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The role of mathematics and self-efficacy in learning quantum mechanics

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Quantum mechanics (QM) is a complex and often difficult topic for physics students. To make sense of the topic, the students need to grasp both the physical interpretation and the mathematical formulations [1-2]. Quantum theory is based on the notion of vector spaces and their features, which makes linear algebra part of the necessary mathematical toolbox.

At the University of Helsinki, the QM curriculum begins in the first or second year of studies, depending on study track. The first course, Basics of quantum physics, covers the basics from the historical background up to a qualitative treatment of the hydrogen atom. Many students struggle with the mathematics on the course, and, partly to address this, the curriculum was changed to include a linear algebra course simultaneously to Basics of quantum physics. Hence, the QM course in 2018 was taken by both students who studied linear algebra at the same time, and students who had taken linear algebra earlier.

To study the effect of this change we administered a mathematics pre-test and a self-efficacy questionnaire based on [3] and adapted for QM, and correlated the results with learning outcomes (exercise and exam scores, N = 50).

Surprisingly, the preliminary results indicate that neither the self-efficacy nor the initial mathematics skills of students correlate with the learning outcomes in Basics of quantum physics. For the first year students, the students who reported theoretical physics as their study track had equal initial mathematics level to their "physics" peers, but had higher self-efficacy beliefs and scored higher in the exercises and exams. Second-year "physics" students scored even lower in all measures. The explanation is likely a selective effect: the "physics" students who take the course in their first year are more comfortable with more advanced physics and mathematics content.

[1] C. Singh and E. Marshman, Review of Student Difficulties in Upper-Level Quantum Mechanics, Phys. Rev. ST Phys. Educ. Res. 11, 020117, (2015).
[2] B. W. Dreyfus, A. Elby, A. Gupta and E. R. Sohr, Mathematical sense-making in quantum mechanics: An initial peek, Physical Review Physics Education Research, 13, 020141, (2017).
[3] J. M. Bailey, D. Lombardi, J. R. Cordova, and G. M. Sinatra, Meeting students halfway: Increasing self-efficacy and promoting knowledge change in astronomy, Phys. Rev. Phys. Educ. Res. 13, 020140, (2017).

Primary author: Dr KONTRO, Inkeri (University of Helsinki)

Co-author: Ms PALMGREN, Elina (University of Helsinki)

Presenter: Dr KONTRO, Inkeri (University of Helsinki)

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