Fostering critical thinking in primary science through *'What if...'* scenarios

A Year 5 classroom study in an independent all-girls school

Layla Hewitt

Abstract

This practitioner study investigates the use of *'What if...?'* scenarios as a strategy to promote critical thinking in Year 5 (ages 9-10) science lessons at an independent all-girls school (Reception – Year 11). The intervention was framed by enquiry and discovery learning theories (Bruner, 1960; Harrison & Howard, 2022). It drew on pedagogical strategies from *'Thinking, Doing, Talking Science'* (TDTS), a primary science teaching approach that emphasises structured dialogue, hands-on exploration and reflective questioning as drivers of critical reasoning (Hanley *et al*, 2020). The findings from this study aligned with outcomes from TDTS research and indicate that *'What if...?'* questions are a low-resource, high-impact tool for developing scientific thinking within tight curriculum timescales. Implications for practice include their scalability for teaching other science topics at Key Stage 2 (ages 7-11), alongside recommendations to explore cross-curricular opportunities.

Over a six-week unit on forces and space, children engaged with weekly imaginative prompts (e.g. 'What if gravity only worked at night?'). Responses were scored using a three-point rubric assessing predictability, reasoning and creativity. Results showed a clear progression from simple, predictable answers to diverse, well-reasoned and imaginative solutions. In addition, quieter and lower-attaining children displayed greater confidence and engagement over the six-week period.

Introduction

Critical thinking – the ability to evaluate evidence, construct reasoned arguments, and reflect on ideas – is a core skill for learners and practitioners alike (Facione, 1990; Elder, 2022). In education, and particularly in science, it extends beyond acquiring knowledge to engaging with enquiry, problem-solving and hypothesis-building. In the classroom, this means that children are encouraged not just to recall facts but to question, analyse and apply knowledge in new contexts, fostering deeper understanding and resilience in problem-solving. For teachers, embedding critical thinking underpins children being able to have effective judgement and communication, enabling them to question assumptions, weigh evidence and make informed, adaptable decisions.

Within my Year 5 class (ages 9-10) at an all-girls school, children demonstrated strong attainment in areas requiring memorisation and structured tasks, but were less confident in problem-solving and reasoning. Developing these skills is especially important for girls,

who, as research shows, may be less likely to take risks or contribute speculative answers in science (Kitmitto *et al,* 2018). During lessons on forces and space, many struggled to engage deeply with abstract or open-ended questions. Instead, they tended to rely heavily on teacher guidance and avoided sharing imaginative ideas. When looking for research-informed classroom resources to address this issue, I came across Explorify's *What if...?* scenarios (Leonardi *et al,* 2023) and an enquiry-oriented teaching approach, *Thinking, Doing, Talking Science* (Hanley *et al,* 2020).

Explorify's *What if...* scenarios

Explorify (website below) is a digital science teaching resource designed to foster classroom dialogue. Explorify's *What if...?* activities present children with imaginative, open-ended questions so that they can explore possibilities and explain their reasoning. Rather than seeking correct answers, these prompts encourage discussion, curiosity and creative thinking (Leonardi *et al,* 2023).

For example, questions such as '*What if humans could breathe underwater?*' or '*What if the Sun never sets?*' create space for children to hypothesise, draw on prior knowledge and justify their ideas. This approach supports:

- **Critical and creative thinking** – children practise connecting ideas, identifying consequences and reasoning through unfamiliar situations.
- **Oracy and collaboration** – activities encourage structured talk, listening to peers and co-constructing explanations.
- **Science capital and engagement** – children are given the freedom to see science as imaginative and relevant, building confidence without the pressure of being right or wrong.

In practice, *What if...?* scenarios provide a low-stakes but high-engagement opportunity to embed scientific thinking and develop children's communication skills, making them a suitable tool for fostering critical thinking.

Thinking, Doing, Talking Science (TDTS)

Thinking, Doing, Talking Science is a primary science teaching approach developed to raise attainment by making science more interactive, discussion-rich and conceptually challenging. It emphasises higher-order thinking, dialogue and hands-on enquiry to deepen children's understanding (Hanley *et al,* 2020).
Key features include:

- **Conceptual challenge** – encouraging children to think beyond recall and grapple with 'big ideas'.
- **Scientific reasoning** – developing skills such as predicting, hypothesising, testing and evaluating.
- **Dialogic teaching** – structured opportunities for children to articulate, justify, and build on each other's ideas.
- **Practical enquiry** – hands-on activities where children actively investigate and apply their thinking.
- **Creativity and imagination** – integrating playful scenarios, stories and thought experiments to spark curiosity.

To address the gap that I had identified during my teaching practice, I implemented a short intervention using Explorify's *What if...?* scenarios, integrated with strategies from *Thinking, Doing, Talking Science* (TDTS).

The intervention aimed to nurture curiosity, foster higher-order thinking and increase children's confidence when approaching unfamiliar or imaginative challenges.
The objectives were to:

1. Build children's scientific knowledge through imaginative questioning;
2. Encourage creative application of knowledge to unfamiliar contexts; and
3. Develop critical thinking through open-ended, dialogic exploration.

By embedding *What if...?* scenarios into the curriculum, I sought to create a supportive space for children to test out imaginative reasoning, while remaining aligned with statutory curriculum requirements.

Context and rationale

The project was conducted in a Year 5 (ages 9-10) class at an independent all-girls school, where I serve as both the class teacher and science/STEM lead. I had observed a significant gap in critical thinking skills within this cohort, particularly a reluctance to engage with problem-solving tasks and new questions.

Research from TDTS highlights the effectiveness of dialogic, exploratory strategies in enhancing children's engagement and confidence in talking about science (Kitmitto *et al,* 2018). Similarly, Explorify's *What if...?* scenarios are designed to provoke curiosity and encourage speculative reasoning by presenting hypothetical challenges such as *'What if humans could breathe underwater?'* or *'What if plants didn't need sunlight?'.*

These resources align with research by Minner, Levy and Century (2010), which suggests that engaging children in speculative reasoning enhances their ability to connect concepts and think flexibly – key components of critical thinking. By combining TDTS-inspired practices with Explorify's *What if...?* questioning, the intervention aimed to create an inclusive, dialogic environment where children felt empowered to explore imaginative possibilities.

Methodology

Research design

A mixed-methods approach was employed to capture both quantitative and qualitative data. This included:

- Pre- and post-intervention questionnaires (quantitative) (see Figure 1);
- Classroom responses to *What if...?* scenarios (qualitative);
- Rubric-based assessment of creativity and reasoning (quantitative and qualitative); and
- Teacher observations and reflective notes (qualitative).

This design allowed for a variety of data, providing a richer understanding of how the intervention influenced children's critical thinking.

Participants and setting

The study involved 19 Year 5 children (ages 9-10) at an independent all-girls school. The single-class sample provided a manageable group for close observation and individualised analysis, though the small size inevitably limited generalisability.

Intervention

The intervention took place over six weeks during the autumn term. Weekly science lessons on forces and space incorporated scenarios linked to curriculum content. Examples included:

- *What if gravity only worked at night?*
- *What if there were two Suns?*
- *What if you had magnets for fingers?*
- *What if there was no Moon?*

Each 15-20 minute session followed a consistent structure:

1. Introduction of the *What if...?* question.
2. Paired or small-group discussion.
3. Use of the Plus, Minus, Interesting (PMI) framework to structure responses.
4. Sharing and whole-class reflection.

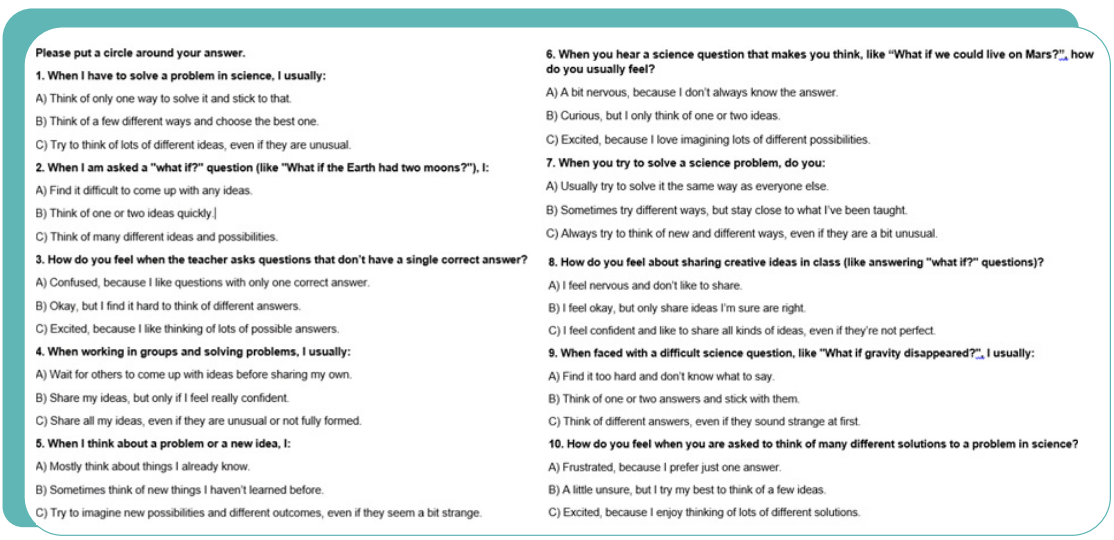
I provided a PMI framework (see Figure 2) to help the children to focus their answers. Each pair had to read the *What if...?* question and think about a positive answer, a negative answer and an interesting way to answer the question posed. I also gave examples of more creative ideas to support the children's learning. I went through the examples at the beginning of each session after I had introduced the *What if...?* question. The PMI framework helped children to consider multiple perspectives, moving beyond surface-level answers to more thoughtful and reasoned responses.

Data collection methods

1. Baseline and final questionnaires (quantitative)

Children completed questionnaires at the beginning (4th November) and end (13th January) of the intervention. These measured confidence, engagement and attitudes toward reasoning, using multiple-choice questions. The aim was to capture changes in their confidence and attitudes toward critical thinking (see Figure 1).

▼ **Figure 1.** Critical thinking questionnaire.



Please put a circle around your answer.

1. When I have to solve a problem in science, I usually:
A) Think of only one way to solve it and stick to that.
B) Think of a few different ways and choose the best one.
C) Try to think of lots of different ideas, even if they are unusual.

2. When I am asked a "what if?" question (like "What if the Earth had two moons?"), I:
A) Find it difficult to come up with any ideas.
B) Think of one or two ideas quickly.
C) Think of many different ideas and possibilities.

3. How do you feel when the teacher asks questions that don't have a single correct answer?
A) Confused, because I like questions with only one correct answer.
B) Okay, but I find it hard to think of different answers.
C) Excited, because I like thinking of lots of possible answers.

4. When working in groups and solving problems, I usually:
A) Wait for others to come up with ideas before sharing my own.
B) Share my ideas, but only if I feel really confident.
C) Share all my ideas, even if they are unusual or not fully formed.

5. When I think about a problem or a new idea, I:
A) Mostly think about things I already know.
B) Sometimes think of new things I haven't learned before.
C) Try to imagine new possibilities and different outcomes, even if they seem a bit strange.

6. When you hear a science question that makes you think, like "What if we could live on Mars?", how do you usually feel?
A) A bit nervous, because I don't always know the answer.
B) Curious, but I only think of one or two ideas.
C) Excited, because I love imagining lots of different possibilities.

7. When you try to solve a science problem, do you:
A) Usually try to solve it the same way as everyone else.
B) Sometimes try different ways, but stay close to what I've been taught.
C) Always try to think of new and different ways, even if they are a bit unusual.

8. How do you feel about sharing creative ideas in class (like answering "what if?" questions)?
A) I feel nervous and don't like to share.
B) I feel okay, but only share ideas I'm sure are right.
C) I feel confident and like to share all kinds of ideas, even if they're not perfect.

9. When faced with a difficult science question, like "What if gravity disappeared?", I usually:
A) Find it too hard and don't know what to say.
B) Think of one or two answers and stick with them.
C) Think of different answers, even if they sound strange at first.

10. How do you feel when you are asked to think of many different solutions to a problem in science?
A) Frustrated, because I prefer just one answer.
B) A little unsure, but I try my best to think of a few ideas.
C) Excited, because I enjoy thinking of lots of different solutions.

2. Classroom 'What if...?' scenarios (qualitative)

Written responses and discussions during the scenario work were collected and analysed. This provided insights into the diversity, creativity and reasoning within children's ideas.

▼ **Figure 2.** Plus, Minus, Interesting (PMI) framework to structure responses.

What if there was no Moon?

Plus	Minus	Interesting
Example: Without the Moon, there would be no extreme tidal waves, making some coastal areas safer from flooding.	**Example**: The lack of the Moon would disrupt Earth's tidal patterns and possibly destabilize its axis, leading to chaotic climate changes and shorter days.	**Example**: Without the Moon, humanity might have developed different myths, beliefs, or scientific advancements based on observing other celestial phenomena instead.

Plus	Minus	Interesting

3. Creativity rubric (quantitative/qualitative)

Children's responses were assessed using a four-point rubric (see Figure 3):

1 = Needs improvement
2 = Developing
3 = Good
4 = Excellent

Criteria included originality, depth of reasoning and diversity of responses

▼ **Figure 3.** Rubric for creativity.

Rubric for Creativity Assessment

Criteria	4 - Excellent	3 - Good	2 - Developing	1 - Needs Improvement
Originality of Ideas	Very creative and unique solutions that show deep thinking.	Creative ideas, with some unique solutions.	Some ideas are predictable or common.	Ideas lack creativity or are repetitive.
Number of Ideas	Provides 3 or more detailed solutions.	Provides 3 solutions with some details.	Provides 2 solutions or fewer, some details missing.	Provides only 1 solution, lacks detail.
Divergent Thinking	Solutions explore different directions and possibilities.	Some solutions are different, but others are similar.	Solutions are somewhat similar, not very diverse.	Solutions are very similar or repetitive.

Ethical considerations

The project was conducted as part of normal classroom teaching, with oversight from the school's Deputy Headteacher, therefore no separate parental consent was sought; however, the learning was referenced in their end-of-term reports. Children were given the option to withdraw at any time, though none chose to do so. Activities were adapted to ensure inclusion of children with learning needs.

Challenges and adaptations

Initially, many responses to the *What if...?* scenarios were predictable and lacked depth. To address this, I introduced scaffolding techniques (Wood, Bruner & Ross, 1976):

- PMI framework for structuring thought.
- Guided questioning to encourage multiple perspectives.
- Emphasis on imaginative 'thinking beyond the obvious'.

These adaptations proved effective, leading to more varied and thoughtful discussions.

Findings

Engagement and participation

From the first session, children were intrigued by the novelty of the scenarios. By week three, most children offered two or more plausible ideas per session. Quieter children and those with lower prior attainment became more willing to share ideas, showing improved confidence.

Creativity and reasoning

Rubric analysis showed steady improvement:

- Week 1: Most children scored 1–2 (predictable or simplistic answers).
- Weeks 4-6: Majority scored 2–3 (reasoned, imaginative responses).

Example answers from PMI:
In weeks 1 and 2, answers given were more simplistic:

Week 1 question – What if we used machines like this?

- *'It's fun to play with.'*

Week 2 question – What if an astronaut gets thirsty?

- *'They have to come back to the space station to take off their spacesuit.'*

From week 4 onwards, the answers given were more detailed and were definitely more connected with the knowledge that had been given in lessons

Week 4 question – What if you had magnets for fingers?

- *'If you had magnets for fingers, you could climb the walls like Spiderman.'*

Week 5 question – What if there was no Moon?

- *'If there was no Moon, scientists might discover new ways to make light at night.'*

Week 6 question – What if there were two Suns?

- *'If there were two Suns, people would have to invent ways to keep crops from overheating.'*

Quantitative results

- Questionnaire data showed increased self-reported confidence in problem-solving.
- Rubric scores reflected a clear upward trend, with most children moving from low (10–15) to moderate (16–22) ranges across the six weeks.

This study investigated the impact of *What if...?* scenarios in Year 5 science lessons on children's critical thinking and creativity. Children completed a 10-question questionnaire (Figure 1) designed to assess different aspects of thinking. Questions 1–5 focused on imaginative idea generation, Q6–Q7 assessed collaborative problem-solving and flexibility in approaching science problems, and Q8–Q10 measured confidence in sharing ideas and generating multiple solutions. Specifically, Q6 evaluated emotional responses to challenging questions, Q7 measured the tendency to try new problem-solving approaches, and Q8 captured willingness to share creative ideas in class.

Quantitative analysis revealed an overall upward trend across the six-week intervention. Children increasingly selected responses reflecting higher-order thinking (C options) across most questions. On 13th January (the end of the intervention), scores were higher for imaginative and independent idea generation (Q2, Q5), but slightly lower for collaborative problem-solving (Q6, Q7), suggesting early challenges in group work that improved over time.

The creativity rubric supported with these findings. On 11th November (near the beginning of the intervention), 10 children scored 2 for originality of ideas, 8 children scored 3, while divergent thinking scores were spread across 1–3. By 12th December, more children achieved higher scores, with 12 children scoring 3 for originality of ideas, and divergent thinking scores increasing overall.

"Overall, the findings indicate that What if...? scenarios, combined with structured support, effectively foster critical and creative thinking. Children became more confident in generating original ideas, considering alternatives, and exploring multiple solutions, showing measurable growth in cognitive flexibility and imaginative reasoning"

The number of ideas generated per scenario given also rose, demonstrating greater creativity and willingness to problem-solve. Observations supported these trends, showing a shift from teacher-dependent responses to more autonomous and collaborative engagement. Structured frameworks such as Plus, Minus, Interesting (PMI) helped children to organise and communicate their thinking clearly.

Overall, the findings indicate that *What if...?* scenarios, combined with structured support, effectively foster critical and creative thinking. Children became more confident in generating original ideas, considering alternatives, and exploring multiple solutions, showing measurable growth in cognitive flexibility and imaginative reasoning.

Practitioner reflections

I observed that children became more curious and confident, eagerly sharing original ideas and exploring alternative possibilities during *What if...?* activities. Group discussions became more dynamic, though collaborative problem-solving and generating multiple solutions remained challenging for some children. Overall, I noted that structured scenarios effectively supported critical and creative thinking, enhancing engagement and participation in the classroom.

Conclusion

The findings from this enquiry showed that using *What if...?* scenarios in Year 5 science lessons supports Bruner's discovery learning theory by encouraging exploration and higher-order thinking, while also using strategies like PMI to scaffold children's ideas (Wood, Bruner & Ross, 1976).

The girls-only setting appeared to enhance children's willingness to take risks, echoing evidence that dialogic approaches are especially effective for girls in science (Hanley *et al*, 2020).

This approach was found to be sustainable within curriculum time and effective in fostering creativity, reasoning and confidence, particularly for quieter children. However, the small sample size, short timeframe and subjective rubric assessments limit the generalisability of the findings.

Overall, a majority of children moved from predictable answers to more reasoned and imaginative responses, with structured frameworks improving both depth and organisation. The study demonstrated that *What if...?* questions can significantly enhance critical thinking, creativity and confidence in science lessons, offering a resource-light strategy. Future research could focus on extending the *What if...?* scenarios to other curriculum topics, assessing longer-term impacts, exploring cross-curricular applications and providing differentiated scaffolding to ensure accessibility for all learners.

Layla Hewitt
Class teacher
E-mail: lala10608@hotmail.com

REFERENCES

Bruner, J.S. (1960) *The Process of Education.* Cambridge, MA: Harvard University Press

Elder, L. (2022) 'Critical Thinking', *Routledge Encyclopaedia of Philosophy*. Published online 30 May 2022. Available at: https://doi.org/10.4324/9781138609877-REE215-1. Accessed 05.09 25

Explorify https://www.stem.org.uk/explorify

Facione, P.A. (1990) *Critical Thinking: A Statement of Expert Consensus for Purposes of Educational Assessment and Instruction.* Executive summary uploaded December 8, 2016. Research Gate. Accessed 04.09.25

Hanley, P., Wilson, H., Holligan, B. & Elliott, L. (2020) 'Thinking, doing, talking science: the effect on attainment and attitudes of a professional development programme to provide cognitively challenging primary science lessons', *International Journal of Science Education,* **42,** (15), 2554–2573

Harrison, C. & Howard, S. (2022) 'Working with inquiry activities to encourage creative thinking'. In: Murcia, K.J., Campbell, C., Joubert, M.M. & Wilson, S. (Eds.), 'Children's Creative Inquiry in STEM', *Sociocultural Explorations of Science Education,* **25.** Cham: Springer, pps. 113–127. doi: 10.1007/978-3-030-94724-8

Kitmitto, S., González, R., Mezzanote, J. & Chen, Y. (2018) 'Thinking, Doing, Talking Science: Evaluation Report and Executive Summary'. *Education Endowment Foundation*. Available at: https://educationendowmentfoundation.org.uk/projects-and-evaluation/projects/thinking-doing-talking-science-effectiveness-trial

Leonardi, S., Tazzyman, S., Spong, S. & Peck, L. (2023) *Evaluation of Explorify.* Interim report for STEM Learning and the Primary Science Teaching Trust. CFE Research, Leicester

Minner, D., Levy, A. & Century, J. (2010) 'Inquiry-based science instruction–what is it and does it matter? Results from a research synthesis years 1984 to 2002', *Journal of Research in Science Teaching: The Official Journal of the National Association for Research in Science Teaching*, **47,** (4), 474–496

Robinson-Smith, L. *et al* (2025) *Thinking, Doing, Talking Science (second re-grant – a two-armed, cluster randomised trial) evaluation report.* University of York. Available at: Thinking, Doing, Talking Science (third trial) https://educationendowmentfoundation.org.uk

Wood, D., Bruner, J.S. & Ross, G. (1976) 'The role of tutoring in problem solving', *Journal of Child Psychology and Psychiatry*, **17,** (2), 89–100