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Addressing Aristotelian Misconceptions: Fostering Conceptual Understanding of Inertia through Interactive Digital Environments

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Abstract: ***Teaching Newton's First Law presents persistent challenges because students often retain intuitive ideas about force and motion that conflict with scientific explanations. This article presents a 45-minute instructional scenario for teaching equilibrium, inertia, and Newton's First Law to lower-secondary students. The scenario combines constructivist and inquiry-oriented learning through the 5E instructional model with the purposeful integration of the PhET "Forces and Motion: Basics" simulation within a TPACK-informed framework. The instructional sequence includes elicitation of prior conceptions, guided simulation-based exploration, collaborative explanation, application to everyday contexts, formative assessment, and reflection. Connections with mathematics, technology and safety, environmental education, and digital literacy are also considered, together with practical implementation challenges and possible extensions. Drawing on relevant physics education research, the proposed approach is expected to support conceptual understanding, student engagement, collaborative learning, and the development of scientific reasoning. The scenario offers a practical framework for connecting Newtonian mechanics with observable phenomena and meaningful everyday applications.***

Keywords: Newton's First Law, Inertia, Conceptual Change, 5E Instructional Model, PhET Simulations, TPACK

1.Introduction

Newton's laws, and especially the first of them, are the basis for understanding how objects move around us. Although they are fundamental concepts, teaching them remains a difficult task. The First Law, also known as the Law of Inertia, often confuses students (Hestenes et al., 1992). This is because concepts such as inertia and zero net force are not something we can see or touch. Our everyday experience, after all, tells us that in order for something to move, some force must be exerted, otherwise it stops. This perception, reminiscent of Aristotle, is very difficult to eradicate, even if it is found that the students correctly solve the exercises mentioned in Newton's 1^{st} Law (Thornton & Sokoloff, 1998).

Traditional methods, which rely on memorizing the formula $\Sigma f=0$ and exercises with numbers, usually do not bring results. Students memorize, but they miss the essence, i.e. deepening the understanding of concepts (AlArabi et al., 2022; McDermott & Redish, 1999). For this reason, modern pedagogy proposes to reverse the terms of the lesson and place the student at the center, to let him discover on his own, to build knowledge on what he already knows or thinks he knows (Bybee et al., 2006; Posner et al., 1982).

In this endeavor, technology gives us valuable tools. Simulations, such as those at PhET Colorado, are not just a "video game." They allow students to experiment, see what happens if they change something, make mistakes without consequences, and visualize concepts that are invisible, such as force (Rutten et al., 2012; Wieman et al., 2008). However, in order to have an effect, they need to be integrated into a well-thought-out teaching path (Podolefsky et al., 2010).

This is exactly what this article attempts: to present a comprehensive lesson plan for Newton's First Law in the second grade of high school, utilizing both modern pedagogical theories and digital tools, in a way that makes sense to children. We are not only interested in learning the law, but in understanding how Physicists think, to cooperate, to use technology critically and to see that Physics is directly related to their lives, such as for example from the use of the seat belt to the protection of the environment (Hazari et al., 2013).

1.1 Constructivism and Exploratory Learning as Theoretical Bases

The philosophy behind the proposed lesson is based on a basic idea that no one learns passively. Our students do not come to class with zero knowledge. They have already formed their own ideas about how the world works, even if they are wrong (DiSessa & Sherin, 1998). What a good teacher does is bring these ideas to the surface, create a little "doubt" when they are not enough, and then help the children build a more scientifically sound edifice on them (Posner et al., 1982). This is the essence of constructivism.

To organize this process in the classroom, there are useful "molds". One of the best known is the 5E learning cycle (Bybee et al., 2006). It is nothing more than a five-stage course, which starts from stimulating the children's interest and, step by step, leads them with the aim of exploring, explaining, applying and finally evaluating what they have learned (Sari et al., 2017). It is a way to turn the lesson into a small adventure of knowledge.

1.2 The Role of Computer Simulations in Teaching Physics

In recent years, a lot of research has shown how valuable simulations can be in physics class. A case in point is the study by AlArabi and his colleagues (2022), who found that students who used PhET for Second Law did much better than those who were taught the traditional way. The difference was so great that it cannot be attributed to chance. This is because simulations help to make knowledge an image, to take shape and color, to be tested and corrected (Tytler et al., 2013). The creators of PhET Colorado themselves, however, emphasize that the secret is not just for children to play with the software. Its value is evident when the exploration is done with a specific goal and after the students have made their predictions (Wieman et al., 2010).

1.3 Tackling Misconceptions and Assessing Conceptual Understanding

How deep are students' misconceptions about forces after all? Tools such as the well-known FCI (Force Concept Inventory) have revealed an unpleasant truth: traditional teaching often produces little or no change in students' intuitive misconceptions (Hestenes et al., 1992). The good news, however, is that the same research has shown that when students are actively involved, when experimenting and discussing, then the improvement can be impressive (Thornton & Sokoloff, 1998). Even for the complex Third Law, a simple, sequential approach with interactive experiments can prove effective (Mansyur et al., 2020). It is not enough to tell them the truth; we must let them discover it.

1.4 The TPACK Model: The Strategic Composition

But in order to do this correctly, more than good intentions are needed. The teacher must have a mixture of knowledge. He must be well versed in Physics, i.e. the subject he will teach, know how children learn and be able to use technological means with ease. The TPACK model describes exactly this composition (Mishra & Koehler, 2006). It is not enough to know how to open a simulation. You need to know when to use it, for what purpose and with what pedagogical method, so that the final result is more than the sum of its parts (Voogt et al., 2013). This is exactly the philosophy behind the present teaching scenario.

2.Identity and Learning Objectives

This work presents a proposed, literature-informed teaching scenario that has not yet been empirically evaluated in a classroom setting. Statements concerning student improvement, attitude change, and misconception reduction are therefore framed as expected outcomes rather than measured effects.

The scenario we propose is entitled "Body Balance – Inertia and Newton's First Law" and is designed for one teaching hour (45 minutes) in the second grade of Junior High School. It is part of the "Forces and Movements" section of the textbook (Institute of Educational Policy [IEP]). Our goal is for children to perceive inertia not as a difficult concept, but as a natural property of bodies, to understand that a body balances when the sum of the forces on it is zero and to be able to formulate in simple words Newton's First Law.

What exactly do we want to achieve? At the level of knowledge, we want them to be able to define inertia, remember the First Law and explain what $\Sigma F=0$ means. At the level of skills, we want them to be able to manipulate the PhET Colorado simulation, record what they see and work together to draw conclusions. At the attitude level, we aim to arouse their curiosity, appreciate that the laws of Physics have practical applications (e.g. in automobile safety) and see that digital models can become valuable assistants in learning.

Phase 1: Trigger & Case Formulation (10 minutes) – Engage

We show a small video from the International Space Station, where we see an object floating and moving smoothly without any apparent thrust. At the same time, we create a five-minute experiment in the classroom: a coin on a piece of paper, we pull it abruptly and the coin stays almost in place. The result is usually surprising. We ask the children to write on the shared Jamboard what they think is happening. Why didn't the coin go away with the paper? Why does an object keep moving in space without anything pushing it? Their ideas are recorded but still haven't been corrected.

This phase is the "Engage" of the 5E model. The video from space shows the law in a frictionless "laboratory", which helps to show its essence (Wieman et al., 2010). The experiment with the coin creates a small "doubt" in the children as their intuition tells them that the coin would follow the paper, but in the end it does not. The recording of hypotheses (e.g. "the coin is heavy", "it has a force that holds it") is crucial, because this is how the original, erroneous ideas emerge that we will then be called upon to question and reconstruct (Posner et al., 1982).

Phase 2: Exploring with the PhET Simulation (10 minutes) – Explore

The students, divided into pairs, open the simulation from PhET "Forces and Motion: Basics" on their computers and enter the "Tug of War" tab. They do not do it by chance. They follow specific steps on a worksheet (Google Form) and test to see what happens when they pull from one side and the other with equal forces, with unequal forces, when no force is exerted and finally, when the mass of the box changes. Each time they record their observation.

Here we are at the heart of Explore. This particular tab of the simulation is ideal because it limits the phenomenon to one dimension, making it easier to analyze it (Podolefsky et al., 2010). The sequence of steps is important: starting from equal forces (stillness), moving to unequal ones (acceleration) and reaching zeros (the box keeps moving), children are led on their own to discover that in order to maintain motion the effect of a continuous force is not necessary. This is the key point to demolish the Aristotelian concept. The worksheet works like a young scientist's notebook recording his experiments.

Phase 3: Edit – Collective Discussion (10 minutes) – Explain

Once the children have completed the exploration, we display on the board the results of the forms they filled out. We see what each group observed. We start a discussion, with questions such as: "What did the cases where the box stood still have in common?", "What happened when we stopped exerting forces?", "What role did mass play?". Slowly, we introduce the scientific terminology: the concept of net force (the vector sum of all forces), the equilibrium condition $\Sigma F=0$ and finally the formulation of the First Law, as formulated by Newton.

This is the explaining phase. The teacher here is not an authority, but a moderator. It helps children to turn their simple observations into scientific language, to give a name to what they saw (Bybee et al., 2006). Discussion has another role such as it enables us to identify any misunderstandings that may persist and correct them at that moment.

Phase 4: Application and Connection with Reality (5 minutes) – Elaborate

The theory makes sense when we see it around us. We show various images such as, a seat belt restraining the driver, a heavily loaded ship that needs kilometers to stop, a spaceship traveling in the void. We divide the class into small groups, where each one takes an example and is asked to explain it in terms of the First Law. Why, for example, does the seat belt protect you? Because your body is inert and wants to keep moving like a car before braking.

This is the stage of expansion (Elaborate). Knowledge is applied to new, familiar situations, and thus becomes more solid and understood (Sari et al., 2017). It is no longer an abstract concept, but a tool to explain the world. The connection with security, technology and everyday life increases interest and shows why it is worth learning Physics (Hazari et al., 2013).

Phase 5: Comprehension Assessment – Formative Quiz (5 minutes) – Evaluate

Before the bell rings, we implement a quick quiz with the mobile phone or computer, using Kahoot or Mentimeter. Four or five questions that check if the key points have been understood: What happens to a body that balances? What does inertia mean? What will happen in a collision if you don't wear a seat belt? The children immediately see their score, and we see if there are any points that need clarification. The quiz has no grade, it is a game that helps everyone see how well they understood them.

This phase is the evaluation (Evaluate) of the 5E cycle, but in the form of formative evaluation. We are not interested in the grade, but in the feedback. The playful form helps to reduce stress and get everyone involved.

Phase 6: Reflection – Closing (5 minutes)

Finally, we ask the children to go back to the Jamboard and write down two things: something that impressed them and something that they think will be useful to them in the future. Their answers are valuable because they show us not only what they took away from the lesson, but also how they connect it to themselves and their lives. More precisely, it is a small account that helps consolidate knowledge.

3.Interdisciplinary Connections: Expanding Horizons

This lesson not only focuses on Physics but also builds bridges with other subjects. The concept of the component, for example, is directly related to mathematics and the addition of vectors, even if we do not analyze it in depth. The discussion about the seat belt takes us directly to technology, regulations and the protection of life. The analysis of the inertia of large vehicles can open a dialogue about the energy they consume and the burden on the environment, linking Physics with ecology. Even the simulation itself gives us reason to talk about computer models: what they show, what they leave out and why they are so useful to scientists.

3.1 Improved Conceptual Understanding

What do we expect to have changed in the minds of students after this lesson? First of all, not to see the First Law as a phrase that they have to learn by heart. We expect them to have "lived" it through experiments. To be able to explain why an object keeps moving, instead of just saying "$\Sigma F=0$". The image of the simulation, with the arrows of the forces that cancel each other out, will stay with them. We believe that their answers to similar questions will be more meaningful and closer to scientific truth, as similar research has shown (AlArabi et al., 2022; Thornton & Sokoloff, 1998). The worksheet, after all, allows us to see their thinking evolve from the initial wrong assumption to the final correct conclusion.

3.2 Developing 21st Century Skills

In addition to Physics, the course cultivates other important skills. Students learn not to accept things as they are, but to ask, assume and control (critical thinking). They learn to work together, share ideas and argue (collaboration and communication). At the same time, they become familiar with digital tools that they will encounter more and more often in their lives (digital literacy).

3.3 Positive Attitudes towards Physics

One of the most important issues is for children to love Physics. When the lesson looks like an exploration game, when they see that what they learn explains what is happening around them (an accident, a rocket launch), then their interest rises (Podolefsky et al., 2010). Physics ceases to be a boring lesson with formulas and becomes an exciting tool for understanding the world (Hazari et al., 2013).

3.4 Addressing specific misconceptions

The script has been constructed to correct specific erroneous beliefs that we know children have (Hestenes et al., 1992). For example, the idea that "to move something requires constant force" is refuted when they see at PhET Colorado the box continuing to slide when the net force is zero. The idea that "if a body is balanced, no forces are exerted on it" is overturned when they see two children pulling and the box standing still. Even the mass-inertia connection, which will be completed in Second Law, is already entering their minds like a seed.

3.5 Implementation Challenges and Proposed Solutions

Any lesson plan, no matter how good it is, can encounter obstacles in practice. The point is to be prepared. The computer may crash or the simulation may not open. For this, it is good to have done a test beforehand and have an alternative plan, such as showing the simulation from the projector or handing out a printed worksheet. Some children may be slower or faster than others. Heterogeneous groups and the assignment of specific roles (e.g. one person operates the mouse, another writes) help everyone participate. Some may be in a hurry to find the "right answer". Here we must emphasize that what matters is the process, the thinking and not the result. Finally, the discussion can get out of hand. In addition to the oral one, we can use Mentimeter to collect short written opinions from everyone, giving voice to even the most shy.

3.6 Expansions and Future Prospects

The 45-minute scenario is just the beginning. If we had more time, we could extend it. In two teaching hours, we would have the opportunity to deal in more detail with the relationship between mass and inertia, or to take the first steps towards Second Law. We could even assign the children a small project: to design a poster or a small presentation about the "safest car", explaining how the First and Second Laws affect its design. And of course, it would be ideal to follow a real experiment in the classroom, with toy cars and dynamometers, to see that what was happening on the screen also applies in the real world.

It would be very interesting, in fact, to apply this scenario in real conditions in a school and measure its results. We could give a test before and after, to see how much the children's understanding improved, but also how their attitude towards the lesson changed.

4.Conclusions

The proposed teaching scenario provides a research-informed approach to making inertia and Newton's First Law more accessible to lower-secondary students. Its central principle is that conceptual understanding can be supported when students actively predict, explore, discuss, explain, and apply physical ideas rather than relying primarily on memorization. The purposeful integration of interactive simulation within the 5E framework provides opportunities to visualize force relationships, examine prior conceptions, and connect Newtonian mechanics with familiar situations such as vehicle safety and motion in space. Formative assessment and reflection further allow teachers to identify remaining difficulties during the learning process. The interdisciplinary connections also demonstrate that physics can contribute to broader technological, environmental, and scientific understanding. Future classroom implementation and pre- and post-instruction assessment would be valuable for determining the effectiveness of the proposed scenario in improving conceptual understanding and students' attitudes toward physics. Overall, the scenario offers a practical foundation for teaching Newton's First Law while encouraging inquiry, critical thinking, collaboration, and a more scientific interpretation of everyday phenomena.

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