

## Should we teach free-body diagrams before or after Newton's Laws?

There are two interesting lesson sequences for teaching force and motion in high-school physics. These are teaching free-body diagrams before Newton's laws (FbN) and teaching Newton's laws before free-body diagrams (NbF). Both sequences were found in physics textbooks. Different authors adopted the sequence that they believe it would affect student understanding better. However, some physics experts did not agree with this. It is therefore interesting to know if we should teach with the FbN or NbF sequence. This motivates us to study the effect of such lesson sequences on student understanding of force and motion. The sample group was grade-10 students from two physics courses in 2020. One course was taught with the FbN sequence (29 students) and the other with the NbF sequence (34 students). Their understanding was evaluated by using an assessment test which consisted of three parts including (1) Newtonian concepts, (2) problem-solving, and (3) free-body diagrams. The result shows that for the Newtonian concepts part, the average scores are 11% for the FbN and 13% for the NbF sequence. The average scores of the problem-solving part are 13% and 9% and those of the free-body diagrams part are 41% and 48% for the FbN and NbF sequences, respectively. The scores of all parts between the two sequences were not significantly different. In addition, student difficulties found in all parts were similar. However, a larger number of students who could provide the equation of motion ( $F = ma$ ) in the problem-solving part was found in the FbN sequence. We might conclude that teaching free-body diagrams before or after Newton's laws did not affect student understanding in the topic of force and motion. Detail of student difficulties in both sequences will be further discussed.

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