You can know the name of a bird in all the languages of the world, but when you're finished, you'll know absolutely nothing whatever about the bird... So let's look at the bird and see what it's doing — that's what counts. I learned very early the difference between knowing the name of something and knowing something.1

- Richard Feynman

HOW LAKEETA CALCULATES THE VELOCITY OF A CAR MOVING WITH VELOCITY 9.5 M/S

It was a great struggle getting my high school physics students to turn in their homework, even when I asked simple, rote questions. It was an even greater struggle when I asked challenging, contextual questions. “It is too hard.” “I tried, but couldn’t do it.” “What homework? I didn’t know there was any homework.” I gave everyone more and more time, more and more chances, and more and more help and hints. I was available to anyone who wanted extra help any time. The homework was an important part of their grade for the class. Almost all my students wanted to pass and here were some easy points. It was confusing to me why so few submitted their homework. There appeared to be little investment and certainly little success.

Recognizing the need to get the students going and on board, I made the homework easier and easier, more like the “fill in the blank” type that they were used to. In other words I pandered. I lowered academic standards.

Eventually, partly in frustration and partly to make a point, I decided to include the following question (verbatim) as one of the problems:

A car moves with a constant velocity of 9.5 m/s. What is the velocity of the car?

I wanted the class to see that they should read the question, see what was right in front of them, and understand what is being asked. On an intellectual level, I thought that I could convince everyone that they could get started on problems by reading them and thinking about them. On a practical level, I thought that everyone could get some credit on the homework and work towards passing. I was therefore disappointed when few students submitted the obvious answer to the question about the velocity of the car.2 Like many other first year teachers, I blamed the kids, the school, and the families. Most of all though, I blamed myself.

Lakeeta was an average performing student. All year I had to point out basic rule infractions (such as eating or texting in class) to her. She let me know bluntly

2 9.5 m/s.
that she did not like to be told what to do. Whenever I asked Lakeeta a physics question to try to get her to understand something, she reminded me that I was the teacher and that I should be giving her answers, not asking her questions. I found humor in my relationship with Lakeeta. I think we both enjoyed our banter and we got along okay. Despite her requests, I never stopped doing what I thought was best to try to get her to succeed. In return, she never stopped eating, texting, and grumbling.

Lakeeta was not very inquisitive about the subject matter and did not seem to care about learning physics, but she tried to get all of her homework in and wanted to pass the class. Like many of my students, she was a product of the system. To her, homework (and class work) was a means of accumulating points. If she looked beyond her report card grade at all, it was about being able to do what she thought was important to prepare for the end of year culminating state exam. To her that meant being told what she had to know. It meant being given the explicit procedures needed to answer the questions. I pleaded with Lakeeta explicitly and implicitly to work towards meaningful understanding of science. I tried to teach her that this was critical to real success. This was foreign to Lakeeta.

One way or another, Lakeeta was able to do much of her homework without me every time, but she sought me out for the problem above about the car. This was the one troubling her. She came to extra help. “I could not do this one because I do not know which formula to use.”

Lakeeta solved her homework problems with strategies that I saw my college physics students use. Which formula had the matching symbols? Which of the problems in the book had comparable surface features? Lakeeta was not alone in her confusion. Lakeeta’s struggle with the car question was not a quirk or an exception. It was a representative outcome of the way many students approached learning in school.

I asked Lakeeta to read the question back to me. She did, albeit with a little attitude. I just looked at her quietly, knowing that she would get annoyed at me. She did not disappoint. After a pause I asked her to read it again, but asked her this time to pay attention to what she was reading. After a short time, she smiled at me. Apparently she understood, both the problem and my point.

DIARY OF A SABBATICAL

As a college professor, it is common to take a sabbatical to travel, write, or research. I spent my sabbatical year as a full time public high school science teacher in a poor neighborhood in New York City. Many colleagues reacted with amazement. Some reacted with horror. Almost all expressed admiration and respect.3

3 I wish that admiration and respect would be given to the many wonderful teachers who do this every year. I wish that this admiration and respect would then be translated into meaningful support, resources, and ongoing professional development.
For more than 20 years, I have been a physicist and a science educator, primarily at the college level. My research is on understanding and improving the learning of science, from elementary school science through quantum physics. Since 1999 I have been Professor in the School of Education and the Department of Physics and Program Director of Science Education at City College of New York (CCNY). In that time I have had the privilege of working with hundreds of K-12 students, with over a thousand science teachers in and around New York City, and with even more college science students who are graduates of the city school system. I wanted to improve my ability to work with all these groups. Choosing to spend my sabbatical where the rubber meets the road was an easy decision.

In the following 12 chapters, I give a diary of my 12 months away from being a college professor. Anyone who teaches high school science, particularly in an urban setting, will likely recognize the accounts as unsurprising. All of these examples, stories, quotes, and data are genuine and representative, including what I wrote about Lakeeta. However, to present 12 critical themes of science education coherently by chapter, I have shifted some of the chronology around. I have also added experiences from the college level and from other K-12 schools in which I have taught, worked, or volunteered. For obvious reasons, I have changed some details which have no bearing on the substance of the accounts. For example, all names are pseudonyms, usually (although not always) reflective of the gender and race of the person. Minor other changes have been made so that schools, students, and teachers with whom I have worked are not readily identifiable.

**PERSPECTIVE**

When discussing education, everyone brings a perspective which colors the way events are interpreted. I am no different. The above quote by Richard Feynman, a renowned scientist, educator, author, and Nobel Prize winning physicist, is revealing of my perspective. So are the quotes at the beginning of each chapter by other great scholars, scientists, and cultural figures. Each quote ties to the theme of the chapter.

Instructional strategies described in and after each chapter are also revealing of my perspective. In particular, I have frequently used the curricula of Prof. Lillian McDermott and the Physics Education Group at the University of Washington, which I consider exemplary. With these curricula, students are actively engaged in activities where they build a functional understanding of the subject. Instructional strategies are based on what is known about how students learn and address specific difficulties that students have.

Most of all, my perspective is that the very highest academic standards and accountability need be paramount. Any policy that compromises high achievement of students must be reconsidered. I make no secret of my worries about recent and current trends in education which come under the banner of “standards” and emphasize “high stakes testing.” My observations as well as my systematic

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4 I had the privilege of working as part of this group as a postdoctoral research associate from 1992-1995.
research have created a perspective that these trends are functionally moving students towards rote and authoritarian learning. I see a focus on a limited view of math and literacy and no meaningful emphasis on science and reasoning. I see results completely counter to high academic standards and accountability. I see what is happening in education as problematic. I see doing nothing about it as worse.

Despite my perspective, in this book I have avoided the oft-cited phrase about American education being a “mile wide and an inch deep.” I have also avoided the “research has shown,” “in the published literature,” and “statistics indicate” approach to writing. High quality research is paramount in meaningful educational reform. Unfortunately, too often I have seen these phrases point carelessly to data which are subject to very different interpretations. These phrases are therefore often followed by conflicting perspectives, depending on whatever point the author is trying to make. So instead I have elected to make this book a narrative of my specific experiences and my direct interpretations. All of the experiences and interpretations are representative of what I saw on sabbatical and what I see in education today. They are genuine and real. That said, research has shown that my interpretations are consistent with what is prominent in the published literature and statistics indicate that students learn better when using the instructional strategies which are in opposition to the mile wide and inch deep approach.5

MATTHEW, RUSSELL, MAKENZIE, AND LILY

Matthew, Russell, Makenzie, and Lily are the only children names in this book that are not pseudonyms. They are the real names of my own children. There is so much that I want for them, some of which relate closely to my work. With respect to my sabbatical, it was particularly exciting to me that Matthew was simultaneously taking the same standard New York State high school physics class that I was teaching (in a different school).

At various times, I have heard from one (or more) of my children that when they grow up they want to be a doctor, engineer, executive, judge, lawyer, military officer, pilot, scientist, and teacher.6 In none of these professions is the training that Lakeeta is used to helpful. These professionals do not work in isolation on de-contextualized short answer problems with no access to resources of information. Rarely in these professions would there be reward for identifying the technical name of something not understood or for plugging numbers into an obscure formula which might or might not be relevant. Instead, these professionals work as part of a team on meaningful, complex problems while skillfully navigating through vast amounts of diverse information. Rewards come from being able to think critically and communicate skillfully.

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5 In other forums I follow a careful research paradigm. I share detailed findings and compelling interpretations built on work of other scholars and researchers. My work, and that of so many others, unambiguously inform and support the main ideas which are presented in this book.

6 Curiously, I have never heard professor.
The training that Lakeeta is getting is not helpful. In my opinion, it is actually harmful. And my concerns about a poor education are not tied to career choice for Lakeeta. When I think about what preparation leads to a good doctor, engineer, executive, judge, lawyer, military officer, pilot, scientist, and teacher, these are the same skills that benefit workers in all arenas. They are also skills of value for customers and merchants, voters and politicians, friends and neighbors, and just about everyone else.

I do not think about how the perception of education can be improved as my children go through their school years, I think about how education can really be improved. My year in the high school, coupled with my long and diverse related work, has given me insight into the way things are and the way things could be. When I think of failings in education and how to fix them, my children’s welfare is a strong motivating factor.

FORMAT OF BOOK

In Part 1 of this book, I describe the beginning of my sabbatical, before teaching in the high school. I give a summary of a summer program for high achieving New York City high school students. In this program it is evident that even the best and most motivated students are not learning science in their schools. However, after they experience a very different learning environment, it becomes clear that real learning is possible. This summer program explores goals of science education, serves as a motivation for much of my work, and frames the rest of the book. Also in Part 1 I describe other relevant motivating experiences. These include teaching college physics, working with high school science teachers, and my own formal preparation to become certified to teach high school science in New York City. I use all of these motivating experiences to present my perspective on what is meant by inquiry.

In Part 2, the chapters each describe a month of my teaching high school during the school year. Each chapter delves into a theme in education largely through presentation of vignettes, such as the one about Lakeeta. There are examples where student performance is alarming. There are examples where educational experiences are exemplary. In total, the chapters reveal my sabbatical experience teaching in the high school.

In Part 3 I both look back and look forward. I reflect on my sabbatical and what I would do differently if I could do it all over again. I relate what I learned to implications for teacher preparation, science education, and systemic change. I also describe how the community of science educators needs to keep the conversation going and move towards education reform.

At the end of each chapter is a reflection on the chapter theme. There is a section called “Strategies that work.” This is a discussion and sample instructional strategies, curricula, and assessments related to the chapter theme that science teachers can use to promote more authentic learning. Finally, there is more on the quote at the beginning of each chapter.
PREFACE

ALTERNATIVE BOOK TITLES THAT I CONSIDERED

In case you are still not clear of what to expect in the remainder of this book, here are a few alternative titles that I considered before settling on the one on the cover:

An inquiry into education, where the rubber meets the road
The complete idiot’s guide to not creating a generation of complete idiots
Your child left behind
Race to the top of what?
Solving all of the world’s problems through improving science education in order to teach future generations to think and reason intelligently

GRATITUDE

I am indebted to the many wonderful people who supported the work that led to this book. In particular I thank the dedicated principal at the high school in which I taught and his amazing teaching and support staff. I was fortunate to be at such a wonderful school. I am also grateful to CCNY for continuously supporting my work in science education. Most of all, I am grateful to every student with whom I have ever worked who at any point was open to trying to learn or able to teach me. There is no doubt that they are the reason that I love what I do.