Student Resources for Unit and Position Vectors in Cartesian and Non-Cartesian Coordinate Systems

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As part of a broader study into students' understanding of students' use of mathematics in upper-division physics courses, this study investigates how students conceptualize unit and position vectors in Non-Cartesian Coordinate Systems using a theoretical framework of resources. We present a case study of Mark, a Senior physics major, and identify the resources that Mark activates while answering conceptual questions without a direct physics context during a one-on-one interview protocol. This analysis identifies specific resources that Mark brings to bear when reasoning about vectors. The results of this case study provide a guide for analyzing additional interviews and allow us to pursue the long-term goal of curriculum development that can be used to improve students' use and understanding of non-Cartesian coordinate systems.

Keywords: Vector Calculus, Resources, Student Reasoning, Physics

Using non-Cartesian coordinate systems is a challenge for undergraduate mathematics students [Paoletti, Moore, Gammaro, and Musgrave, 2013; Montiel, Vidakovic, and Kabael, 2008] and this challenge continues into upper-division physics courses where application becomes increasingly important [Hinrichs, 2010; Sayre and Wittman, 2008]. As part of a broader study to develop research-based curriculum materials for physics courses that bridge the gap between middle-division mathematics and upper-division physics courses, this work attempts to shed light on student thinking about vectors in Cartesian and Non-Cartesian coordinate systems through the use of a Resources Framework [Hammer, Elby, Scherr, and Redish, 2005]. The research presented explores the thinking of a single student—Mark–as revealed during a semi-structured, one-on-one interview, and identifies the student's thinking as activated conceptual and procedural resources. Mark is a high-achieving, senior-level physics major, and was selected for detailed analysis due to the clear explanation of his thinking. From Mark's data, identified resources can be grouped into clusters based on the content of the student's thinking [Vega, et al., 2016]. Examples of such clusters are basis unit vectors, position vectors, and velocity vectors. Connections between these resources are also observed, allowing a mapping of the student's thinking as the student works through a series of questions.

In this poster, we present a map of Mark's activated resources and, based on the data, the connections between those resources to understand Mark's complicated thought process. This detailed analysis provides insight into the kinds of ideas undergraduates might activate when faced with questions about unit vectors and position vectors, in Cartesian and non-Cartesian coordinate systems. For instance, Mark initially demonstrates a clear understanding of unit vectors in polar coordinates. He notes that unit vectors are of unit length, and point in the direction of increasing coordinate, in this case, increasing r and theta. These are both identified as specific resources within the unit vector cluster. Later in the interview, Mark activates additional resources that conflict with these unit vector resources, namely, that the unit vectors of r and theta can be written in terms of the unit vectors of Cartesian coordinates. This conflict demonstrates a potential area of interest for curriculum development.

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