

AI Physics Tools (AI@TPT)

ChatGPT and deliberate practice for interpreting graphs

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Students often see graphs as entities decoupled from reality, representations that serve their own purpose. Asking students to regularly translate between diagrams, the corresponding equations, and their physical interpretation can help them to see the physics behind the abstract modeling of a physical concept in the classroom.¹ Student difficulties with reading graphs are the subject of extensive STEM education research.² Deliberate practice and the testing effect—both well-researched phenomena in cognitive psychology—can help familiarize students with the translation between diagrams and physical concepts. But creating a large number of questions for our students is time consuming. This is where the assistance of large language models (LLMs) such as ChatGPT becomes handy.

Deliberate practice and the testing effect

Graphs are usually related to abstract symbolic equations in math lessons. In physics lessons, graphs provide a link between what is happening in a physical situation and its representation in equations. To teach students how to interpret a physical situation depicted in a graph, the teacher must relate the diagram to its physical meaning. This process requires deliberate practice.³ In order to achieve a certain fluency in a skill, students must regularly translate between graphs, physics, and equations. This requires two components: routine classroom procedures throughout the school year and a stimulus to push students beyond their comfort zones. One way to establish this frequent challenge in the classroom is to test students regularly—not for assessment purposes, but as a learning opportunity. In concrete terms, this means using the testing effect. The testing effect is in the service of learning and promotes long-term retention. Effortful retrieval from memory, as with multiple-choice questions, leads to greater learning gains than simple review of the learning material. Eric Mazur's peer instruction⁴ is a tried and proven implementation of the testing effect in physics lessons.⁵ If the creation of multiple-choice questions were not so time consuming, multiple-choice questions would be a promising way to use the testing effect.

How to generate multiple-choice questions with ChatGPT?

With the help of ChatGPT, multiple-choice questions can be generated efficiently. A well-thought-out structure of the prompts, i.e., the instructions for ChatGPT, is an advantage. Several consecutive prompts can often be advantageous. A fa-

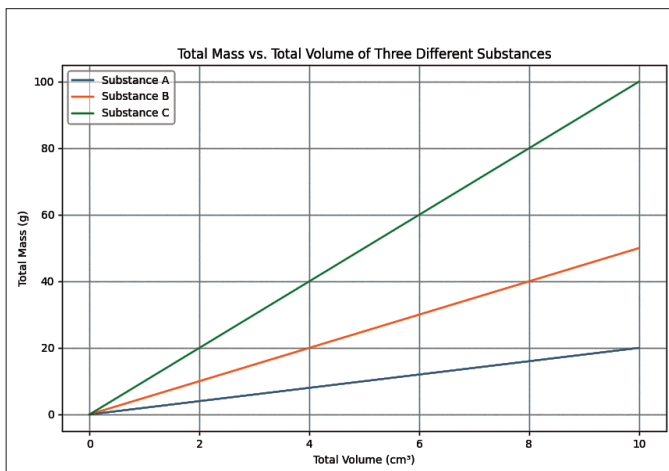


Fig. 1. Graph drawn by ChatGPT.

vorable sequence of prompts to create a corresponding multiple-choice question whose content requires the interpretation of a graph may be as follows:

- 1) Draw the graph (according to the topic).
- 2) Optional step: Modify the graph (according to special additional wishes).
- 3) Give general conditions under which the previous graph would not be appropriate.
- 4) Create a multiple-choice question about the graph that includes some of the previously mentioned incorrect interpretations as possible answers.

The following example is intended to give an impression of the steps actually carried out. ChatGPT's responses have not been reproduced in full here—omissions have been noted in the text with three dots [...].

Topic: Mass as a function of volume

Input: Can you draw me the graph for total mass versus total volume of three different substances?

ChatGPT: Sure, [...] [See Fig. 1.]

Input: Can you think of a condition under which the above graphic would be wrong?

ChatGPT: Yes, there are several conditions under which the above graph might be incorrect or misleading:

1. Mixtures or Solutions: [...]
2. Phase Changes: [...]
3. Non-uniform Density: [...]
4. [...]

Under any of these conditions, the linear relationship depicted in the graph would not hold, and the mass versus volume plot would be incorrect or would require additional context to interpret accurately.

Input: Can you give me a multiple-choice question on the above diagram that focuses on the physical interpretation under which the diagram is valid or not?

ChatGPT: Certainly! [...]

Question: Under which of the following conditions would the linear relationship depicted in the mass versus volume graph for the three substances be invalid?

- A. If the substances experience significant thermal expansion or contraction.
- B. If the densities of the substances are constant across the given volume range.
- C. If the substances are ideal gases at constant temperature and pressure.
- D. If the substances are mixtures with non-uniform compositions.

Answer Choices:

[...]. The correct answers are A and D.

Discussion and results

There is a good chance that educators will be able to use artificial Intelligence (AI) to quickly and regularly generate multiple-choice questions.⁶ The results are promising when used specifically for the generation of questions in the context of the physical interpretation of graphs. It is always advisable to check the correctness of the multiple-choice question that has been created. The best protection against misleading or incorrect AI results is in-depth expert knowledge. However, it is not possible for a single teacher to achieve this in all areas of physics. An exchange of the generated multiple-choice questions in a community of like-minded teachers is extremely useful as a solid quality control.

References

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AI Physics Tools (AI@TPT) features similarly structured short papers (generally less than 1000 words) describing tried and tested classroom examples using AI applications. Submissions should be sent to Jochen Kuhn and Stefan Küchemann (aitpt@physik.lmu.de).