The Impact of Physics Context on Student Thinking About Vector Product Directions

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Introduction and Background

Although in mathematics curricula, vectors are typically not covered in depth until calculus 3 or linear algebra, vector quantities are used extensively in introductory physics (e.g., Knight, 2017); mathematical operations on vectors are prevalent in this context. The body of literature examining student understanding of vectors includes assessment instruments, but typically with significant focus on computational issues and/or the impact of context (Van Deventer, 2008; Mikula & Heckler, 2013; Heckler & Scaife, 2015; Barniol & Zavala, 2014; Carli et al., 2020). Other work has attended to more conceptual understanding about dot and cross products (Zavala & Barniol, 2013; Barniol, Zavala & Hinojosa, 2013). To more explicitly explore the role of context and aspects of task features on student performance, our research goals are to identify (1) how different contexts impact student ideas of vector concepts and (2) how performance on vector concepts varies with course level. We analyze how introductory physics students describe the direction of dot- and cross products in different contexts.

Methods

Multiple-choice, online surveys were administered in each semester of calculus-based introductory physics (PHY1, PHY2) after relevant instruction. Several prior tasks have had answer choices that are a mix of scalars and vectors, leaving some ambiguity about students' understanding of the vector or scalar nature of the products. To disentangle calculation errors from student understanding, we asked about the magnitude and direction of each product in separate questions. Surveys included several tasks asking about the magnitude and direction of dot and cross products, first as a pair of generic vectors in a 2-D coordinate system and second in a physical context. The physics contexts were mechanical work, magnetic flux, and the Lorentz force. We discuss the results of the direction tasks.

Results and Discussion

In the non-physics context, PHY2 students performed better than PHY1 students on both the dot- and cross product direction tasks. The most common incorrect answer, in both classes, was a direction *between* the two vectors; student explanations suggest the incorrect application of vector addition principles and ideas of combining vectors. From the non-physics to the physics context within each course level, there was no significant shift between correct and incorrect responses, for both the dot- and cross product tasks. However, there was a significant shift from *between* to other answers. The most common incorrect responses varied in the physics contexts in ways that reflect reasonable confusion with the physical quantities.

These results suggest that context does not impact overall performance but does impact which distractors students select. We are working on adopting or modifying existing analytical frameworks to explain the context dependence of student responses. Symbolic forms (Sherin, 2001), models of transfer (e.g., Lobato, 2008; Rebello et al., 2017), and dual-process theories of reasoning (Evans, 2006; Heckler, 2011; Kryjevskaia et al., 2014; Speirs et al., 2021) are three promising prospects that may provide insight on the impact of different contexts.

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