Ricardo’s “short” blurbs for the PER homepage

# Educational implications of the interplay between physics and mathematics

Physics and mathematics are deeply interwoven and there are many educational consequences of this fruitful, yet complex, relationship. Our research involves considering the following three complementary dimensions:

1) Historical and Epistemological Studies

Physics and Mathematics have been deeply interrelated since the very beginning of scientific knowledge and this mutual influence has played an essential role on both their developments. Historical case studies show us not only physics problems motivating the creation of mathematical concepts but also “pure” mathematics being used to derive conclusions about the “real” world.

2) Learning/Cognitive Perspective

The main difficulties students face when using mathematics to solve physics problems and/or transferring their knowledge from a mathematical to a physical context need to be investigated. Moreover, it is important to understand how the ability of using mathematics as a reasoning instrument in physics – instead of using it as a mere calculation tool – is developed.

3) Teaching/Didactic Perspective

Teaching activities and materials have to be carefully designed in order to encourage students to structure their thought mathematically in physical contexts. Due to the crucial responsability of the teacher for the success of this challenge, such didactical aspects have to be sistematically approached in teacher education. Aditionally, criteria for evaluating the quality of instruction, regarding the focus on several aspects of the relationship of physics and mathematics, should be established.

**Examples of research questions**

* What characterizes good explanations in didactical settings (e.g. lectures, textbooks) that highlight the structural role of mathematics in physics?
* How can historical and philosophical studies on the relationship between mathematics and physics improve the teaching of these disciplines?
* What are typical difficulties to understand the application of mathematical concepts and structures (e.g. matrices, complex numbers, vector calculus, etc.) in physics? What are appropriate teaching strategies to circumvent them?

**Examples of publications**

A thematic issue of the journal Science & Education guest-edited by Ricardo Karam on this topic (Volume 24, Issues 5-6) can be found [here](http://link.springer.com/journal/11191/24/5/page/1).

**Karam, R.**,Uhden, O. & Höttecke, D. (2019). The “Math as Prerequisite” Illusion: Historical Considerations and Implications for Physics Teaching. In: *Mathematics in Physics Education.* Pospiech, G., Michelini, M. & Eylon, B-S. (eds.). Springer, p. 37-52.

**Karam, R**., Krey, O. (2015). Quod erat demonstrandum: Understanding and explaining equations in physics teacher education. *Science & Education*, 24(6).

**Karam, R.** (2014). Framing the structural role of mathematics in physics lectures: A case study on electromagnetism. *Phys. Rev. ST Phys. Educ. Res.* 10, 010119.

Uhden\*, O., **Karam**\***, R.**, Pietrocola, M., Pospiech, G. (2012). Modelling Mathematical Reasoning in Physics Education. *Science & Education*, 20(4), 485-506. \* Both authors contributed equally.

# Using history of physics to teach physics

For over a hundred years we have been teaching and learning physics through textbooks. This is the result of a well-established tradition and has many advantages. However, it also makes physics teaching more distant from the original ideas of the discipline and tends to obscure their historical genesis. What if we went back to the origins and read the primary sources? Could physics students make sense of them, and, more importantly, would they gain something from being confronted with ideas-in-the-making?

This idea may sound appealing until one opens a random original source (e.g., Newton’s *Principia*) and is overwhelmed by its complexity. Unfamiliar concepts, notation, mathematical formalism, etc. often make primary sources simply unintelligible at a first glance. The challenge is, then, a matter of didactical design. This research investigates the pedagogical potential of primary sources by carefully selecting excerpts of original sources and identifying deep insights they provide compared with traditional teaching.

**Examples of research questions**

* How can primary sources be used productively to teach physics and in the education of future physics teachers?
* What characterizes good excerpts of original sources in terms of their pedagogical potential?
* Which pedagogical lessons can be extracted from selected excerpts of original sources of specific topics and how can they enable critical reflection about the traditional way these topics are taught?

**Examples of publications**

**Karam, R.**, Lima, N. W. (2022). Using history of physics to teach physics?in *Connecting Research in Physics Education with Teacher Education 3*, Guisasola, J. & McLoughlin E. (eds), The International Commission on Physics Education, Dublin.

Lima, N., **Karam, R.** (2021). Particle velocity = group velocity: A common assumption in the different theories of Louis de Broglie and Erwin Schrödinger. *American Journal of Physics*, 89, 5, p. 521-528.

**Karam, R.** (2020). Schrödinger's original struggles with a complex wave function. *American Journal of Physics*, 88, 6, p. 433-438.

**Karam, R**. (2018). Fresnel’s original interpretation of complex numbers in 19th century optics. *American Journal of Physics,* 86, 4, p. 245-249.

**Karam, R.**, Coimbra, D., Pietrocola, M. (2014). Comparing Teaching Approaches About Maxwell’s Displacement Current. *Science & Education*, 23(8).