Preface (Volume 2)

"Only the student knows."
Edwin Taylor[1]

With the resounding popularity of what is now Volume 1 of *Student Friendly Quantum Field Theory*, subtitled *Basic Principles and QED*, came a flurry of fervent requests from students to write a second volume on the weak and strong interactions. This book is the response to those requests.

As with Vol. 1, I do things in this book that no other texts I am aware of do. For but one example among many from Vol. 1, Chap. 3 therein shows the explicit, far from trivial, derivation from the quantization postulates of the coefficient commutation relations, which form the very foundation of the entire theory of quantum fields. Yet, such a derivation does not seem to be presented elsewhere, and students are typically informed that "it can be shown", asked to do the derivation themselves in their spare time, or told it is simply a postulate of the theory.

In this Vol. 2, there are more such things – things that seem to have gone missing from many presentations of the theory. Chap. 5 herein, for example, presents the explicit transformations between the three most common gamma matrix representations, which otherwise seem to be very hard to find in the literature. Chap. 6 delineates, step-by-step, how every term in the electroweak Lagrangian transforms to make that Lagrangian symmetric under $SU(2)\times U(1)$. In Chap. 7, every term in the low energy Lagrangian is derived from the terms in the high energy Lagrangian. Chap. 9 deduces the four electroweak four-currents and their corresponding charge operators, then explains why two of those operators are taken as zero. Chap. 9 also takes over twenty pages to explain and develop charge, parity, and time transformations in depth, and provides a one page wholeness chart summary (pg. 342) of all relevant terms and their transformations under *C,P*, and *T*. And there is more, much more, you will not find in other texts.

In the Preface of Vol. 1, I listed some of the pedagogic principles I employ in that and this book. In this preface, I add a few more below, which should have been included in that list. After that, I discuss the effort, frustration, and time consumption involved in extirpating errata. And finally, I close with a bit of personal philosophical musings on the teaching of science, engineering, and mathematics.

Pedagogic Principles Employed

As a brief review, in Vol. 1, I enumerated the following of my teaching philosophy basic tenets: avoidance of brevity, holistic previews, wholeness chart overviews, reviews of background material, sticking to basic concepts without peripheral tangents, minimal time/maximal learning problems, small-step by small-step derivations, liberal use of concrete examples, margin overview notes, key equations highlighted in boxes, fundamental definitions underlined, and shunning of debilitating terms like "trivial", "obvious", etc. In that volume and this, I also use several more, as delineated below.

Bottom line summaries

After detailed treatment of a subtopic within a chapter, students, even those who followed every step, all too often wonder "Now, what exactly did we just do? What is the meaning and final result of all this?". I answer this question for them with clearly marked "Bottom Line" (underlined and/or bold face) paragraphs at the end of many presentations within chapters.

Under and over brackets in equations

In going through line after line of equations, where former equations are plugged in and many manipulations occur, I use brackets above and/or below parts of those equations indicating what those parts are equivalent to. See, for example, Chap. 5, equations (5-33) and (5-35). I have found this can save students a lot of time and eliminate confusion.

Numbering terms in equations with many terms

Sometimes, evaluations of relations entail a large number of terms in a given line, followed by re-arranging and combining of such terms in subsequent lines, where keeping track of which terms go where can be challenging. To help in keeping things straight in such cases, I put a number or letter, enclosed in a box above or below each term, and keep that boxed number/letter with the term in subsequent lines, as the derivation proceeds. See Chap. 6, (6-157) to (6-160), as one such example. This simple procedure helps one keep tabs on which terms go where, and can save considerable time, as well as frustration.

Simple, sometimes imprecise, preliminary expositions

On occasion, in introducing new, mentally challenging concepts, I present things in a manner that may not be exactly correct, but is easier to understand. This allows the new learner to get a feeling for what is going on, without becoming bewildered by a fully precise, and thus far more complex, rendition of the topic. By seeing it for the first time in this manner, the student gains a sense of where we are headed, what the ultimate objective is, its importance, and how it fits into the overall structure of knowledge we are in the process of exploring. We then generally avoid the common "what in blazes is going on?" student syndrome.

[1] E. F. Taylor, Guest comment: Only the student knows, *Am. J. Phys.* **60**(3), March 1992, 201-202.

After we cover enough ground for students to become more comfortable with the theory and concepts involved, I either then point out the imprecisions in our earlier introduction, or I assign a problem asking them to determine those imprecisions themselves. The final result is close alignment of student understanding with the precise essence of the theory.

One example of this is the introduction to transition amplitudes in Chap. 1 of Vol. 1. The presentation is simple, but not (as noted clearly there) completely correct. Had it been, virtually no students would have understood it. In Chap. 8, 252 pages later, when students have covered the necessary ground to truly understand transition amplitudes, they get a problem asking them to detail the imperfections of the original introduction.

I realize many lecturers will take issue with this approach and consider it unsuitable, even though it is little different from using analogies, which are inherently imperfect and thus, incorrect, but whose use, nonetheless, is widely recognized as a valuable teaching aid.

In practice, I have found this method greatly helps students reach the goal line faster, and with deeper comprehension. Feedback from students has been ample in this regard.

Errata

Errata are the bane of every author, each of whom learns, with her/his first book, how insidious and ubiquitous they are, and how excruciatingly difficult and time consuming they are to eliminate.

This book, for instance, has on the order of two million characters in it. If I were 99.9% accurate, that would still leave two thousand or so errors.

Editors, reviewers, and readers in substantial number can proof read a book and detect many errata, but later readers always seem to come up with more. One seasoned editor told me that she was continually amazed by how many typos slip through the cracks of repeated edits, by skilled editors.

The late and truly great theorist Joe Polchinski noted, in his memoirs, that when planning his now famous string theory text, he vowed to have zero errata. He ended up with over 400. For Vol. 1 of *Student Friendly Quantum Field Theory*, I also had hundreds, and estimate I spent several hundred hours correcting them (plus several hundred more revising portions to make them clearer and easier to understand).

So, if you the reader feel frustrated with the number of corrections posted on the website for this book or those in other books, please think kindly of us authors. Our frustration much exceeds yours. We and our teams of editors/reviewers are doing our best. Our very, very best, in spite of how it might seem to the uninitiated.

Problems with "The System" of Present-Day Science and Technology Education

Problems I see inherent in physics/math/engineering education, as presently structured, are these.

1. Professors and teaching assistants spend 50% of their time teaching, yet zero percent of their training was on how to do so. Very few have taken even an afternoon seminar on teaching itself, let alone an actual course in it. Doesn't this seem strange? Doesn't it seem conducive to poor quality teaching?

2. Communication skills of technically trained people tend, on average, to be inferior to those of their liberal arts leaning brethren, and teaching, if it involves anything, involves communication.

3. Those who become professors, those who teach and write the textbooks, were typically the very brightest students, who had far less trouble with the extant texts and teaching skill level of their instructors. So, they are less likely to understand problems the more typical student encounters, and more likely to simply parrot the modes of teaching they themselves encountered as students.

4. After years of working in a subject area, one becomes so familiar with it, and it seems so obviously true, that it can be difficult to understand what exactly it is that new learners could have a difficult time with.

5. Material is almost invariably presented at such a fast pace that few, if any, students completely understand all of it. And since later subject matter is structured upon the foundation of prior subject matter, this leads to holes in that foundation. I call this the "Swiss cheese" model of education. I think almost all of us have had the experience, hours, days, months, or even years later, of thinking "Oh, now I see what that meant." Surely, it would be better if that hole had been plugged the first time around. And just as surely, an educational system that left fewer such holes would be better. Should we educators not be asking ourselves if there is any way we can move in the direction of such a system?

Suggestions for Improving "The System"

The solution I propose is simple.

1) Require university instructors to take courses in teaching, particularly of technical subjects,

2) have them solicit, and listen open mindedly to, student feedback on how to best present material, and

3) have them study and emulate the teaching methods of others whose methods students have responded to enthusiastically.

Granted, this would require a fair degree of instructor humility. But, I submit, the rewards, such as higher grades, student expressions of gratitude, and fewer conceptual holes in each student's knowledge base, would provide a sense of fulfillment for teachers that would be hard to beat.

Pedagogic Philosophy

My high school football coach was fond of saying "defense is 90% desire". So, I suggest, is good teaching. Desiring to help students means putting in the time to learn what we, as educators, can do to help them learn better and more efficiently. A major part of that is soliciting feedback from them. Have them tell us how we should present the material.

In doing this myself, I've learned quite a number of things. The two most important, I believe, are these.

First, show them, at the start, an overview of what we are doing, where we are headed, and how it fits into the overall framework of their studies. And return to this theme after they have covered a given section of material. Don't let them flounder in the "what is going on?" wasteland. Begin with a bird's eye roadmap view, then present the details, then finish with the bird's eye view again, in somewhat greater depth. Tell them what they are going to cover, then cover it, then tell them again what they just covered.

Second, put every little step in derivations and analyses. I, personally, have, cumulatively, wasted untold hours trying to see how an author/teacher got from one line to the next. Many times, in formally working things out myself, I found the missing steps were numerous, at times extending even to two or three pages. This, I submit, is not how the learning process should go.

Those who study education as a life's work have long known that learning comes fastest in the smallest bites. Yet, this lesson seems to have made it into few STEM educational circles. I sincerely hope it starts making greater inroads soon.

So, in general, as I noted in the preface of Vol. 1, I'd rather have readers spending their study hours learning new material than squandering it trying to figure out where they got the wrong sign or incorrect factor of two in some routine, but time devouring, algebraic marathon. That is why, in these volumes, I do pedagogically fruitless things like this for the reader, step-by-step. I do this because it saves time, and I consider efficiency in learning the name of the game.

Yet, I've been criticized by field theory experts for being too simple. But, as I said in Vol. 1, the proof is in the pudding. In 150 or so messages from students sent to me (see the book website) or posted on Amazon, all praised the clarity of Vol. 1, and not one felt it was beneath them. Can we not let the new students judge pedagogy, and let the critics form judgements based on what they have to say. "The student knows", as Edwin Taylor has advised us.

He also said "Why not ask, then learn ourselves – from the only person who can teach us." The students can make our texts and classroom teaching better, if we will only listen. Since I began writing Vol. 1, I have actively solicited help from students on how best to present material to them. And I have listened. My books are virtually co-written by numerous student contributors. Vol. 1 has been revised four times in eight years, all such revisions (plus the original) incorporating extensive input from new learners.

And is it not a general practice among successful companies to solicit advice from their customers on how to improve their product or service? And does not that solicitation lead to more success for the company and more satisfaction for the customer? Why should we not do the same?

It is very, very hard for seasoned practitioners in a field to present material in a way that is too simple and too easy for students. It is very, very easy to make it too difficult. As educators, we should strive to err on the side of simplicity. Such an error costs very little in time or energy, as such material can be covered quickly. Errors in the other direction, on the other hand, can cost new learners a great deal of time and energy, with the resulting lack of progress generating much frustration, exasperation, and self-doubt.

There are many things I have learned from students. Most are summarized in the preface to Vol. 1 and above herein. We teach them the physics, but they can teach us how to teach that physics. Let's listen to them.

And Finally, My Thanks to Many of You

I, and those who learn from the books later, are indebted to the many, many readers who, by sending me feedback, have improved the books' quality and clarity immeasurably. On the behalf of the learners yet to come, and myself, I thank you all, profoundly.

Robert D. Klauber
October 2021