Equation is not Causation : A Problem Statement for Educational Research

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SİSTEM DÜŞÜNCESİ DERNEĞİ

Existing research suggests that unguided instruction is generally less effective and can lead to students acquiring misconceptions or incomplete and disorganized knowledge. However, guided learning is not immune to the risk of misconceptions, as teachers and textbooks may inadvertently contribute to their formation. In light of these concerns, we propose an investigation into the application of system thinking tools, specifically stock-flow diagrams, to teach the concept of acceleration. By using stock-flow diagrams, we aim to provide a clearer understanding of the cause-and-effect relationship between force, mass, and acceleration and mitigate the potential for misconceptions arising from equation-based representations.

Context and Purpose

Equations are helpful for students to summarize scientific ideas, quantify relationships, and make predictions. However, for a better conceptual understanding, it is crucial to underline that an equation does not necessarily imply causation. In this poster, Newton's Second Law of Motion is taken as a typical example to highlight the importance of considering the underlying causality and propose the use of stock-flow diagrams as a means to achieve that.

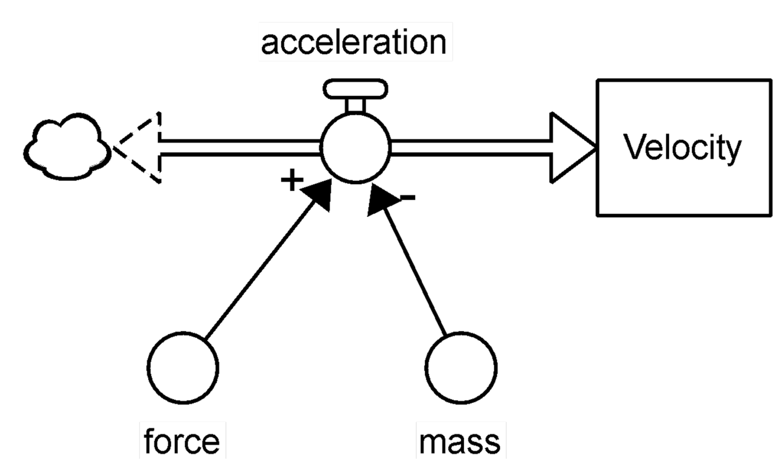
Although equations below are mathematically equivalent, only the third one depict causality: *Acceleration is a result of force and mass.*

$$\vec{F}_{net} = m\vec{a} \qquad m = \frac{\vec{F}_{net}}{\vec{a}} \qquad \vec{a} = \frac{\vec{F}_{net}}{m}$$

This ambiguity might prevent students from recognizing that acceleration is directly proportional to and produced by a net force acting on an object and easily cause misconceptions related to the relationship between force, acceleration, and velocity; such as:

- expecting a constant velocity from a constant force (Champagne et al., 1980; Sequeira & Leite, 1991)
- thinking if two objects have the same velocity, then they should have the same acceleration (Rosenquist & McDermott, 1987; Trowbridge & McDermott, 1980)
- thinking if an object is not moving there is no force acting on it (Clement, 1982)

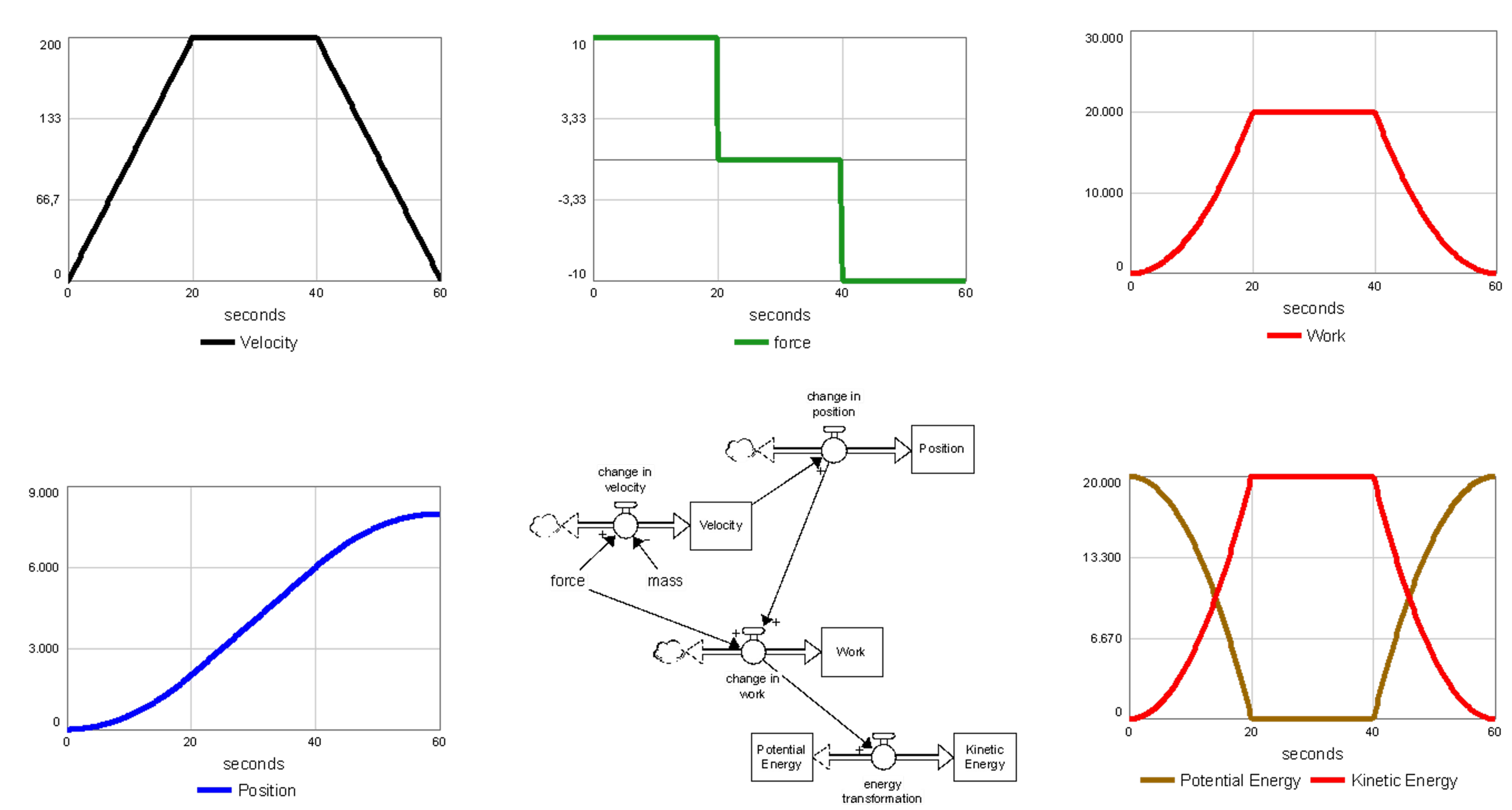
Approach



A simple stock-flow diagram clearly shows the nature of relations

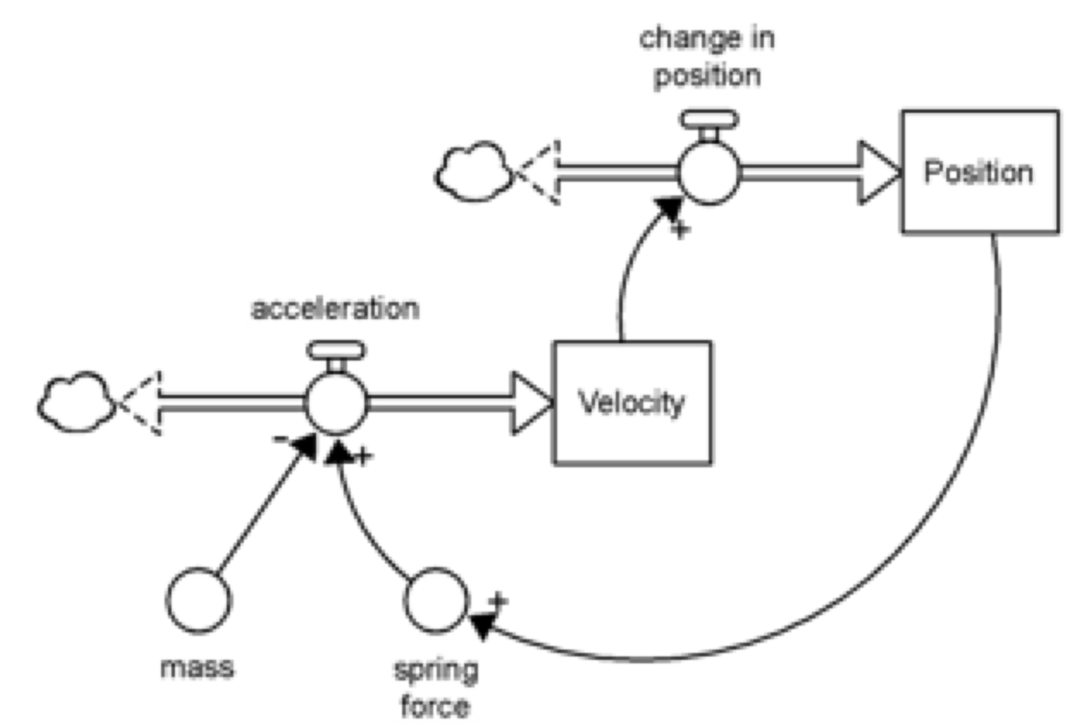
- Acceleration is a result of force and mass
- If there is no force on an object, the object will continue to have the same velocity. (Acceleration is a flow whereas velocity is a stock.)

An example from a lesson plan for 8th grade science lesson:



Results & Conclusion

Although system dynamics mostly deals with endogenous behavior of social systems, there is a potential to use stock-flow diagrams to explain basic causal relationships in K-12 physics education. The applications can be extended also by adding feedback.



In addition to this potential, there is a need for educational research to explore the potential benefits of using stock-flow diagrams as instructional tools for constructing mental models about causal relationships in physical phenomena. These visual representations could offer a promising approach to overcome the limitations and ambiguities inherent in equation-based learning.

Selected References

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