Principle Theory or Constructive Theory?

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Abstract

Einstein made a distinction between principle theories like Newtonian mechanics and constructive theories like kinetic theory of gases. Are these two distinct types of theories fundamentally different from each other or can they be regarded to belong to just one type of theory? We explore this issue with respect to the theory of scientific study and come to the conclusion that there is only one type of (scientific) theory, and the constructive theory is a principle theory with only one principle, which we call the default-principle theory rather than calling it a constructive theory. One reason why constructive theories are considered as default-principle theories is that it provides a natural progression from default-principle theory to a principle theory as science progresses. This also avoids the suggestion that constructive and principle theories are considered as completely distinct entities without any interaction with each other, which may hinder scientific progress.

Keywords: philosophy of science, theory, model, principle

1. Introduction

Einstein made a distinction (Flores, 1999) between principle theories (Lange, 2014) like Newtonian mechanics and constructive theories like kinetic theory of gases. If these two types of theories are fundamentally different, then the theory and model of scientific study by Luk (2010;2017) are incomplete because they only recognize principle theories although it is mentioned that a theory may contain models in (Luk, 2018). If they are fundamentally different, then why should scientific knowledge be organized into these different types of theories? Is it because one type of theory facilitates top-down explanations while the other type facilitates bottom-up explanations (Flores, 2000) as they are interpreted in an explanatory-predictive paradigm (Morgenbesser, 1963)? Or, are these two types of theories fundamentally belong to the same type of theory? We tackle this issue by using the default principle which we will formulate in the next section.

2. Default Principle

First of all, what distinguishes a principle theory from another type of theories? The first defining characteristic is that a principle theory has at least one principle. Otherwise, it will not be called a principle theory. According to Luk (2018), a principle theory may optionally have one or more (generalized) model. Therefore, we can enumerate the two possible types of principle theories as follows. Type A principle theories are like Newtonian mechanics where the principles or laws are directly applied to the models that are considered separate from the theory that contains only laws and postulates. Type B principle theories have at least a principle that is applied to one or more generalized models. These generalized models may optionally refine to specific models that are separate from the theory and that directly correspond to the experiments. Alternatively, these generalized models may directly connect to the experiment entity without going through any other model (see Luk [2010]). Since for both Type A and Type B principle theories, they have principles, it would appear that principle theories are distinct from constructive theories which only have models without any principles.

However, we can construct a default principle as a principle for the principle theories, similar to creating the number, zero, for the number theory, or a placeholder in mathematics. The default principle states that there are no other principles apart from this one in the default-principle theory and this default principle specifies that the construction of models is based on the abstraction/simplification/approximation/idealization of physical models (outside the theory and close to the physical situations) or of the physical situations. Note that a default-principle (principle) theory has zero or more (generalized) model in the theory. If it has a default principle plus a (generalized) model in the theory, then it can be considered as a constructive theory. If the principle theory only has the postulates and the default principle, then the default principle applies to the (generalized) model outside the theory, which we will argue later that this is possible.

When we include a model in a theory like the default-principle theory, there is a problem because there are models outside the theory and models inside the theory. So, how can we distinguish the different types of models and why should some model be inside the theory and some outside? One observation of models outside the theory is that these models are close to the experiment or physical situation. So, these models typically make simplifying assumptions so that the models are tractable (Luk, 2010). These simplifying assumptions are made not because they are believed to be true but that they are convenient to produce a tractable model and therefore a solution to the problem. On the other hand, models inside the theory are closer to the theory, which is believed to be true (Luk, 2020). Therefore, if models inside the theory are part of the theory, then these models need to be believed to be true. Therefore, these models do NOT make simplifying assumptions, which are believed to be false, unlike models outside the theory. Otherwise, we may have a false theory (Lutz, 2013). Hence, when we derive a model from the principles and we make some simplifying assumptions that we do not believe to be true, then our model becomes a model outside the theory. If we derive a model that we do not need to make any simplifying assumptions that are thought to be false, then our model may be considered as in the theory or as part of the theory.

Another complication occurs when we are dealing with generalized models which simplify the detailed models that are considered outside the theory. The problem is that the generalized model ignores some of the details of the detailed model outside the theory. Is the generalized model making simplifying assumptions? If so, how can the generalized model be part of the theory? Our answer is that we need to distinguish two types of simplifying assumptions. One type simplifies the model so that it is tractable and such type of assumptions is not believed to be true and so the model is outside the theory or not part of theory. Another type simplifies the model so that we arrive at a general model that can be instantiated to different detailed models outside the theory. Here, the simplification is done to make the model more general instead of making some false assumptions for the model to be tractable. Therefore, we believe that such generalized model should be part of the theory. Note that for a theory to be believed to be true, we only need the model or the theory to have a one-to-one mapping (i.e., injective) to the physical objects or events (Luk, 2010; 2020). We are not required that every physical object or event must be modeled by the theory or the generalized model in the theory, because we do not require the mapping to be surjective. Therefore, simplifying detailed models outside the theory by dropping some of their constructs to arrive at the generalized model is allowed without affecting the claim that the theory is believed to be true.

Note that there may be further complications where there is a generalized model which makes some simplifying assumptions that are false but they are made to make the generalized model more tractable. In this case, the generalized model is outside the theory since a theory can be believed to be true. In this case, the principle theory may just have the postulates and the default principle that applies to this generalized model outside the theory. Therefore, it is possible that a default-principle theory does not have any model inside the theory. However, a default-principle theory must have at least one model inside the theory or/and at least one model outside the theory. In this case, the default-principle theory may have theoretical assumptions or presuppositions apart from the default principle. Again, the theoretical assumptions are supposed to be true whereas model-specific assumptions may be false.

3. Case Study

One might think that the kinetic theory of gases is a good example of a constructive theory as mentioned by Einstein. It turns out that the kinetic theory of gases is a principle theory because it relies on Newton's law of motion (i.e., principles) applied to microscopic constituents to obtain a macroscopic equation. In particular, Newton's second law is used to derive the formula for the kinetic energy which in turn is used to derive the well-known (PV/T) relationship between pressure, volume and temperature of a(n) (ideal) gas. This derivation is based on constructing a simplified, idealized model for the microscopic constituents, and proceed to derive the well-known relationship by applying Newton's law of motion. We argue that this model for the microscopic constituents belongs to the theory. The reason is that we can verify this model by testing the PV/T relationship of some gas in an idealized container in a controlled experiment. Therefore, this model is believed to be true if the PV/T relationship is verified. When we apply this PV/T relationship to other physical models like the engine piston or the air conditioner, these physical models may be outside the theory because these physical models are more akin to the physical situations, and some model-specific assumptions may be made. Note that in the kinetic theory of gases, the explanation is not just bottom up. It actually has to apply Newton's second law to derive the equation for the kinetic energy to be used in this simplified situation. Therefore, the explanation is a hybrid of top-down and bottom-up explanation.

In biology or medicine, germ theory is an example of a constructive theory. The model of the constructive theory is that diseases are caused by germs. The germs need to come into contact with the host. Then, the germs need to multiply in quantity in the host to some level that the germs become a threat to the health of the host. In this case, the host may feel ill or sick, and may even die. This description or mechanism of contracting disease is a simplified, idealized model which can be regarded as inside the theory (since we did not make any false assumption). Note that one may argue that bacteria which may be germs are cells. So, they can be subsumed under cell theory which has principles or tenets. However, some germs are not bacteria like viruses so that germs cannot be considered to be completely based on the cell theory. Hence, the germ theory is distinct from the cell theory and the germ theory cannot inherit the principles of the cell theory. The default principle can be applied here where the default principle states that the model in germ theory is an idealized, simplified, approximate and abstract description (or model) of the physical situation. Therefore, the germ theory can be thought of as a default-principle theory or constructive theory (without any principles apart from the default principle).

Initially, quantum mechanics can be thought of as a constructive theory of microscopic constituents and events. However, as a constructive theory it defies some common sense in (macroscopic everyday) mechanics like nonlocality interaction. Therefore, it was thought to be not very satisfactory, leading to many different interpretations of quantum mechanics. Instead of constructive theories, Clifton, Bub and Halvorson (CBH) (2003) formulated a principle theory for quantum mechanics based on information-theoretic constraints which are interpreted as principles by Van Camp (2011). Therefore, some scientific knowledge may start off with being a constructive theory and later a principle theory may be developed as in quantum mechanics.

4. Implications

Why are we interested in default-principle theories? What is the motivation to combine principle theories and constructive theories into one type? We have mentioned that our first motivation is to ensure the generality of the theory and model of scientific study by Luk (2010; 2017) to include constructive theories. Our second motivation is that eventually, it may be that all theories are principle theories (without the default principle) in science even though there is no guarantee to such an outcome. The reason why we may only have constructive theories at present is because we have not discovered the overarching principles yet since discovery of principles may take a long time when there are sufficient evidence, models or knowledge that warrant such a discovery. Therefore, the absence of principles does not mean that we have no principles forever for the domain of study. It may be that it has not been found yet. In fact, we should encourage scientists to discover these laws or principles for their subject to develop into a mature science discipline although sweeping generalizations should be avoided. By using the default-principle theory to include the constructive theory, we remind our scientists to look for principles or laws that are important in the domain of study. Our third motivation is to avoid the distinction between principle and constructive theories as it suggests that there are two fundamentally different types of theories where it suggests that one type cannot evolve into another type. For scientists, we actually want constructive theories to evolve into principle theories as general laws or principles are discovered that increases the generality of the scientific knowledge.

Flores (1999, 2000) has been indicating that principle theories has top-down explanations (Kitcher, 1989) and constructive theories have bottom-up explanations (Salmons, 1989).

With the existence of default-principle theory, does it lead to a top-down or bottom-up explanation? Note that the default principle has no explanatory power, so it would suggest that there is only bottom-up explanation for default principle theories. One point that needs to be clarified is that top-down explanation does not really start from the top. Instead, when constructing models to explain, it is bottom up. However, at some point of the model construction, the principles or laws are used, so this becomes a kind of top-down from the principles. Therefore, the top-down explanation is more akin to a hybrid type of explanation rather than purely top-down. Having said that, the default-principle theory may also be a hybrid involving top-down and bottom-up explanation. Instead of using principles, the default-principle theory can use theoretical assumptions or presuppositions to explain certain phenomenon. Therefore, it might be premature to suggest that constructive theories (or default-principle theories) only result in bottom-up explanations as there may be theoretical assumptions or other theoretical properties that the explanation may use to give an account of the concerned phenomenon.

In philosophy of physics, there has been some debate about the kinematics and dynamics in special relativity (Janssen, 2009), which was thought to be related to the dichotomy between principle theories and constructive theories as distinguished by Einstein. However, this debate is not very related to our discussion here because they are not focused on whether the theory has or not has principles. Instead, they may be more concerned whether the explanation (Felline, 2011) should stop at some principle (e.g., Lorentz invariance) (Frisch, 2011) or continue with more fundamental explanation based on dynamics (Brown, 2005; Brown and Pooley, 2006). Note that once the principles are formulated, the constructive theories would have some principles so that the constructive theories become principle theories because it is the principles that facilitate the model in the constructive theory to explain the observed phenomenon. For example, in the kinetic theory of gases, it is Newton's second law that derives the formula for kinetic energy which facilitates the derivation of the PV/T relationship. Ideally, we hope that the theory contains the mechanism or model to explain how the phenomenon comes about while at the same time the theory has the principles that facilitate the mechanism or model of the explanation, where the principles are general so that they can be applied to different situations or models to explain various phenomena. Since in this ideal situation, the theory has principles so it is a principle theory instead of a constructive theory. In the case of special relativity, it is not a matter of whether the explanation should be based on the principles or based on the dynamics. Instead, we hope for obtaining an ideal principle theory where the principles facilitate an explanation of the phenomenon based on dynamics so that on the one hand we have the mechanism (or model) to explain the phenomenon in special relativity and on the other hand we have the general principle that drives the mechanism (or model) of the explanation. At present, the philosophy of physics debate rests on the concern that the principle theory is based on kinematics rather than the dynamics to explain phenomena in special relativity. Some authors (notably Brown) found the kinematics explanation compared with the dynamics explanation unsatisfactory, and therefore the issue is not directly concerned with whether principle theory or constructive theory should prevail. In summary, Brown may be satisfied with a principle theory or a constructive theory provided dynamics is used to explain the special relativity phenomenon, and that is why the debate in philosophy of physics is not really relevant here.

Luk (2010) suggested that mature science needs to have all the elements of theory, model, experiment and physical situation together with some linkage between them. For a default-principle theory, it does not have any other principles to be applied, so that the theory and the model outside the theory are not linked together. Therefore, a discipline that has a default-principle theory without any linkage to the detailed model outside the theory cannot be considered as a mature science. To claim the discipline as a mature science, some kind of linkage must exist between the theory and the model. Therefore, a discipline that has a default-principle theory with a (generalized) model (inside the theory), which is specialized into a detailed model outside the theory can be considered as a mature science. This is because the default-principle theory has some content in the theory to claim it has some substance (i.e., the model in the theory), and the default-principle theory can be connected to the detailed model outside the theory. Therefore, a mature science may have a default-principle theory with a (generalized) model in the theory. For a default-principle theory, note that mature science must also have detailed models outside the theory, which are subsumed under the same (generalized) model in the theory. Without any detailed models outside the theory, there would not be any model (outside the theory), and so the discipline with a default-principle theory cannot claim to be a mature science like physics.

5. Conclusion

We proposed the default principle as a principle for a special type of principle theories. A default-principle theory with a (generalized) model inside the theory is the same as a constructive theory. However, the (generalized) model in the theory has the requirement that it does not make (simplifying) assumptions that are believed to be false so that the entire theory may be believed to be true. Instead of using the distinct term, constructive theory, we consider that the default-principle theory as a special type of principle theory so that we encourage scientists to discover laws or principles later to make the default-principle theory into a theory with concrete principles, because such laws and principles are highly valued by scientists as they can be applied across many different situations and therefore are important properties to know. By subsuming the constructive theory under principle theory, we have rescued the theory and model of scientific study by Luk (2010, 2017) from incompleteness.

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