**Heads or tails?**

Henry has tossed a coin nine times.

For each of the last five tosses, the coin has landed on heads.



Next time, is the coin most likely to land on heads or tails?

*Put a tick (✓) in the box next to the best answer.*

|  |  |  |
| --- | --- | --- |
| **A** | Heads. |  |
|  |  |  |
| **B** | Tails. |  |
|  |  |  |
| **C** | Equally likely to land on either heads or tails. |  |

*Physics > Big idea PMA: Matter > Topic PMA5: Nuclear physics > Key concept PMA5.4: Radioactive half-life*

|  |
| --- |
| **Diagnostic question** |
| **Heads or tails?** |

**Overview**

|  |  |
| --- | --- |
| Learning focus: | Radioactive half-life is the predicted time it takes for half of a large sample of radioactive nuclei to decay randomly. |
| Observable learning outcome: | Explain how randomness can lead to predictable outcomes. |
| Question type: | Simple multiple choice |
| Key words: | Random, unpredictable, uninfluenced |

**What does the research say?**

Students often have difficulty in understanding what randomness is, and they find it even harder to understand how something predictable, like radioactive half-life, can emerge from a set of random events (Hull and Hopf, 2020). In a review, of the research about how students are able to understand and use probability-related ideas in science topics, Hull, Janksky and Hopf (2021) explore why these ideas are so challenging.

A common misunderstanding about randomness is known as the gambler’s fallacy. This states that if a roulette ball has landed on black several times in a row, then next time it is more likely to land on red (Hull et al., 2021). Instead, because it is a random event, the next roulette ball is equally likely to land on either red or black. An explanation for this misunderstanding is that people may be imposing their idea of what they think a random pattern should look like, in order to predict what they expect to happen. Another misunderstanding is to think that an event is *random* only because there is *insufficient information* to know for sure what will happen. In this case, the term ‘randomness’ is being used to describe unpredictability, which is not the same thing.

Students’ belief that ‘only clearly determined events can lead to predictable outcomes’, is described by Hull et al. (2021) as a *deeply held* misunderstanding. It is a misunderstanding that can lead to students forming several other common misunderstandings about radioactive half-life. For this reason, Hull et al. (2021) strongly recommend that students are taught how random events can sometimes lead to predictable outcomes, and are given opportunity to consolidate that understanding, before learning about radioactive half-life.

**Ways to use this question**

Students should complete the question individually. This could be a pencil and paper exercise, or you could use an electronic ‘voting system’ or mini white boards and the PowerPoint presentation.

The answers to the question will show you whether students understood the concept sufficiently well to apply it correctly.

If there is a range of answers, you may choose to respond through structured class discussion. Ask one student to explain why they gave the answer they did; ask another student to explain why they agree with them; ask another to explain why they disagree, and so on. This sort of discussion gives students the opportunity to explore their thinking and for you to really understand their learning needs.

*Differentiation*

You may choose to read the questions to the class, so that everyone can focus on the science. In some situations, it may be more appropriate for a teaching assistant to read for one or two students.

**Expected answers**

C

**How to respond - what next?**

Whether the coin lands on heads or tails is completely random, and for the next throw it is equally likely that the coin will land on either heads or tails. The next toss is not affected in any way by what has gone before.

A Some students may think the coin will land on heads again. These students may argue that the previous five results have shown that the coin is biased towards heads. It is common in any random sequence to have runs of the same outcome – and more often than humans would typically predict.

B It is most common for students to suppose that the next toss is more likely to be tails, because it has not come up very much in the last few throws, and that another tails is ‘overdue’. However, there is nothing about the previous results that can change the outcome of the next toss.

If students have misunderstandings about explaining how randomness can lead to predictable outcomes (or not), it can help to lead a discussion on why the result of the next coin toss is unpredictable and equally likely to be heads or tails.

Careful questioning should elicit understanding that:

* the next toss is no different to any of the earlier ones;
* there is no physical connection between what happens in one toss and what happened in earlier ones; and
* the chances of either outcome for every toss is always going to be exactly the same; because
* tossing a coin is a random process.

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Images: Peter Fairhurst (UYSEG).

**References**

Hull, M. M. and Hopf, M. (2020). Student Understanding of Emergent Aspects of Radioactivity. *International Journal of Physics and Chemistry Education,* 12(2).

Hull, M. M., Janksky, A. and Hopf, M. (2021). Probability-related naive ideas across physics topics. *Studies in Science Education,* 57:1.