How do scientists explain basic concepts in quantum physics?

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Abstract. Quantum physics is often perceived as complicated, unintuitive an hard to explain. In a study in the form of an expert novice dialogue we asked young scientist doing research in quantum metrology to explain such concepts to an interested first year university student. Here we report our findings on content structure and explanatory elements used within these explanations.

Introduction

Taking a look at both popular media and school books, quantum physics seems to be perceived as a hard to understand and therefore hard to explain topic of an almost mythical quality. People who do research in a subfield of quantum metrology will need a working understanding of quantum physics in order to do their work. We might therefore assume that they are experts in quantum physics. The leading question for our research has been: How do these experts in quantum physics explain its basics concepts, when challenged to do so by a novice of this field?

Explaining in science and science education

Explanations are an integral part of both science and science education. While these two kinds of explanations share a lot of features, there are also some notable differences. In the context of didactics the explanation has to be understood as a communicative act. The question to whom something is explained becomes relevant. A scientific explanation's quality is determined by whether or not the logical argument is correct and the empirical data, as well as the scientific laws used, are true. A science teaching explanation however has to be both factual true as well as appropriate to the recipient [1].

Study design

PhD students doing research in quantum metrology were asked to explain basic concepts as well as their own research to a first year engineering student. This explainee was not subject of the study, but rather a briefed student assistant. The explainers were given the specific task shortly before meeting the explainee, giving them 20 Minutes of time to prepare. Materials such as diagrams, equations and passages from physics books were provided. Explainers could choose between one of two topics: The Heisenberg uncertainty principle or the behaviour of quantum objects in a Mach-Zehnder interferometer. After explaining one of these two topics they were asked about their own research. A schematic overview of the procedure of one explanation can be found in figure 1.

Expert novice dialogue

The expert novice dialogue method has been developed and successfully implemented by Kulgemeyer and Schecker [2]. It is based on a constructivist communication model (see for example Merten [3]). The key characteristic of such a model is, that the adressee does not merely perform a passive role. In order to achieve successful communication they have to actively accept the communication attempt by the communicator. Therefore the communicator needs to vary all aspects of their communication in such a way, that the adressee will be interested and able to accept their communication offer. Kulgemeyer and Schecker identified four aspects of communication: factual content, context, code and representation form.

Even though this model has been specifically developed to describe school students' science communication competence, it is also applicable for the situation described above. As it shares the common feature of an expert-novice situation.

Analysis and Results

At the time of writing we are still in the process of acquiring more data and analysing it. Some preliminary results can already be reported. All explanations featured a high proportion of the explainer talking with only 10% of the talking done by the novice on average. For the explanation of the Heisenberg uncertainty principle, which was favoured by the experts, it was interesting to see a varied degree of mathematisation. Some experts chose to use mostly qualitative statements and simple graphs while others relied on the full prior knowledge of a first year engineering student, talking about concepts such as integrals, Fourier transformations and matrices. Despite these differences in level of mathematisation, in terms of what kind of mathematical reasoning was used, all explanations could be grouped into three categories. These were, in order of decreasing frequency: algebraic, using wave properties and trigonometric explanations.

Some more detailed results will be available at the time of the conference.

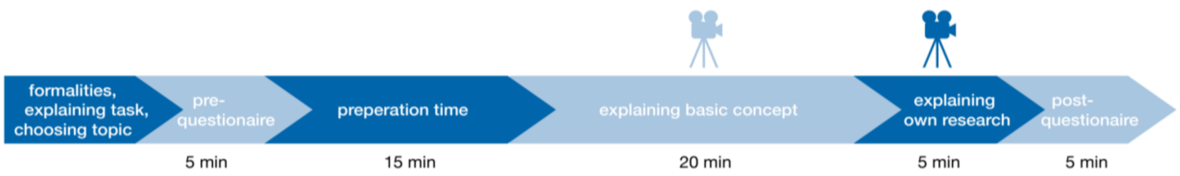

Fig. 1. Process of explanation for the study

References

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