Vectors in Science Education

Students learn that some physical quantities behave like vectors fairly early in school science lessons right across Europe. However the nature of vectors and the application of the vector algebra model to real life situations is often poor. This leads to misunderstanding and confusion for the student and prevents them from accessing deeper meaning essential to the civil and mechanical engineer, not to mention physicists and architects.

There are difficulties caused by the incorrect use of the negative sign and a failure to accept that acceleration is a vector because of the use of the word deceleration in English. Velocity is rarely derived from the change of displacement so that endless confusion arises from the use of the word speed, again in English! Most learners think that the vector nature of force for example simply means that in the downwards direction it is positive and upwards it is negative!

My own observations after teaching and providing professional development courses for 40 years is that the use of the word instantaneous when describing speed or velocity is rarely used when it is needed. This results in misunderstanding many situations in kinematics with resulting turmoil in the mind of the student. Again the unfortunate student fails to appreciate that if an object is slowing down then there must be an instantaneous acceleration in the opposite direction to the instantaneous velocity.

Consider the example of the object moving in a semicircular path as shown in the PowerPoint. There is nothing intrinsically difficult in the question yet physics undergraduates who have been taught for many years about vectors and the vector nature of some physical quantities are unable to answer the two questions. Physics teachers are necessarily drawn from the ranks of these students with the result that any misconceptions amongst these undergraduates will be perpetuated. Even worse is that many science teachers are drawn from other disciplines and will never have the opportunity to adjust their cognitive frameworks as the physics student might have.

If we can accept that vector algebra should be applied to vector quantities we can then start using calculus and describe velocity as the rate of change of displacement with all that that implies. The last part of the PowerPoint shows how Kepler's second law can be used to show that there must be a force acting on a planet towards the Sun in the opposite direction to its position vector, this of course being the gravitational force.

There are a number of good resources for TI-Nspire to help the learner explore vectors and the way they behave. The challenge for us science teachers is to integrate the vector model more fully into the particular science model to promote elaborative learning as opposed to iterative learning.

From the Science Nspired website, USA:

- https://education.ti.com/en/tisciencenspired/us/home
- https://education.ti.com/en/tisciencenspired/us/physics/forces-and-motion

And from Sweden on the T^3 Europe website:

- https://www.t3europe.eu
- https://resources.t3europe.eu/t3europe-home?q=Vector%20calculus