

# “THE ELEGANCE OF QUANTUM MECHANICS”: AN AT-DISTANCE PROPOSAL FOR SECONDARY SCHOOL STUDENTS

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## INTRODUCTION: THE STATE OF THE ART AND OPEN PROBLEMS

Quantum Mechanics has been the focus of physics education research since the 90s and, nowadays, researchers no longer express doubts on the fact that it is fundamental for the culture and the awareness of the individual citizen and of the whole society (Redish, 2000; Besson, 2017). From surveys on teacher training (Stefanel, 2008; Fera, 2011; Giliberti, 2014; Krijtenburg-Lewerissa, 2017), it emerged that most teachers - mainly with a degree in mathematics - often do not have a coherent framework of modern physics in general, and of quantum physics in particular. Furthermore, the didactic path presented in textbooks is limited to a pseudo-historical presentation, which provides a hyper-simplified explanation of the fundamental concepts, in an attempt to bypass the problems associated with students' lack of adequate mathematical tools, leading to deep misconceptions.

## OUR COURSE: “THE ELEGANCE OF QUANTUM MECHANICS”

In this presentation we describe the work of designing, testing, and evaluating the effectiveness of a course entitled, “The elegance of quantum mechanics”, presented in Academy Year 2021/22. The activity - done online - was offered to teachers and students of the last three years of high school (120 participants overall), from October 2021 to January 2022, through weekly appointments of one and a half hours each. Lessons were integrated with slides, questions with *Kahoot!* and graphic examples with *GeoGebra* (<https://www.geogebra.org/m/aqf2dgn3>).

Course effectiveness was assessed by collecting and analyzing different types of data deriving from an anonymous satisfaction survey, 9 Google Forms (given after each of the first nine lessons, with a total of 38 open questions and 24 exercises; for example: <https://forms.gle/Nr2umPc53FCCi3KZ9>), and 19 individual interviews, aimed at investigating strengths and criticalities. This analysis allowed us to identify the reasoning that students commonly use in facing some conceptual issues of quantum mechanics. The following will be discussed:

- strengths of the activity, regarding the mathematical aspects, the use of *GeoGebra* and *Kahoot!*;
- criticalities, especially in dealing with spaces with more than 3 dimensions, with the concept of self-adjoint operator, and concerning the confusion between states and operators;
- materials (<https://pls.fisica.unimi.it/materiali/>).

A new course, implemented with the improvements mentioned above, is expected to start in October 2022.

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