Connecting with quantum: Examining the educational value of the Bohr atomic model using embodied cognition and variation theory

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Abstract. Teaching quantum physics requires teachers to be mindful of how students connect bodily experiences with abstract models. However, the abstract nature of the quantum realm implies a lack of well-functioning real-world analogies. In the current study, we examine the prominent Bohr atomic model and its presence in educational materials through the joint lens of embodied cognition and variation theory. Together, these two theoretical perspectives open up new ways of seeing educational values and pitfalls in the use of the Bohr atomic model. Finally, this approach can be used to make suggestions on designing teaching sequences and materials.

Introduction

Quantum physics (QP) is often seen as a mysterious yet exciting field of study. This is partly because students' experiences of the macroscopic, 'normal' world are markedly different from the quantum realm [1]. With less access to bodily experiences, more attention is required towards understanding models to compensate for the lack of real-world analogies. Thus, teachers need to aid students in making sense of, constructing, and reasoning with models [2]. This instructional focus aligns with the historical and conceptual approaches to teaching QP that both emphasise the decisive role of models in tackling novel conceptual problems [3].

In this study, we examine the educational value of one of the most prominent models in QP, the Bohr atomic model. Bohr introduced this model in 1913 [4] and posited that electrons orbit the atomic nucleus in circular, stationary orbits that can be explained by quantised angular momentum.

Even though modern QP has realised the Bohr atomic model to be incomplete, its place in educational practices remains. Thus, there is a need to examine further the educational value of this model, particularly its affordances to help students navigate between the embodied classical world and the disembodied quantum realm.

Theoretical Framework, Research Question & Original Aspects

We draw on two theoretical perspectives, the variation theory of learning and embodied cognition, to investigate the affordances of the Bohr model in QP education. While variation theory emphasises the importance of experiencing differences and similarities to discern and understand scientific concepts [5], embodied cognition perspectives focus on how bodily experiences in the world shape thinking and understanding at a fundamental level [6]. Combining both perspectives offers a novel and comprehensive approach to studying the affordances of models in quantum education. We pose the following research question: *How can embodied cognition and variation theory contribute to a deeper understanding of the role of the Bohr atomic model in QP education?*

Method

By conducting a scoping review, we identify the current use and implementation of the Bohr atomic model in early quantum physics textbooks and online resources. At this stage, the focus is on gathering a breadth regarding *how* (in a descriptive sense), *in what context*, and *for what purpose* (explicit and implicit) the Bohr model is used. This serves as the basis for the theoretical analysis that focuses on identifying the different affordances and, by extension, the educational value of the Bohr model.

Anticipated results and conclusion

Our preliminary analysis has identified the strong potential of embodied inference [7], specifically within the framework of Bayesian inference, for aligning with the principles of variation theory. For example, we note that phenomena like electron 'jumps' are introduced in early QP education to help students transition from the continuous orbits of the solar system model to the discrete orbits in the Bohr model. Clearly, the idea of 'jumping' electrons has a metaphorical origin, connecting the abstract target domain of QP to the source domain of learners' bodily experiences. We argue that this metaphor provides a prospective critical variation, seen as necessary by variation theory, to help students discern the importance of discreteness vs. continuity in the model. More generally, through examining such strategies using available textbook materials, we aim to highlight and investigate the role of bodily experiences for learning through variation.

To conclude, we argue that combining embodied cognition and variation theory provides a novel and fruitful approach to understanding the value of the Bohr model and other similar models in QP education. During the conference, concrete examples will be demonstrated, and implications for designing teaching sequences and materials will be further discussed.

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