A Travel Guide for Physics

Jakob Schwichtenberg[a,1],

Abstract

We introduce an expository physics wiki which publishes explanations at different levels of abstraction. The primary goal is to put great explanations into the spotlight and to make it easier for students, researchers and laypersons alike to find helpful resources. The Physics Travel Guide is a novel learning medium which can augment traditional ones like textbooks and lectures. In particular, it is ideally suited for self-directed learning following a non-linear (spiral) learning philosophy. The wiki can be edited by anyone and a first version is available online at `www.physicstravelguide.com`.

[1]E-mail: `jakobschwich@gmail.com`

1 Introduction

In his lectures on Finance theory in the Fall of 2008, Andrew Lo told the following story [1]

"[Y]ou're going to have to focus on two concepts that are probably alien to you. The notion of a stock and a flow. Now when I say stock, I don't mean common stock or equities, I have a different term in mind. By stock in this context, I mean the stock of assets. The level of assets. And by flow I mean the rate of change of assets. You know when I was in grad school, we started discussing this concept on the first day of macroeconomics, and then one of the students in the back of the room said, excuse me, Professor, but isn't that just the distinction between a variable and its first derivative? And the professor was a little bit taken aback and said, well, yes, that's right. But let me give you another way of thinking about it that is somewhat more intuitive. And that is, think about a bathtub, and think about the faucet turned on and the water flowing into it. The stock is the level of the water. The flow is how fast the water is coming into the tub. And so after that explanation the student still seemed confused, and so the professor said, you know what, some people find bathtubs intuitive, other people find derivatives intuitive. So to each his own."

What this little anecdote nicely exemplifies is that everyone possesses a unique combination of knowledge, experiences and interests. As result, there are huge differences in what kind of explanation different people find illuminating. For example, it is common that someone with years of experience in a field prefers rather abstract arguments, while beginners often find intuitive analogies more helpful.[2] But, as described in the anecdote quoted above, sometimes it's the other way round.

Unfortunately, this aspect of learning is rarely acknowledged. In lectures and textbooks, all students are expected to understand a given concept through the same single explanation. This is understandable because the time in lectures and the pages in books are strictly limited resources. But it also means that only a subset of the students will be able to understand the given explanation [3]. Many students will be left behind and feel frustrated.

Another shortcoming of traditional teaching methods and resources is that they are based on the assumption that students are able to learn a topic by following a linear narrative. However, subjects as complex as physics cannot be mastered in some monotonic order. Instead, the same concepts must be revisited over and over again at various stages of the learning process. In addition, a linear approach is extremely fragile. If a student fails to understand a single key idea, he/she will not be able to follow the remaining line of arguments. Moreover, a linear narrative makes it far too easy for students to lose sight of the bigger picture and to miss many important connections.[3]

But all this is neither the teacher's, nor the student's fault. Even the best teacher will not be able to find an explanation that everyone will understand. And even the best student (whatever that means) will not be able to understand a concept, if the given explanation is not a good fit for his/her unique knowledge, experiences and interests. Instead, the real cause of the problems outlined above lies in the very nature of the learning mediums used. The goal of this paper is to discuss a new tool called the Physics Travel Guide, which augments existing learning mediums and can help students to learn more effectively.

[2] This often leads to problems when experts try to explain concepts to beginners. This phenomenon is known as the 'curse of knowledge' [2].

[3] Similar arguments apply to many other fields. But here we will restrict ourselves to physics, because this is the field I'm most familiar with.

2 The Physics Travel Guide

The Physics Travel Guide is an *expository wiki* which was created to make it is easy to:

- Find explanations at different levels of abstraction.
- Learn topics non-linearly.[4]
- Understand the big picture and the connections between different concepts.

However, the goal is not to create yet another online encyclopedia. The goal of an encyclopedia is to collect facts. In contrast, the goal of the Physics Travel Guide is to move past dry facts and share the Aha! moments which make learning memorable and fun

This is accomplished through the following key features:

- Each page explains the topic at hand in three levels of abstraction. These levels are called *intuitive*, *concrete* and *abstract*.[5] Moreover, each page emphasizes why the given topic is interesting and how it fits into the bigger picture.
- Internal links make it easy to jump between related concepts.
- Everyone can contribute. This is essential because it is important to capture as many perspectives as possible in order to provide appropriate explanations for different kinds of learners.
- The objective of each individual topic page is twofold. One goal is to collect resources (textbooks, lectures, published online notes, papers) which explain the topic particularly well and label these resources as *intuitive*, *concrete* or *abstract*. For most topics great explanations already exist. But often these are incredibly hard to find and hidden in old textbooks or papers buried somewhere on the arXiv.

  So in other words, one goal of the travel guide is to help that great explanations get the attention they deserve.[6]

  A second goal is to be a platform for new illuminating explanations. By sorting the existing explanations using the labels mentioned above, it becomes obvious which explanations are still missing.[7]

Below are a few concrete examples how the three levels of abstraction can look like in practice.

[4]Concretely, it allows anyone to learn physics following a self-directed spiral philosophy. For a great essay on the spiral approach to learning, see `https://www.av8n.com/physics/spiral-approach.htm`

[5]We will discuss concrete examples below.

[6]In contrast, for example, Wikipedia's goal is to collect references to the standard textbooks and original papers. But these are certainly not always the best resources to learn about a given concept.

[7]Formulated more abstractly, the goal of the individual topic pages is to minimize *research debt*, c.f. Ref [4].

2.1 Examples

- **Lagrangian Formalism**
  - *Intuitive:* Nature is lazy. Rescue swimmer example.
  - *Concrete:* $L = T - V$, Euler-Lagrange equation.
  - *Abstract:* Sections of the tangent bundle.
- **Quantum Anomalies**
  - *Intuitive:* Fermions get lifted up from the Dirac sea in the presence of gauge fields.
  - *Concrete:* Axial anomaly, triangle Feynman diagram.
  - *Abstract:* Cocycles and index theorems.
- **Special Relativity**
  - *Intuitive:* Train thought experiment. Time dilation, length contraction.
  - *Concrete:* Light clocks, Minkowski metric and four-vectors.
  - *Abstract:* Poincare and Lorentz group.
- **Higgs Mechanism**
  - *Intuitive:* Cocktail party analogy.
  - *Concrete:* Vacuum expectation value, Higgs potential minimization.
  - *Abstract:* Vacuum manifolds, cosets.

3 Implementation

A concrete implementation of the ideas outlined above based on the open source software DokuWiki (`www.dokuwiki.org`) is available online at `www.physicstravelguide.com`

- All original content is published under the CC Attribution-Share Alike 4.0 International licence (`http://creativecommons.org/licenses/by-sa/4.0`).
- Previous version of pages can be viewed and restored at any time.
- The names of all contributing authors are listed at the bottom of each page.
- Topic pages are organized in categories like: Formalisms, Theories, Speculative Theories, Models, Equations, Experiments, Formulas, Theorems, Basic Tools, Advanced Tools, Basic Notions, Advanced Notions, Open Problems and Branches.
- As of January 30, 2019
  - 14.631 users have visited and spent, on average, 2m 19s on the site.
  - 355 users have signed up.
  - 340 topics pages have been created on general topics like the Lagrangian Formalism but also more specialized concepts like Duality, the Pendulum or Gauge Symmetry. (However, naturally many pages created so-far are stubs.)

A FAQ

Why was the name Physics Travel Guide chosen?

Travel guides allow travelers with different budgets and interests to find suitable restaurants, accommodations and sights. Moreover, they provide context, explain why certain sights and restaurants are interesting and allow them to explore a city or country on their own terms. In this analogy, traditional teaching mediums are like guided bus tours.

Who is it for?

The Physics Travel Guide was created to lower the entry barrier to technical topics for laypersons, students and researchers alike. Specifically, it is a tool for:

- Students who prefer to learn at their own pace and want to know more than what is taught in the lectures.
- Lecturers and teachers who want to find inspiration and get ideas on how to explain specific concepts differently.
- Researchers who want to learn technical topics more quickly.
- Interested laypersons who want to understand the main ideas behind abstract concepts.

Who can contribute?

The Physics Travel Guide is currently not complete and never will be. But everyone can help to make the current gaps smaller.

- Beginners can add helpful analogies and beginner-friendly references to the *intuitive* section of topic pages.
- Students with some understanding of the underlying mathematics, can contribute to the *concrete* sections.
- Experts can help to get rid of misunderstandings and add rigorous statements to the *abstract* sections.

But, of course, it's equally possible that experts contribute intuitive explanations and that students add technical arguments to the *abstract* sections. In any case, each contribution (even if it is only a link to a helpful explanation elsewhere) potentially helps hundreds of students.

In contrast, most Wikipedia pages at a mature stage consist of rigorous and abstract paragraphs which are only edited further by experts.[8]

[8] While non-experts can edit these pages, usually their changes get deleted quickly. This is not a bad thing per se, but simply a result of Wikipedia's goal to be an online encyclopedia.

References

[1] A. Lo, *15.401 Finance Theory I* (Massachusetts Institute of Technology, Fall 2008).

[2] J. Froyd and J. Layne, Faculty development strategies for overcoming the curse of knowledge, in *2008 38th Annual Frontiers in Education Conference*, pp. S4D–13–S4D–16, 2008.

[3] S. Freeman *et al.*, Proceedings of the National Academy of Sciences **111**, 8410 (2014), https://www.pnas.org/content/111/23/8410.full.pdf.

[4] C. Olah and S. Carter, Distill (2017), https://distill.pub/2017/research-debt.