Symposium: Calculus in physics

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Abstract. We report on four studies on the interplay of calculus and introductory and intermediate university physics: (1) how students use and think about integration in the context of a charge distributions; (2) introductory physics students' responses to graphical and algebraic questions on differentiation in the context of one-dimensional kinematics and electrostatics problems; (3) the development of a teaching-learning sequence on ordinary differential equations in a service-taught mathematics course; (4) students' experiences with partial differential equations in the context of the heat equation.

1 Students' use and understanding of integration in intermediate electromagnetism

Integration is a math tool widely used across physics contexts. It is perhaps the foremost mathematical technique in intermediate level electromagnetism courses. This presentation reports on a study of how students use and think about integration in such an electromagnetism course. We have investigated students' views on integration before they enter the course, and interpreted the results in terms of their concept image of integration. We found that students primarily see integration as a process of evaluation, and that the majority of students have no conceptual aspect in their concept image of integration.

At the end of the course students were asked to describe in detail how they would calculate physical quantities like charge and electric field given a general linear non-uniform charge distribution; they were also asked to evaluate these from a given algebraic expression. We found that while the majority of students included the need to integrate in their description for charge only 35% used integration in their calculation of that quantity in the next question.

2 dx versus Δx – more than a translation to Greek

Student understanding of velocity and interpretation of kinematics graphs is a well-studied topic in PER. One of the difficulties described in literature is the so-called 'interval-point confusion', where students focus on a single point of the graph when they should be using an interval. For example, some students calculate instantaneous velocity from one point on a graph (i.e., as x/t) instead of two (e.g., $\Delta x/\Delta t$ or dx/dt). Interval-point confusion may, for kinematics, indicate a lack of understanding of the concept of instantaneous velocity as the ratio of the differentials of position and time.

To gain deeper insight into student understanding of differentials and derivatives, we developed a questionnaire that probes student ideas on instantaneous velocity and electrical field (as the derivative of potential with respect to position) in both graphical and symbolical representations. Many students from four different universities (incorrectly) refer to a particular case (e.g. E-field of a point charge) or confuse average and instantaneous velocity or electric potential and field.

3 Tutorials on Ordinary Differential Equations in a service-taught module for physicists

The study of ordinary differential equations (ODEs) is a crucial prerequisite of many topics in advanced physics. Having surveyed a cohort of physics students who completed a typical service module on ODEs, we found that many of them possessed a fragmented concept image of ODEs and insufficient instrumental understanding to succeed in physics modules involving ODEs.

To improve the situation, we designed a set of tutorials that sought to address these issues. In addition to targeting specific issues with their instrumental understanding (primarily the manipulation of exponents and indefinite integration), the intervention focused on broadening their concept image of ODEs. Tutorials were designed on the meaning of the derivative, direction fields, and the solution nature of an ODE among other things. Interviews with students revealed significant gains in the understanding of ODEs as well as an appreciation of the guided-inquiry approach employed throughout the tutorials.

4 Blending mathematics and physics: student difficulties with boundary conditions for the diffusion equation

The intrinsic mathematical nature of physics implies that understanding in physics is strongly connected with the ability to think about the world using mathematical structures. Mathematics is used to articulate relationships among variables in physics, and mathematical facility allows for a richer understanding of empirical results. Getting insight into the way students blend mathematics and physics is therefore a frequently studied topic in physics education research.

In this contribution we report on an exploratory study on students bringing together mathematics and physics in the context of partial differential equations, more specifically the heat/diffusion equation. We administered task-based think aloud interviews with twelve students of two universities. The interviews were analysed using an interpretative deductive content-analysis based on conceptual blending. Results show a number of difficulties relating to mathematical concepts, physics concepts and to the blending of both fields, such as difficulties with functions of two variables, and the mathematical description of boundary conditions.