

Development of quantum concepts via different two-state approaches

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Abstract. In the last decades two-state approaches were increasingly considered useful for introducing quantum physics to students on all levels. Some promising results were reached. However, a thorough evaluation with reliable and validated instruments is still missing. In addition, it could be possible that some two-state approaches are more suitable to some quantum concepts than to others. In order to be able to evaluate and compare different approaches instruments are developed. In the project “DQC-2stap” first steps towards this goal are taken. We describe the development of a questionnaire on the measuring process and a corresponding activity for in-service teacher education.

Introduction

A two-state approach to quantum physics seems to be a suitable and flexible means for teaching quantum physics. As two-state systems are the simplest possible quantum systems they may serve as an easy-to-handle mathematical framework to explore some of the fundamentals of quantum physics. The basic quantum concepts are not only clearly visible but also discoverable by students themselves while a comprehensible mathematical formalism is used. Such an approach can be taught in different contexts, e. g. with polarization, with spin, with a double-well system or with still other systems with two basis states. However, the question arises if all these approaches are equivalent in the sense that they are all equally well suited to teach the most important quantum concepts such as quantum state, superposition, uncertainty, entanglement and measuring process with similar success with respect to understanding by high school students. It could be thought that different approaches have different strengths and weaknesses. In order to find hints in this direction in the project DQC-2stap “*Development of quantum concepts via different two-state approaches*” a questionnaire should be developed that sheds light onto this question. This process is accompanied by corresponding teacher education activities.

Project objectives

The ultimate goal of the project DQC-2stap “*Development of quantum concepts via different two-state approaches*” is to give recommendations for teachers or educators at university on how two-state approaches and appropriate teaching material can be optimized in the sense that students understand best the quantum concepts.

First, it should be identified which of the two-state contexts mentioned above is most suitable for teaching which quantum physics concept at the secondary school level. Especially specific learning difficulties of students should be identified. To this end a questionnaire is developed.

Secondly, the gained insights into students' learning difficulties in two-state approaches will be used to develop or improve secondary school teaching proposals and material based on the two-state approach within a design based research process. This research goal needs longer time and will profit from cooperation with other projects in the Quantum Flagship education initiative.

Development of questionnaire

In order to limit the complexity of the questionnaire development, we initially restricted ourselves to the concept "quantum physical measurement process". This concept was also chosen because the measurement process lies at the core of the peculiarity of quantum physics. So the research question is:

Which understanding and learning difficulties do students show with respect to the measuring process?

In a first step, we work on the development of a first version of a questionnaire to evaluate our teaching materials with secondary school students. Herewith we focused on the understanding of the measuring process. Based on own teaching experiences, on existing questionnaires and on a classification of aspects of the measuring process sample items were developed. These were graded with respect to their suitability independently by all the members of the group and the item with highest grades were taken. The items were mostly closed single choice items with required justification and some open items.

In the next step the questionnaire was tried with selected students, adapted and refined. Then a pilot with teacher students was made. The resulting final version is now being tested with school students in Hungary, Slovenia and Italy, whereof first results will be presented.

Activity of teacher education

Since it is an overarching aim of this project to derive recommendations for teachers or educators at university on how two-state-approaches can be optimized towards student learning of quantum physics, teacher education courses are developed and conducted within this project. In this talk, we will describe one of these teacher education courses developed by the project partners from Udine (Italy): A teacher training consisting of 5 meetings (4 hours each, once a week) has been completed in March 2022 preparing teachers for the implementation of a field study into teaching/learning quantum physics via a polarization-approach (one of the two-state-approaches comprised in our pilot project). The teachers attending the course filled in four tutorials on the different topics such as the phenomenology of polarization. In this GIREP presentation, we report on the teacher training course in more detail. Furthermore, we give insights into the analysis of the four tutorials and the discussions during the training.

Outlook

Using the questionnaire, we will conduct field studies in order to compare learning outcomes from students who are introduced into Quantum Measurement via different two-state-approaches. We will use the outcomes of the questionnaire for a) a refinement of the different teaching sequences, and b) for answering the question about the suitability of different two-state-approaches to introduce students to Quantum Measurement.