Graphs in Physics: Do They Depict Reality?

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Abstract. While graphs are to represent reality, they are also to satisfy conditions for being mathematical entities, out of which *function test* is the most crucial. A survey of some physics resources has revealed that presented graphs do not always satisfy this condition which can create unrealistic interpretations. A group of twenty-five college physics students was asked to scrutinize a randomly selected velocity-time graph. Majority of these students (N=16, 64%) questioned the graph validity and its interpretation. The study findings suggest a better alignment of physics and mathematics representations.

1 Vertical Line Test and Depicting Reality

Functions assign a single unique output for each of their inputs. When referred to graphs, this condition can be verified using the Vertical Line Test (VLT) which states that "A curve in XY-plane is the graph of a function of x, if and only if no vertical line intersects the curve more than once" ([1] p. 17). The test assures that for each function input, $x=a$, the function equation produces only one output, $f(a)$, that is unique and real. The idea is visualized in Fig.1. While the graph on the left side passes the VLT (the line in red), the graph on the right side fails to pass the test at x_1 and x_2.

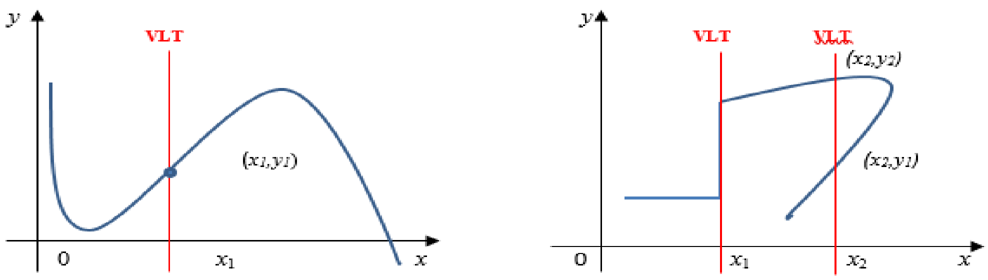

Fig.1 Application of the VLT to examine graphs for functions.

Why is the VLT is essential in physics? The test assures the *Leibnitz law of continuity* which states that nature must behave continuously is satisfied. In a slogan form, the law says that nature never makes leaps, or that all-natural changes are produced by degrees [2]. Practically, the VLT assures, for instance, that an object has a unique location at any time instant, or that at any time instant a unique net force acts on it or that at any location it possesses unique kinetic energy and so forth. Unfortunately, graphs in physics, especially in kinematics, often do not adhere to the VLT (see, e.g. [3] pg. 1137) which jeopardizes the graphs interpretations questions the purpose of studying the VLT in mathematics courses.

2 Students' Interpretations of a Graph that Does not Pass the VLT

The following graph (see Fig. 2), selected from an internet resource, was to model a real velocity of a cricket ball. The graph was given to analyze to a group of twenty-five college physics students. The students were not made aware that the VLT that they studied in mathematics classes should apply to physics graphs as well. The students were invited to answer the following question:

Does the velocity-time graph represent a real motion? Support your answer.

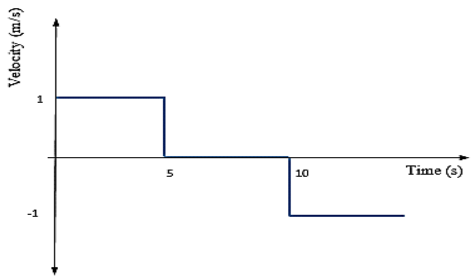

Fig. 2 Velocity - time graph

The majority of the students (N=16, 64%), stated that the graph does not represent a real motion. and the rest of the students (N=9, 36%,) claimed otherwise. Following are some of these responses, verbatim. *The graph cannot represent a true motion b/c it has no slope at t = 5s and t = 10s; no, the graph shows the velocity of the object going immediately from a positive value to 0 at t = 5s and then immediately from 0 to a negative value at t =10s; no, because objects do not suddenly change velocity as represented in the graph; they gradually change, no b/c the acceleration is undefined at t=10s and t=5s.*

While the students explicitly used the VLT to challenge the graph, they pointed out the flaws of the graph at t = 5s and t =10s as showing an unrealistic rapid change of velocity which in fact reflects the VLT. Some of the students went further and pointed out the impossibility of creating a position-time graph. The rest of the students (N=9, 36%,), claimed otherwise.

3 Discussion

The graph (see Fig. 2) was incorrect, and most of the students realized that when explicitly being asked to challenge it. However, when given similar graphs to analyze, students consider such graphs as correct and try to answer questions, and such situations can make evaluations of such answers problematic for the instructor.

Presenting realistic graphs helps the learner make sense of principles and tools that they study in mathematics courses and assure transdisciplinarity of the theorems. Leinhardt [4] claimed that “often students who can solve graphing or function problems in mathematics seem to be unable to access their knowledge in science” (p. 3). Could the lack of consistencies in graph sketching be one of the reasons for the lack of skills transition? I hope that this study will initiate actions toward eliminating these inconsistencies.

References

[1] Stewart J. Calculus Concepts and Contexts, 2nd edn (Pacific Grove, Ca: Brooks/Cole, p.17).

[2] Jorgensen LM. The principle of continuity and Leibniz's theory of consciousness. *Journal of the History of Philosophy*. 2009;47(2):223-48.

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