Do NOT change the Order of Newton's Laws

Martin Lieberherr
Mathematisch Naturwissenschaftliches Gymnasium Rämibühl, Zürich, Switzerland

In a recent article (1), Stocklmayer et al. advocate starting with Newton's third law and putting emphasis on it. I argue against this idea for the following reasons: Newton's third law is not universally true. As they state, it is not valid in an accelerated frame of reference. A ball on a carousel will accelerate without a reaction force being present. The third law does not hold for gravitational forces between celestial bodies, because it would imply action/reaction faster than the speed of light. The third law cannot be an underpinning for the first two laws, because they have a different philosophical status: The first two laws are more like axioms or principles. They are useful or not. The third law is a real physical law. It can be tested experimentally and can be right or wrong. The first two `laws' could still be useful if the third does not hold (2). And most important: An extended treatment of the third law takes away the time needed to discuss momentum. Momentum is a much more versatile concept and it is still valid in modern physics. The best reason to put emphasis on the third law is non-physical: It is needed for the final test!
In (1), the first law is used as a special case of the second. This is not a good idea either, as has been eloquently stated by Ridgen (3). The first law should be used to find an inertial reference system.

For the past ten years, I introduced Newton's laws along the following line (about three lessons with 16 year old high school students):

A) In newtonian dynamics, we want forces to be the cause of acceleration of bodies. But there's a problem:

B) I put a coin on the overhead projector, draw a coordinate system on a transparency, place it over the coin, and wiggle the transparency. Teacher: What's the problem now? Student: The body accelerates, but there's no force acting on it. Teacher: What shall we do? Student: Discard that reference frame. Teacher: That's exactly how to use Newton's first law: Take a body and suspend it in a way that no net force is acting on it. If this body accelerates, discard the reference system. If the body remains at rest, you have chosen a good (inertial) system. Seismometers use the first law to measure the acceleration of the reference frame.

C) Now that it is reasonably clear what an inertial system is, I proceed with Newton's second law: $F_{net}=ma$. Equilibrium of forces is a special case of the second law: $F_{net}=0$.

D) Newton's third law is motivated by experiment: Two students on skateboards push each other with their hands. Both accelerate, so there must be two forces deliberately labeled action- and reaction-force. Following an argument of Newton - internal forces must cancel - it can be shown that action- and reaction-forces are of equal size but opposite direction. Otherwise a body could accelerate itself, a fact that is not observed in nature. If the third law would not hold, you could lift yourself over the fence by pulling at your bootstraps.

I avoid presenting Newton's laws as a logically complete system. The loose ends are most welcome as starting points for further investigations: from the first law to inertial forces to general relativity, from conservation of momentum back to the third law and to the second law, from 'action at a distance' to field theory, etc. Leaving some moderately loose ends behind safes time because introductions can be made shorter, and provides opportunities to review the theory from a higher level, thus going through a second learning cycle.

References

1. S. Stocklmayer, J.P. Rayner, and M.M. Gore, "Changing the Order of Newton's Laws," Phys. Teach. 50, 406-409 (2012)

2. J.C. Sprott, "Anti-Newtonian dynamics," Am. J. Phys. 77, 783 (2009)

3. J.S. Rigden, "Editorial: High thoughts about Newton's First Law," Am. J. Phys. 55, 297 (1987)