesimple.co.uk/curious-brain

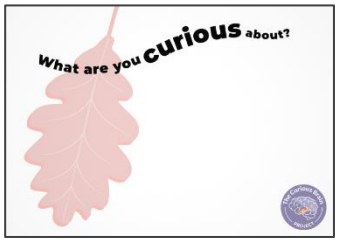
# Appendix 2 – Pupils' Responses

## How does curiosity make you feel?



- Curiosity makes me feel excited to ask questions
- It makes me feel happy and weird inside
- Mae chwifryddedd yn gweneud i fi teimlon counfused! [curiosity makes me feel confused]
- It means you are curious
- Curiosity makes me feel so smart, and you can get more things in your head, it will make you curious
- Happy frustrated or angry
- Happy and sometimes sad
- Mae chwifryddedd yn neud i mi fimlo cyfrous [curiosity makes me feel giddy]
- Excited
- Interested
- Curious because curiosity make feel confuse or don't know this
- Interesting
- Am not curious
- Im curious about playing games
- It makes me feel the need to ask questions
- Happy annoyed
- Curiosity make me curious and really interested in a item or object
- Make me feel happy

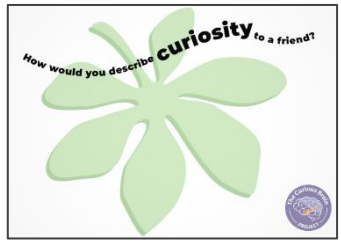
## What are you curious about?

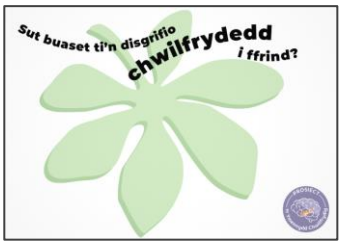




- About learning new things
- I'm curious about the hippocampus
- What else is in this place [techniquest]
- About what the prizes are
- The tongue
- The [science communicator name] rap
- Me alpha male sigma
- I'm curious about how lamps work
- Hippocampus
- Am curious about what's gonna be the prize, what is in the brain
- I want to know are octopus the most romantic creatures cause they have 8 hearts
- Why dogs can only see some colours
- Techniquest contest
- Make up, blue tac
- Make up, blue tac, my digestive system
- I'm curious about what my friend is thinking about!
- I am curious about volcanoes. Does the smallest volcano erupt?
- I am curious about why the earth has so many layers?
- How do volcanoes form? Because they are not like a plant!?!
- Techniquest

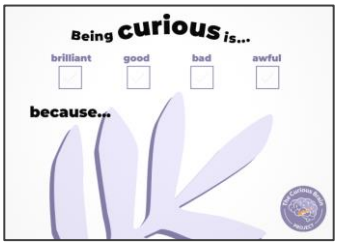
## How would you describe curiosity to a friend?

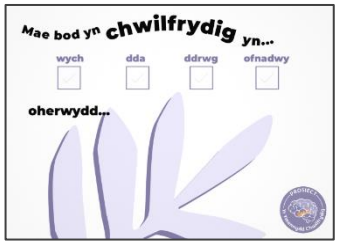



- It makes you want to know what something is
- Something that makes you wonder and ask questions (adult)
- The hippocampus [and drawing]
- I would describe curiosity as a feel or emotion that happens from time to time
- Like that don't know something
- When you see something and wonder what it is
- It is when you're curiosity about something
- Good and helpful
- I would tell him that being curious makes you feel happy
- I would say it's something that makes you interested about something
- I would tell them everything i know about it
- The sea horses gives you curiosity
- Well curiosity is really fun
- Curiosity
- When you're curious about something or your brain is curious
- Being curious is to question things
- It is the hippocampus that makes you curious about different stuff or items
- [drawing of hippocampus and heart]

## Being curious is brilliant/good/bad/awful, because...




- Good (2 responses)
- Brilliant (4 responses)
- Good: you don't always know what to expect
- Brilliant: it helps you learn / mae yn helpa dysga
- Brilliant: it makes you smart
- Good: it's good because if you wasn't curious about things then you wouldn't want to learn
- Brilliant: aydych chi'n gallu yweld pethau newydd [you can see new things]
- All selected: I think curiosity can be good or bad, depending on what you're curious about. But, I think it's MOSTLY good
- Brilliant: I can get to learn things
- Brilliant: it exercises the hippocampus
- Brilliant: it helps you find things out
- Good: it helps you think more
- Brilliant: it is amazing
- Brilliant: it makes you think about everything
- Good: is good to be curious about something and tell other people why
- Good: it helps you think!
- Good: if you're curious you'll wanna learn more and the more you learn the more smart you are
- Good: I like it
- Good: so you can be more creative
- All selected: you can be really excited about something and you can be sad or anger
- Good: you learn new things
- Good, Brilliant: it helps you memory to adapt to what you are thinking
- Good: it helps you learn more stuff and help your brain develop
- Brilliant: being curious gets your hippocampus working and you'll learn more
- Good: I think being curious is good because it makes you use your hippocampus and helps learn more
- Good: it's good about gaion(?)
- Good: it is good to ask questions and trying to find out about stuff when you're curious
- Good, Brilliant: it makes me feel interested in something
- Brilliant: it helps you learn about new things and helps you learn more about important things
- Good: it helps you push yourself forward to do things that you are curious about
- Good, Brilliant: you find out new things
- Brilliant: it makes me ask questions and it uses my brain power which helps me learn
- Brilliant: maen bwysig i gofyn cwesiwnau a ffeindio yr atet ir cwestiwn [it is important to ask questions and find the answer to a question]
- Brilliant: being curious is brilliant because you want to find out more about something and you can also learn lots of stuff
- Good, Brilliant
- Brilliant: I get to ask more questions
- Brilliant: I think when you're curious it's just good so you can then learn new things
- Brilliant: it helps you learn