Qeios

Peer Review

Review of: "Some Mathematical Issues Regarding a New Approach Towards Quantum Foundations"

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The paper under review is the latest in a series of works by Prof. Inge S. Helland, devoted to a new reconstruction of quantum mechanics (QM).

Before expressing my opinion about this paper, let me first address the question on everybody's mind: Why would one seek a new interpretation or reconstruction of QM? Don't we already have enough of them?

The purpose of each new interpretation or reconstruction of QM is to provide a more rigorous and foundational understanding of quantum theory. This involves re-examining and formalizing the mathematical structures and principles that underpin QM, often with the goal of addressing conceptual issues or inconsistencies, such as the measurement problem or the nature of quantum states and observables. Another purpose is to extend the formalism to accommodate new theoretical developments or experimental findings, ensuring that the theory remains robust and applicable in various contexts.

By contrast, the recent series of works by Prof. Helland was inspired by the idea of developing an interpretation of QM that is sufficient to reconstruct the mathematical framework of QM, rather than the usual approach where QM interpretations are dictated by the mathematical framework.

Prof. Helland calls his approach *the General Epistemic Interpretation (GEI)*. The most crucial element of GEI is Theorem 1, which is based on the notion of *a conceptual variable*. So, instead of scrutinizing the mathematical correctness of GEI, let me focus solely on this notion.

According to GEI, a conceptual variable refers to a physical variable that may be *accessible* or *inaccessible*, meaning it might be possible or impossible to assign numerical values to it.

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Then again, one might say that conceptual variables are, in fact, unobservable or latent variables. Hence, *what is the purpose of calling them by another name, such as conceptual variables? What is conceptual about hidden variables?*

As stated by GEI, referring to unobservable or latent variables as "conceptual variables" highlights their role in bridging the gap between theoretical constructs and our understanding of physical phenomena. The term “conceptual” underscores that these variables help frame our thinking and interpretation of the hidden aspects of a system.

In the context of quantum mechanics, labelling these as "conceptual variables" emphasizes their utility in forming a comprehensive picture of quantum states and observables, even when direct measurement isn't possible. Essentially, it indicates that these variables are part of our conceptual framework for understanding the underlying structure and dynamics of a quantum system. The "conceptual" aspect of hidden variables thus points to their role in shaping our theoretical models and interpretative frameworks, rather than being directly accessible or measurable quantities.

Conceptual variables are often used in *epistemic processes*, which involve obtaining knowledge about a quantum system through measurements or statistical investigations.

This raises a further question: *If epistemic processes are all about understanding what we can know about a quantum system, rather than what the system itself is inherently like, do these processes contradict realism?*

As stated by GEI, even though in some interpretations of QM (e.g., the Copenhagen Interpretation), there might seem to be a contradiction between epistemic processes and realism, other frameworks (such as the Many-Worlds Interpretation or the de Broglie-Bohm Theory) can reconcile the two by proposing different mechanisms or ontologies for quantum phenomena.

Another important concept of GEI is that of *epistemic conceptual variables (e-variables)*. This concept posits that these variables exist both in the real world and in the mind of an observer. The question is: *How is this concept different from subjectivism?*

According to GEI, the key difference is that e-variables emphasize the role of epistemic processes in understanding a pre-existing reality, while subjectivism focuses solely on the observer's perspective without necessarily positing an independent reality. In this way, by highlighting the existence of a real-world aspect, e-variables offer a way to reconcile the objective and subjective elements in

quantum mechanics, providing a framework where both the physical reality and our knowledge of it play crucial roles.

GEI places particular emphasis on *a maximally accessible conceptual variable (MACV)*. In the context of epistemic processes and conceptual variables, a MACV is a variable that is as fully accessible or measurable as possible within the constraints of the theory. This means that the variable can be precisely determined or assigned a numerical value through measurements or observations, given the limitations of the experimental setup or theoretical framework.

One might immediately ask: *Aren't all physical variables supposed to be maximally accessible?*

Consistent with GEI, there are inherent limitations on what can be measured and known about a system simultaneously in QM. These limitations are due to the principles of quantum theory, such as the Heisenberg Uncertainty Principle, which states that certain pairs of physical properties, like position and momentum, cannot both be precisely measured at the same time. Moreover, quantum entanglement and superposition add layers of complexity that further limit our ability to access and measure all physical variables completely. This means that not all physical variables in a quantum system can be maximally accessible at once. MACVs are those variables that can be measured or known to the fullest extent possible within these quantum constraints, representing the highest degree of information that can be obtained about a particular aspect of the system.

Be that as it may, it is still difficult to see any benefit of a conceptual variable, accessible or otherwise, especially given that maximal accessibility can be understood as synonymous with measurability within the constraints of quantum mechanics.

However, my main objection is not to MACVs but to the assumption in GEI that *a function of an inaccessible variable can be accessible*. According to GEI, if a variable x is inaccessible, it means that we cannot measure or assign a precise value to it directly. However, the function $y = f(x)$ can still be accessible if we have a way to measure y indirectly (e.g., through modelling or inference).

This resembles the situation with *ether*, once hypothesized as an all-pervasive medium through which light waves were thought to propagate. Although ether itself was inaccessible and couldn't be directly measured, the effects of objects moving through it, such as the length contraction of a rod, were hypothesized to be observable.

Similarly, according to GEI, while conceptual variables may be inaccessible directly, their influence can be inferred through indirect measurements and the behaviour of other measurable variables. Just

as scientists attempted to detect the presence of ether through its hypothesized effects on moving objects, physicists in quantum mechanics use observable phenomena to gain insights into the underlying variables and processes that might be hidden or conceptual.

This brings me to my final question: *Would the simplest explanation of the behaviour of measurable variables be the one that rejects conceptual variables?* After all, the concept of ether was rejected for not being the simplest explanation. Therefore, applying Occam's razor, which states that the simplest explanation is usually the best, might lead us to prefer interpretations that do not rely on hidden or conceptual variables, focusing instead on measurable phenomena directly.

It seems that the only way one could accept GEI is if it were to have greater explanatory power than other interpretations of QM. Indeed, while simpler models are preferred, they must also account for all known phenomena. Hidden variable theories, like the de Broglie-Bohm theory, aim to offer a more complete, deterministic picture of quantum mechanics, at the cost of added complexity. These theories argue that hidden variables can provide deeper insights and resolve conceptual issues that simpler interpretations might not fully address.

However, I seriously doubt this. The different interpretations of QM have similar explanatory power when it comes to predicting experimental outcomes. This is one reason why there is no universally preferred interpretation among physicists. So, unless the General Epistemic Interpretation of QM can demonstrate that it has no conceptual issues or inconsistencies and can accommodate new theoretical developments, it would remain one of the many.

Declarations

Potential competing interests: No potential competing interests to declare.