

OPINION PIECE

The interplay between physics and philosophy in undergraduate education

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Recommended citation:

Chan, S. C. (2014). The interplay between physics and philosophy in undergraduate education. *Journal of the NUS Teaching Academy*, 4(1), 18-26.

<https://doi.org/10.24112/ajsotl.43302>

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INTRODUCTION

Many friends, who read physics and philosophy at university, often recount a popular question asked of them, when colleagues learn about their academic background, “How are physics and philosophy linked? Are they not, of themselves, intellectual silos?” Physics, as the most fundamental of the sciences, is concerned with understanding the nature of reality. Philosophy, as the most rigorous of the arts, is concerned with understanding our knowledge of this reality. Casual pub conversations with university friends indicate that many may be sceptical about whether there can be significant interplay between the two bodies of knowledge, let alone how there can be connections between physics and philosophy as part of undergraduate education.

Elsewhere in this edition of *JNUSTA*, Professor A. J. Leggett makes two observations which motivate the links between physics and philosophy. This is the starting point of this essay. Leggett maintains that these links are present at two levels. The first level views physics and philosophy as two different bodies of knowledge. He notes that “many of the really fundamental issues in physics long predate what most of us would call ‘modern’ (i.e., post-16th century) science”. These issues include questions about the nature of mass or motion, which still remain open, even with the advent of general relativity and quantum mechanics. This suggests that there are considerable historical links in the motivations for physics and philosophical inquiry. Having said this, I believe that it is necessary to draw a distinction between the various fields of philosophy, i.e. between those which involve substantial interaction with physics, and those which do not. The sub-disciplines in philosophy are manifold: logic, metaphysics, continental philosophy topics (e.g. existentialism), philosophy of science, philosophy of mathematics, philosophy of cognitive science, and ethics. In this commentary, I will be concerned with only two main areas which interact significantly with physics: the philosophy of physics, and the philosophy of science.

The second level is that of academics who are able to competently bridge physics and philosophy. Leggett points out that, in the past, “few (philosophers), if any, would have been able to argue toe-to-toe with professional physicists about e.g. the issues raised by Bell’s theorem”. This situation has now been changed, with major research and teaching groups at the University of Oxford (beginning in the early 1960s), Princeton University and the University of Pittsburgh, having

“professional philosophers of physics”, who have post-doctoral physics research backgrounds and have read philosophy as well

In subsequent sections, my broad aim is two-fold. First, I explicitly flesh out the link between physics and philosophy in two contexts, the first of academic debate between physics and philosophy, in terms of how one body of knowledge informs the other, and the second, the context of how an undergraduate education, jointly in physics and philosophy (with equal importance placed on both subjects), leads an undergraduate to naturally make connections.

Having made this link clear, I then turn to my second aim: to state the impact of such interactions between these two subjects on the undergraduate at the end of four years of study, whether they choose to go into academia or otherwise. Given the highly intellectual nature of an undergraduate programme in physics and philosophy, it is important to also argue for the possible benefits of such a programme, for those who might choose non-academic career paths. In closing, I conclude with some thoughts and caveats about the ingredients essential to the Oxford Master of Physics and Philosophy programme¹.

MOTIVATION FOR THE INTERPLAY BETWEEN PHYSICS AND PHILOSOPHY

How is there interplay between physics and philosophy? Where does physics end, and philosophy begin? True, physics and philosophy might take fundamentally different academic approaches to analysing an issue – the physicist today analyses problems with (minimally) the conceptual and mathematical tools of relativistic and quantum-mechanical paradigms, the philosopher (assuming at minimum an undergraduate background in physics) analyses problems from the point of view of how the starting premises and first principles of a scientific theory yield consistency with experimental results, and whether there are other viable models which can successfully accommodate the phenomena. However, this does not immediately suggest that one approach is distinct from, or even superior, to the other. I want to advance the claim that there is no clean distinction between physics and philosophy, if our aim as academics is to study ideas and puzzles for their own sake, motivated by our intellectual curiosity about the nature of the world around us. Instead, we should view physics and philosophy as being different, but having *complementary* ways and priorities in which they frame and analyse an issue (i.e. they have different *means*) in order to gain better clarity on issues in physics (i.e. they share similar *ends*).

¹ University of Oxford. (2013). Admissions – undergraduate courses – physics and philosophy (online). Retrieved July 15, 2013, from http://www.ox.ac.uk/admissions/undergraduate_courses/courses/physics_and_philosophy/physics_and_philosophy.html

I remember a lecture as part of a physics second-year quantum mechanics course. The “Measurement Problem” often does not occupy much space in a university-level quantum mechanics course (or a textbook), since it is often deemed to be too “philosophical” in nature. This lecturer devoted a good ten minutes to discussing its significance, and later spent an entire tutorial attempting to nail down a very clear line of thought on the issue. To our surprise, his seriousness about the concept was an outgrowth of his willing enthusiasm to take physics concepts seriously, and think about them from first principles. As a physicist, he was not the least dismissive of these supposedly abstruse “philosophical” concerns.

The basic idea of the “Problem” is as follows: in quantum mechanics, the quantum state is taken to completely specify all the properties of a system at a given time. The quantum state can be described as a *superposition* of different states.

In the absence of measurement, quantum states evolve according to a deterministic equation (the Time Dependent Schrodinger Equation) which specifies exactly the quantum state at some future time. However, when we make a measurement of a quantum state, the outcome quantum state does not evolve according to this equation. What seems to be a *brute fact* of nature is that the resultant state is only *one* of the states in the superposition. Moreover, we do not know in advance which of the states will result – we only know the *likelihood* of whether the state will result.

All this will not seem to be a problem for the physicist, especially if his or her goal is to “shut up and calculate”, whilst solving lofty quantum mechanical problems. This, though, is where the physicist and philosopher of physics embark on different trajectories. The philosophical concerns now come into the picture. In order for the theory of quantum mechanics to obtain, physicists may appear to be forced to make certain assumptions about the “*brute facts*” of the process and outcome of measurement. Why should we be justified in accepting that the apparent brute fact that the evolution of the quantum state according to the Schrodinger equation is suspended during measurement? There seems to be no sufficiently convincing underlying answer to this fact of nature. In addition, if we accept, for the sake of argument, that there are two incompatible evolutions of the quantum state (in the presence of measurement, and without measurement) at the micro-level, why is it the case that we do not observe the phenomenon of superposition at the everyday, classical macro-level of cars, donkeys and skyscrapers? This, in turn, leads us to ask if there is at a certain point, a distinction between the processes governing the evolution of quantum states at the micro level as opposed to the macro level.

These are the starting concerns which motivate the work of philosophers of physics. While some physicists frame the issue of measurement as a “side” concern, there are also other physicists (particularly those working in the foundations of physics) who take these questions seriously because they cherish the ideas for their own sake. Oxford has many physicists who are keen on philosophical concerns. There are those who are dismissive of the need to dive into these concerns – “Get real! You do not need to solve these problems in order to get a set of experimental results!” they argue.

It would be prudent to guard against making such a quick move. At heart, the *ends* of research, for both the physicist and philosopher of physics, are similar (but not necessarily the same) – both aim to attain greater clarity about our knowledge of the world. What differs, then, are the *means* of attaining the ends. For instance, in seeking to resolve the Measurement Problem, the physicist’s line of attack might be to turn to competing theories to see which theory might give results which agree with experimental data at the micro-level and everyday macro-level. The philosopher of physics, however, would first disambiguate what is meant by “The Measurement Problem” in different contexts, then get a clear grip on how the theory might be incompatible with phenomena, compare rival theories, weigh the principles and assumptions which have to be given up if one theory (e.g. the de Broglie Bohm pilot wave theory) is to be favoured over another. Finally, the philosopher of physics nails down the clearest line of thought about how to reason about a particular physics issue.

So, physics and philosophy should be taken to be complementary sides of the same coin. Both might agree on the central problems of the day which have to be resolved, but differ in their approaches. The philosophers are more likely to be interested in the foundational issues and sensitive to the weight given to key premises and logical consistency in the arguments for a certain scientific idea. The physicists, on the other hand, are keen on the consistency between theories and experimental outcomes, and (experimental physicists) emphasise the rigour in the assumptions which undergird experimental outcomes.

Taken together, this means that there are advantages to both lines of inquiry, and the links between physics and philosophy exist in how they might mutually inform each other as they investigate similar issues in physics from different angles of attack. This sets us up nicely for the next issue – how might undergraduates, as part of their education, gain a foothold into this top-level debate between physicists and philosophers, and in doing so, naturally make the connections between physics and philosophy?

THE OXFORD UNDERGRADUATE’S PERSPECTIVE

The first step is to grasp the key concepts of both physics and philosophy in undergraduate studies – there is no escape. Before a fruitful conversation between physics and philosophy can take place, the building blocks of mathematical and philosophical reasoning must be in place. Crucially, undergraduates are expected to be no less competent than their pure physics (or pure mathematics) counterparts in numerical reasoning, and as fluent and critical in argumentation as their peers reading politics, philosophy and economics (PPE). The compulsory first third of the course (Year ¹ and a part of Year ²) is focused on the fundamentals. For instance, in the first year, from the physics side of the house: linear algebra, calculus and waves, mechanics and special relativity. From the philosophy side of the house: elements of deductive logic, introduction to philosophy (general philosophy and the Leibniz-Clarke correspondence).

The second step is the progressive introduction of papers which bridge the divide between physics and philosophy. The key here is that each paper must not attempt to sacrifice depth and rigour in discussing an issue in physics for breadth. So, each paper is taught over eight tutorials with a particular issue taking centre-stage in each, and an essay (about ²⁰⁰⁰⁻²⁵⁰⁰ words) written to serve as the “vehicle” for the tutorial discussion. In the first year (where the physics fundamentals are still being acquired), the paper which fulfils this role is the Leibniz-Clarke correspondence, a series of discussions on the nature of space and time between Leibniz and Samuel Clarke (who represented Newton’s intellectual position) in the ¹⁷th century. In the second and third years, the papers taken are philosophy of science, philosophy of special relativity and the philosophy of quantum mechanics. A good portion of the modern assumptions in special relativity build upon the ¹⁷th century ideas of Leibniz and Newton. This is in agreement with Leggett’s claim that a good part of modern physics has historical origins tied up in philosophical ideas.

Much has been written, and critiqued, on the merits and pitfalls of a tutorial-style system of education, so I will not delve into these issues here. However, I make two observations in passing about the difference between these philosophy of physics tutorials and traditional philosophy tutorials in Oxford. I then link this to how it encourages the undergraduate to make connections between physics and philosophy. First, because of the intent of not sacrificing accuracy and rigour of physics in philosophical discussions, a considerable amount of time in the tutorial is often spent getting a grip on two things: derivations of theorems and key conclusions, and breaking the derivation down to its bare essentials to think clearly about the assumptions made at each step. For

instance, one tutorial aimed to achieve the clearest and most rigorous derivation of the Lorentz transformations in special relativity. In addition to taking apart Einstein's original ¹⁹⁰⁵ paper "On the Electrodynamics of Moving Bodies", the tutor drove the discussion forward by making us think from first principles about the assumptions needed at each point of the derivation (e.g. whether one of Einstein's two starting postulates carried more import than the other, or whether there was a sound clock-synchrony convention set up in order to compare events in two reference frames). Having worked through in detail all the steps of Einstein's derivation, the next task was to re-construct a "clean" version of the derivation from first principles, with as minimal philosophically-loaded assumptions as possible. This exercise was highly instructive in integrating physics and philosophy. The concepts studied are physical concepts since they span classical electrodynamics and special relativity, but the issues attacked from the angle of: how can we *know* that one step leads logically to the next, and if so does the step *actually* lead to the next? What is the main mechanism or step doing the significant work in the derivation? Undergraduates thus make the link between physics and philosophy by acquiring a nuanced grasp of physical concepts (and not mere "knowledge" in the sense of mastering a rigorous proof and knowing to apply the results in different contexts), the confidence to relate mathematical concepts to physical ideas and then translating these ideas to logical arguments (and vice versa).

The second observation is that the tutorials strengthen the joint understanding of physical concepts and philosophical ideas by *learning, un-learning and re-learning*. Often, a working understanding of a concept is picked up through the main physics lectures (which tend to precede the philosophy of physics tutorials). The concept is then reinforced through physics tutorials and laboratory practical sessions. However, upon first contact with philosophical papers on the concept (as many as ten papers can be on the reading list for a single essay topic), the undergraduate often realises that he or she has only mastered some elements of the concept from the numerical and analytical perspective, and missed out on the key assumptions involved in the derivation. The sudden realisation that the apparent "understanding" of the concept is but some level of *hand-waving* hits hard, and forces him or her to re-evaluate the concept from the philosophical lens (unlearning), before attempting to reconcile the different, but complementary ways of thinking about the issue from a unified philosophy of physics perspective (re-learning). Admittedly, the process of destroying the initial mental model is often arduous, but the final result of re-learning is highly intellectually rewarding, in seeing the emerging connections between physics and philosophy.

TAKEAWAYS AT THE END OF FOUR YEARS

What is the overall value of such a background in physics and philosophy, even if the graduate does not go on to a career in academia? I assert that there are at least two main outcomes which are valuable: first, the ability to switch effectively between numerical analysis and qualitative argumentation; and second, the skill to quickly get up to speed on unfamiliar concepts by learning from first principles.

The first is the lowest-hanging fruit which follows from years of reading physics and philosophy on equal footing, and from the intellectual motivation to study an idea for what it is worth – instead of seeing physics and philosophy as wholly-separate and irreconcilable fields. Clearly, for those interested in entering the fields of government, finance and banking or non-governmental social organisations, the analytical abilities will be of use in understanding the abstract and numerical aspects of an issue (e.g. numerical statistics and performance indicators of whether a particular financial programme is more successful than rival programmes), and translating these ideas clearly into the black-and-white medium, and making a watertight presentation of the analysis, as part of the duties of a competent staff officer.

The second relates to having the confidence to rapidly pick up an unfamiliar concept through thinking for oneself how, exactly, to analyse an issue. Often, we feel uncomfortable when learning a new concept because the terms and ideas seem unfamiliar. So, there is a natural tendency to respond by saying, “I have not taken a course in this topic” or “I have not been trained to do this”. Due to the steep learning curve of the philosophy of physics tutorial topics, there is no opportunity to hunker down when confronted with an unfamiliar concept. Here is an example. At first sight, the physics concepts seem entirely familiar after having been discussed in the context of physics lectures (e.g. the concept of “entropy”). Later, the sense of unfamiliarity creeps in when the concept is analysed from the philosophical angle (e.g. is the concept of “entropy” achieved from a principle-based approach of thermodynamics, or a bottom-up constructivist approach of statistical mechanics, and how do the two relate to each other). However, there is no way to back down from this sense of unfamiliarity – there are no lectures or books which present a clear view of the “textbook-correct” approach to thinking about these issues. The undergraduate is free to develop his or her own clear and rigorous line of attack on the issue. This can be extremely discomfiting at first. Fresh from the A-level examination system in Singapore (which indirectly incentivises an appeal to so-called “definitive” sources of intellectual authority), undergraduates may tend to assume that there is a “standard” set of approaches to thinking about

an issue, instead of thinking from first principles for *ourselves* about how we would think about an issue. After three years of doing so on a weekly basis for each new tutorial topic, the mode of thinking becomes natural and this rapidly increases the undergraduate's confidence in thinking from first principles.

FINAL THOUGHTS

In closing, two caveats about the Master of Physics and Philosophy programme should be made. First, to take full advantage of the specialised nature of the programme, there must be significant initiative on the part of the undergraduate. The specialised structure of the programme (with reviews of the course content carried out nearly every year) is conducive for undergraduates who want to make connections between physics and philosophy, but ultimately the actual learning *has to be done* solely by the undergraduate him- or herself. In the first two years, there can be no substitute for the dogged persistence of getting up to speed with the demanding academic requirements of the course, before being able to make the connections across physics and philosophy. In fact, a tutor once remarked to a friend that “You should have been mentally prepared for this – this is not for the faint of heart!”

Second, the programme is resource-intensive, on the part of the university. There is a formal system of instruction (tutorials, seminars and lectures) and examinations which complements the informal, self-driven means of study. What the university provides is a near-complete collection of books in the specialised fields of philosophy of physics and philosophy of science, and teaching-learning assignments with tutors who are subject-matter experts who are at least post-doctoral researchers.

Overall, I have argued that it is possible to build links between physics and philosophy in the contexts of academic debate as well as undergraduate education. The links are motivated by the observation that physics and philosophy are not necessarily distinct and separate disciplines; instead, we should be encouraged to view them as complementary lines of inquiry (the *means*) in understanding physics issues and concepts *for what they are* (the *end*).