A qualitative study of the ways students and faculty in the biological sciences think about and use the definite integral

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In this poster, I share my methods and pilot interview results concerning a qualitative study of the ways undergraduate students and faculty from the biological sciences think about and use the definite integral. In this research, I utilize task-based interviews including five applied calculus tasks in order to explore how students and faculty think about area, accumulation, and the definite integral. Early results from pilot interviews helped me revise the interview protocols and indicate that student reasoning may be affected by experience and context. In presenting this poster, I hope to gain feedback from the community on my research methodology and potential analytical strategies.

Key words: calculus, biology, definite integral

The teaching and learning of calculus is currently a topic of great interest. The MAA recently supported a large-scale survey of calculus programs that has generated a great deal of literature surrounding calculus instruction at the undergraduate level (Bressoud, Mesa, & Rasmussen, 2015). Furthermore, there have been calls by researchers for investigations of how calculus is utilized by non-mathematics majors. Rasmussen, Marrongelle, & Borba (2014) call for "research that closely examines the ways in which calculus ideas are leveraged in the client disciplines, how these ideas are conceptualized and represented in the client disciplines, and what these insights might mean for calculus instruction" (p. 513). One of the most prominent client disciplines of calculus are the biological sciences. In their survey of over 10,000 undergraduate calculus students, Bressoud, Carlson, Mesa, & Rasmussen (2013) found that 30% of all Calculus I students intended on pursuing careers in the biological and life sciences (p. 691).

Mathematics is important for the biological sciences. In 2003, the National Research Council (NRC) published a report titled BIO2010, suggesting university biology programs develop stronger connections between the life sciences and the mathematical, physical, and computer sciences (NRC, 2003). As a result of that report, a number of undergraduate biology departments across the country incorporated changes in how the quantitative sciences are utilized; some revised the calculus sequence to focus more on mathematical techniques while others created a brand new degree program focusing on quantitative biology (e.g., Usher et al., 2010).

The definite integral is an important topic in introductory calculus that has been a focus of researchers since the 1980s (e.g., Jones, 2013; Orton, 1983; Sealey, 2014; Thompson & Silverman, 2008) and plays an important role in both mathematics and biology. Definite integrals are used when modeling population growth and cardiac output, as well as in chromatography (Horn, 1987). When asked what biology students need from calculus, biologists typically cite numerical approximation methods (e.g., the trapezoidal rule for approximating area under a curve) and a focus on modeling as opposed to the ability to manipulate complicated algebraic techniques (Horn, 1987; NRC, 2003). Additionally, researchers have shown that biology students tend to have lower self-efficacy when it comes to their mathematical ability when compared to physics and engineering students (Brent, 2004; Chiel, McManus, & Shaw, 2010). While calculus plays a vital role in the preparation of biology students and biological science programs have attended more to quantitative skills, there has not been a great deal of research on how students understand and use their calculus knowledge specifically in biological settings.

This research project serves as such an examination as I explore how undergraduate students and faculty members from the biological sciences think about and use the definite integral. My research questions in this study are: (1) What are the ways beginning and advanced undergraduate students majoring in the biological sciences think about and use the definite integral? (2) What are the ways professional biologists think about and use the definite integral? and (3) What are the similarities and differences in how beginning undergraduate students, advanced undergraduate students, and faculty members in the biological sciences think about and use the definite integral?

Methods

In order to investigate how students and faculty think about and use definite integrals, we need rich descriptions of the ways in which they attend to and use the definite integral while solving problems and working in their field. Therefore, I am using task-based interviews in which I ask participants to talk about their knowledge of definite integrals and calculus, as well as solve applied calculus problems as the data source for my study. I am interviewing 10 beginning and 10 advanced undergraduate students majoring in the biological sciences, and 5 faculty members from the biology department at a large southeastern public university. The calculus tasks span graphical, analytical, and tabular representations and are set in primarily biological contexts. Two of the tasks parallel each other in structure and form, using the same graph but with different axes labels. One task is biologically-based and the other utilizes a car's position and velocity. Interviews with the faculty members focus on how the participant uses calculus and the definite integral and how important they feel mathematics in general, and calculus in particular, is to their work and to their students.

Conceptual framework and data analysis

Researchers have previously investigated the ways in which students reason about applied integration problems (Jones, 2015; Sealey, 2014). My data analysis procedures begin by analyzing the students' responses for the overarching conceptualization of the definite integral they are attending to using the three primary conceptualizations illustrated by Jones (2015) and then drill down into how they are using those conceptualizations to solve the problem using aspects of Sealey's (2014) Riemann Integral Framework as applicable. While these frameworks serve as a foundation to my data analysis, I will employ a pseudo open-coding scheme in order to identify additional themes that may be unique to individuals from the biological sciences.

Pilot Study

This past semester, two undergraduate students volunteered to participate in informal interviews in order to help me revise my interview protocol and I was able to both edit my items, as well as determine that the items were sufficient for collecting appropriate data. For example, I found that each student reasoned differently on the parallel tasks; one student called on an area under the curve conception in the biologically-based task but not the velocity task. I hope to continue exploring the ways undergraduate students and faculty reason about the definite integral with a full run of interviews in January 2016.

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