**Tossing coins**

Some students toss one hundred coins.

They record the number of heads and the number of tails.



How many heads do you think they are most likely to get?

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

|  |  |  |
| --- | --- | --- |
| **A** | Exactly fifty. |  |
|  |  |  |
| **B** | Between forty and sixty. |  |
|  |  |  |
| **C** | More than sixty of fewer than forty. |  |

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

|  |
| --- |
| **Diagnostic question** |
| **Tossing coins** |

**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.

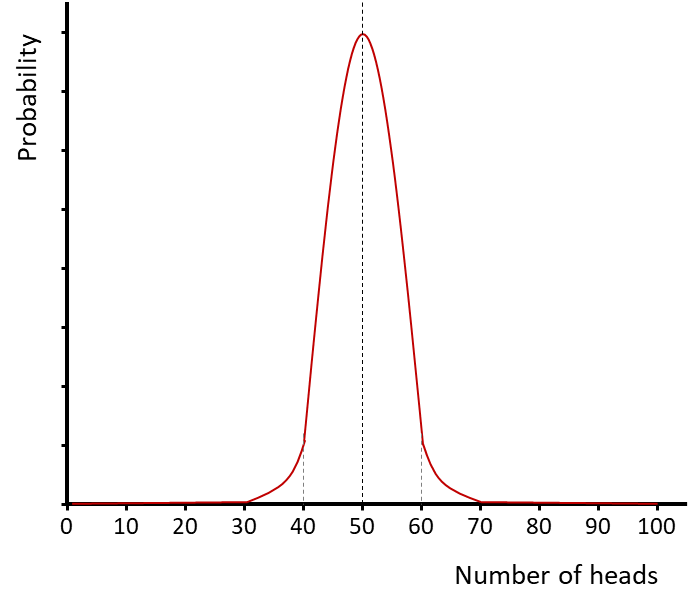
*Differentiation*

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**

B

**How to respond - what next?**

Whether the coin lands on heads or tails is completely random, and it is equally likely that each coin will land on either heads or tails. For a hundred coins, it is likely that *about* fifty will land heads and *about* fifty will land tails. In fact, the chances of there being fifty heads is greater than the chances of 49 or 51, but the chances of there being a number between forty and sixty that is not fifty, is much bigger than the probability that there will be exactly fifty.

The graph shows the probability of obtaining each number of heads from 0 to 100.

A Some students may think that because the chances of each coin landing on heads is fifty-fifty, then there will be exactly fifty heads. These students are using the probability of a random outcome to determine the result. But, as the outcome of each toss is random, they cannot be so certain.

C A few students may think that because the outcome of each toss is random, then the final result will be random and very unpredictable.

If students have misunderstandings about explaining how randomness can lead to predictable outcomes (or not), it can help to lead a discussion on why it is likely that the number of heads is close to fifty, and not exactly fifty.

It may be useful to guide the students though what happens when there are four coins tossed. The table below shows all of the possible combinations of outcomes.

|  |  |  |
| --- | --- | --- |
| Number of heads | Possible ways to obtain this number of heads | Number of combinations |
| 0 | TTTT | 1 |
| 1 | HTTT, THTT, TTHT, TTTH | 4 |
| 2 | HHTT, HTHT, HTTH, THHT, THTH, TTHH | 6 |
| 3 | HHHT, HHTH, HTHH, THHH | 4 |
| 4 | HHHH | 1 |

**Acknowledgments**

Developed by Peter Fairhurst (UYSEG).

Image by PublicDomainPictures from Pixabay.

**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.