New horizons: A quantum physics concept for grade 9 students

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Abstract. The significance of quantum physics in secondary school curricula is increasing, raising the question of modern approaches to the topic for younger target groups. For this purpose, a state-of-the-art teaching concept has been developed to introduce quantum physics conceptually to grade 9 students, focusing on the electron spin in the context of the quantum computers. Formative evaluation revealed promising results and experiences. In the talk we report the development process of the concept and teaching materials as well as first findings from summative evaluation regarding student learning achievements, changes in affective variables and teachers' assessments.

Introduction

Quantum physics is, without a doubt, a fundamental scientific theory, holding immense potential for future technologies and therefore bearing relevance to society as a whole. Furthermore, quantum technologies of the new generation, such as quantum computers, enable promising approaches for quantum literacy especially in secondary school education [1].

Given the general educational character of quantum physics as a fundamental part of modern physics, there is a need for contemporary aspects in quantum education. Additionally, modern aspects of quantum physics enable innovative approaches to introduce the topic on a conceptual level even before final high school years, in order to grant access to a broader audience.

Therefore, the objective of this Design-Based-Research project is to develop and evaluate a teaching concept focusing on qualitative quantum physics and quantum computing, targeting especially grade 9 students as an especially young audience.

Theoretical Framework

In order to meet the needs and challenges of quantum education in general and for this young audience in particular, the teaching concept is based on a ‘Spin-First’ approach. Hence, concepts and phenomena are addressed using an exemplary two-state quantum system [2]. This approach, especially in the context of quantum technologies and information, offers numerous advantages from a science education perspective compared to more traditional approaches [3]. The considered systems are often much simpler than those in traditional curricula. Furthermore, the subject matter is more straightforward to grasp with regard to linguistic and conceptional aspects.

Outline of the Course Design

The developed teaching concept introduces quantum phenomena using the electron spin as an exemplary two-state quantum system and emphasizes conceptual understanding. Focusing on a sensitive teaching language, classical concepts are distinguished from quantum physical ones. On the other hand, commonalities and connections between these two areas of physics are emphasized as well. The course deliberately and completely abstains from the concept of waves to avoid known learning difficulties (e. g., [4]) and to reduce required prior knowledge in the subject of waves and in the field of mathematics.

The course includes in total seven chapters and numerous teaching materials have been developed, including a textbook, a workbook, a simulation, and guidelines for teachers.

Research Questions for Summative Evaluation

With regard to the summative evaluation, several research questions arise, including:

- How effective is the concept in terms of declarative knowledge and to what extent does the concept contribute to the development of appropriate quantum physical conceptions?
- How does the intervention affect students' interest in physics, their current interest in physics, and their subject-related self-concept in physics?
- How do teachers assess the concept?

Methods for Development and Summative Evaluation

Due to this widely unexplored target group, the whole study is conducted in an exploratory manner. As inherent to Design-Based-Research projects, the development and theory-building process went through cyclical phases, drawing on the elaborated design principles.

After a first draft for structure and design principles was developed, a formative evaluation took place in the form of teaching experiments with students from the target group (N=11).

Based on these qualitative results, the teaching concept was adjusted and teaching materials were developed. The concept then underwent a total of six design-redesign cycles in 2023 through formative field studies (N=131) for further development and improvement, incorporating e. g. feedback from learning diaries, interviews, and practitioner input. Simultaneously, two test instruments were developed in order to assess learning achievement variables and therefore serve as a basis for summative evaluation, which began in the summer of 2023.

The summative evaluation is conducted as a field study as well, running until summer 2024 and involving in total approximately N=500 grade 9 students from Germany. External teachers implement the teaching concept after undergoing a teacher training. In a Pre-Post-Follow-Up-design, questionnaires containing developed scales for cognitive variables, as well as already existing scales for affective variables are used. Additionally, interviews are conducted on a sampling basis in order to triangulate gathered quantitative data.

Preliminary Results and Outlook

Teaching experiments suggested that the approach can, to a great extent, successfully convey the intended content. Additionally, findings from formative development and evaluation steps indicate preliminary educational success with regards to the defined learning objectives.

This suggests promising results in the summative evaluation, of which first findings will be presented in the presentation.

References

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