Reasoning About Relative Motion: A Frames of Reference Approach

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In introductory physics classes, student frequently experience difficulties with relative motion problems. Previous studies have categorized student difficulties with reference frames, or used computer simulations or experiments to create seeming paradoxes that students would need frames of reference to resolve; however, these studies failed to define what they meant by a “frame of reference” in the mind of a student. In 2016 I carried out a pilot study that used our cognitive definition of a conceptualized and coordinate frame of reference (Joshua, Musgrave, Hatfield, & Thompson, 2015) as well as quantitative reasoning (Thompson, 1993) to guide an instructional intervention and analyze the difficulties the student had with relative motion tasks. Both constructs proved to have great explanatory power, as they revealed aspects of the student’s thinking that were not commonly explored in previous studies. Both the results of this study and their implications will be the topic of my poster.

Key words: Relative Motion, Frame of Reference, Velocity, Physics, Quantitative Reasoning.

It is commonly acknowledged that the reason students struggle with relative motion tasks is because they fail to correctly use reference frames. Some studies have focused on categorizing student difficulties with reference frames (Bowden et al., 1992; Panse, Ramadas, & Kumar, 1994). Others have tried interventions based on computer simulation designed to have students experience different points of view (Monaghan & Clement, 1999, 2000) or to build experiences with seemingly paradoxical conclusions that students would need reference frames to resolve (McDermott, 1984; Trowbridge & McDermott, 1980). However, when I looked closely at these studies, I could not help but notice that velocity was frequently seen as an aspect of a single object. Even though students were asked to find an object’s speed in “a new reference frame”, the task was still framed as the object’s velocity instead of the rate of change of distance between an object and a reference point with respect to time. Moreover, most of these interventions sought to simply build student intuition about velocity as an isolated quantity instead of an intensive quantity composed from distance and time.

To address this gap in the research, I investigated how a single student reasoned about tasks involving relative motion. After a clinical interview where I asked the student to work through several tasks, I used the theories of quantitative reasoning and conceptualized and coordinated frames of reference entail, to analyze the student’s reasoning. Among other results, I found that the student was unusually attuned to the necessity of a reference point (though not always sure of how to utilize one) but completely unaware of the idea of a directionality of comparison. My analysis of the student’s work guided the content of an instructional intervention, followed by a chance for the student to rework the original relative motion tasks. He showed great improvement in being able to both explain answers he previously thought were correct without justification, and to complete some previously blank tasks. He also used his commitment to reference point to spontaneously coordinate reference frames. I believe that my data, as well as my analysis of the data using my construct of a cognitive frame of reference and quantitative reasoning, will be of interest to the math education community as they showcase an area of applied mathematics where our students commonly struggle, as well as a potential avenue for improved instruction.
References


