MANU KAPUR

PRODUCTIVE FAILURE

UNLOCKING DEEPER LEARNING THROUGH THE SCIENCE OF FAILING

Praise for *Productive Failure*

"This book reveals the transformative power of Productive Failure through compelling narratives, insightful research, and practical strategies. Manu Kapur shows how embracing failure is a critical tool for progress, innovation, resilience, and triumph."

—John Hattie,
Melbourne Laureate Professor Emeritus,
Chief Academic Advisor, Corwin,
technical advisor to i-Ready Assessment, and
co-director of Hattie Family Foundation

"At a time when there is concern regarding the quality of outcomes in education, fresh approaches to learning and teaching are much needed. *Productive Failure* brings new and applicable thinking to values first espoused by Socrates, relating to the importance of failure in our learning journeys. Manu Kapur's timely research, detailed in this captivating book, encourages us to design for failure, to start with the problem rather than being fed the solution. It is affirming to all of us who have experienced failure and have thereby grown stronger."

—Sue Cunningham,
president and CEO, Council for Advancement
and Support of Education (CASE)

"An accessible mix of science and practice, Manu Kapur's carefully crafted argument about the value of Productive Failure is relevant in two important ways. First and foremost, it concretizes a fundamental human truth: deep learning and meaning making require engaged struggle with the issue at hand – a struggle that is immensely enriched by embracing failure. And beyond its universal educational implications, the book is also of special relevance today, when in all fields, the promise of generative AI could easily lure us into thinking that we now have tools to skip the struggling phase."

—Etienne Wenger-Trayner,
social learning theorist at Social Learning Lab,
Sesimbra, Portugal and author of Communities of Practice

"It's a truism these days that you have to fail to succeed. To learn from failure, we need a wise guide like Dr. Manu Kapur, who shows us that failure is the secret recipe of success. With his expert guidance, Dr. Kapur demonstrates how to fail productively in ways that move you forward instead of setting you back. Grounded in solid research and filled with practical advice, *Productive Failure* is a pleasure to read."

—Dr. Keith Sawyer,
professor at the University of North Carolina at
Chapel Hill and author of *Learning to See:
Inside the World's Leading Art and Design Schools*

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Unlocking Deeper Learning Through the Science of Failing

Manu Kapur

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For

Dev Kapur

and

Arvi Sudhir Kapur

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Foreword

The year was 2005. My talk was over. The conference theater was almost empty. I wanted tea but a pesky PhD student stopped me. He was eager to show me some data, so I obliged, and we sat and looked at his data for a while. Education is rich in human values, but the sciences of learning are built on data.

I forgot his name but a few years later, I was setting up the program of a European conference when I read an intriguing paper. It was about learning in teams. The approach was exactly opposite to my own work. But the counterintuitive results were demonstrated with an unimpeachable rigor. I invited the author to give the keynote and he seduced the audience by the elegance of his proof. That was Manu Kapur, and it was his first keynote ever, on Productive Failure.

You will enjoy the same relentless logic while reading his book. The research findings interlock with each other, page after page, as the wheels of a Swiss watch. It is what it takes to demonstrate that a learning activity that has all the hallmarks of failure ends up producing better outcomes.

How people learn is a complex science. Learners and teachers are neither cells in a tube nor photons in a vacuum. Pupils for instance are not the same on a rainy day or when the first snow whitens the landscape, lighting up the pupils' eyes! Instead of tackling this complexity, some books depict learning and teaching in very general terms. Not this one. It clearly establishes evidence that trying to solve a problem before being told how to do so leads to better learning outcomes, despite the failure to solve this initial problem. Or more precisely, because of it. Some education experts try to sell a miracle method supposed to revolutionize education. Not this book. There is no miracle in education.

Instead, the magic of Productive Failure is demystified, chapter by chapter. At the core lies the intensity of cognitive engagement. No matter what the gurus of cognitive load claim, building knowledge is demanding. Learning is not a quiet river; some difficulty is desirable. The findings of this book are not only about cognition, but also about emotion. Manu integrates neuroscience findings to decompose the emotional rollercoaster along which we get the motivation to get mastery of difficult skills. The most important things we learn in our lives are not the easiest ones.

This book is about deep learning. Don't read it if you believe that all that matters is to store knowledge pieces in our brain as we put a book on a shelf and retrieve it later. Or rather, read it twice. Deep learning is about making meaning. Recently I came across the idea that if one travels at the speed of light, time stops. I understand every word of this sentence, I memorized it easily, but I am not able to do anything as I don't really get the meaning. Deep learning is about building actionable knowledge and it takes some failure to feel when and how some knowledge can be activated to tackle a real problem. Not simply to answer a quiz.

Twenty years later, Manu is giving keynotes around the world. At the end of his keynote, many pesky students will catch him with questions. Years later, one of them may write a book that Manu will preface. This is how the science of learning is moving forward.

But this book has not been written for a scientific audience. It speaks to all those who share our goal and our vision: to make learning and education more effective. This book is for them: learners, teachers, and policy makers, but also parents, sport coaches, and managers. All of us are learners.

Prof. Dr. Pierre Dillenbourg
Associate Vice-President for Education
EPFL – Swiss Federal Institute of Technology, Lausanne
Switzerland

Introduction: My Forays into Failure

All it took was a moment. I was 21. Till then, life was going exactly how I had dreamed of and trained hard for – becoming a professional soccer player. Then a snap, and I felt my knee give way. A bad tackle during a regular practice session had turned into my worst nightmare. It was a career-ending injury. My orthopedic surgeon assured me that I would walk again, but a professional career was not in the cards anymore. To this day, I am not completely over it. Like paper, once crumpled, it cannot be undone. Still functioning, but the scars remain for life.

People often ask me how I came up with the idea of Productive Failure, the notion that we could somehow *intentionally* design for failure and bootstrap it for deep learning. After all, many people have talked about the value of learning from failure. These accounts, however, are largely reactive; they talk about learning from failure *after* it happens. The idea of Productive Failure is to be proactive; that is, if failure is so powerful for learning, then we should not wait for it to happen. We should intentionally design for it for deep learning.

I like to believe that I came up with the idea in a moment of brilliance during my doctoral studies at Teachers College, Columbia University, in New York City. The truth, however, is that many things in my life led me to it. As Steve Jobs put it, "The dots connect looking back." My dots were my failures, big and small, which slowly but surely nudged me toward it. But all of it only became clearer in hindsight. The lived experience was anything but.

Soccer Dreams

My journey started a long time ago, in my teenage years. I was in the sixth grade, doing stuff teenagers do. Falling in love was perhaps the most significant and consequential. However, unlike the first crush most people have in school, my first love was soccer.

As a teenager growing up in India, all I ever wanted to be was a professional soccer player. My father bought us our first color television just in time for the 1986 World Cup in Mexico. Diego Maradona was the man of the moment, and everyone I knew wanted to be like Maradona. I did too. Even though I was only in the sixth grade, I went for my high school team trials. In a country where everyone aspires to be the next cricket star, I took to soccer, and quite effortlessly so. And before the end of that academic year, I was the vice-captain and playmaker of my high school soccer team.

When I look back at my soccer years, a simple philosophy stands out. Training in the northern Indian city of Chandigarh in the foothills of the Himachal Mountains, my coach, Mr. Thomas, used to drill into us that matches are often won or lost in the last five to ten minutes of the game. Everyone can play well when they are fresh, he would say, but it is those who can push when extremely exhausted who make the difference in the last passage of play. Therefore, true to that philosophy, he designed our training to focus on preparing us for those game-changing moments.

How? By taking us to *the other side of failure*.

The idea was to train until you fail, and then you push just a little bit more. Do your push-ups and pull-ups till your arms buckle, and then push some more. Do your endurance training till your body cannot endure anymore, and then push some more. Of course, all this was done in a way that was safe to avoid injuries. Pushing just beyond the limit was sufficient. All the time to take the body to its limit, and then push a little bit more.

Why? Because good things happened on the other side of failure: this is where players maximized their physical and mental strength, and learned how to work the mind and the body together for optimal growth and performance. And our coach was right: when you look at tough games that go right to the end, quite often it is on the other side of failure where these games are won or lost. Lesson learned. In retrospect, this was the first of several dots I was to connect on understanding failure.

Unfortunately, just as I had made it to the national youth team, my soccer career ended with the injury. It was Spring of 1995. I remember it vividly. In one moment, everything that I had trained for in my life till then was gone. I was a case study in depression and failure. As effortless and enjoyable as soccer was, everything else after was quite the opposite, effortful and exhausting. Nothing seemed to work or make sense. So, the only thing I could do was to try to push through my backup option: finishing up my Engineering Bachelor's.

Struggling Through My Engineering Studies

It was not until my final year of engineering school that I started to take my studies seriously, for until then my life was all about soccer. In the final year of the engineering bachelor's degree, all students had to do a thesis. One could not graduate without completing a thesis. And I was certainly not in the mood for failing again. I was determined to succeed, but my professor and thesis advisor had other ideas.

First, I had to choose a project. Because other than soccer, the only other thing I was good at was math, I chose a project that involved a lot of mathematical analysis. My professor gave me a challenge to solve a special case of a differential equation in fluid dynamics. I was happy. It was mathematics and required neither an experimental setup nor building stuff. It was math and me, simple.

I tried several methods to solve the problem, without making any major inroads. After a couple of months, I saw my professor and showed him all I had done. He was quite pleased, even though I had not been "successful." He suggested I try a new approach, explaining the gist of it. I went back to the drawing table, working on it for a month, and still was not able to solve the problem. I could show that the professor's approach could not lead to a solution, but I wasn't able to actually improve upon it to solve the problem. When I saw the professor again, he was once again quite pleased, and gave me yet another approach. And again, the same result. This went on for three to four months; I'd follow through on all the approaches and suggestions, show that they couldn't solve the problem, but a full solution remained elusive.

By the end of the summer, I was panicking because I was nowhere near the end of this process, and I needed to graduate by the end of the year or else my scholarship would run out. I met the professor again at the start of the semester, sharing with him my predicament and concerns. He looked at me, and said, "Manu, all the strategies you have tried, including the ones I suggested, are known not to work." I was angry, but I tried not to show it. Why had he made me go through eight months of trying things that were known not to work? My professor explained, "Now that you have understood what does not work, you understand the problem way better than anyone else. Now I will tell you one last strategy. The problem cannot be solved mathematically. It has to be solved computationally."

It gives me goosebumps to this day when I think about that meeting. He was indeed right. Much as I hated admitting it at the time, I did understand the problem better and developing a computational solution and running simulations turned out to be straightforward. I did that quickly, and within a couple of months or so, I had completed the project and was even given the highest distinction for it. This was the second of several dots.

Looking back, both my soccer training and final year engineering thesis were the first two dots. In both, I was intentionally and repeatedly taken to the other side of failure. If I was paying attention, I would have connected the dots. I did not, or perhaps could not. Far from connecting the dots, I was merely happy just being able to graduate on time. I barely made it through with second-class honors, knowing very well that engineering was not what I wanted to do. My heart was simply not in it. I suppose, against the backdrop of a soccer career, it was hard for anything to come close.

It was time for trying out some other options. With some luck, I joined a management consulting firm, but within a few months even that did not work out, and I quit. Dot number three. Then, I ventured into the start-up world of the late Nineties during the Dot Com boom. This dream too fizzled out when the Dot Com boom turned into Dot Com doom. Dot number four.

By now, all my friends were already well into highly successful careers as doctors, lawyers, management consultants, and bankers; all I had to show was a string of failures – dots in a pattern that I had yet to realize – that I had in just about everything I had tried. I was running out of options.

And then, an opportunity to teach came along. Left with no other options at the time, and with bills to pay and make ends meet, I was forced into my fourth option: teaching.

Into the Classroom

Because I was reasonably good at math, I decided to become a math teacher, teaching the subject to high school kids for five years. It started as a one-year contract position, and I took it to give me some breathing space to figure out what I wanted to do with my life. As it turned out, this singular decision led directly to the discoveries that made my academic career a success and prompted me to write this book. However, these discoveries did not come from my prowess and skill as a teacher; instead, and as you will see, they are the direct result of my failure to teach mathematics to my students and my wondering why, exactly, this was so difficult.

I actually enjoyed teaching, and I still do. This did not mean I was good at it. I merely liked the idea of trying to help someone understand something new. And math, though a logical and well-structured domain, is known to be hard to learn, and consequently, hard to teach. I was up for the challenge.

My teaching philosophy was simple: I thought that if I could engage my students, explain the concepts as clearly as possible, then show them, step-by-step, exactly what to do and how to do it, I'd achieve transformational results. I spent a lot of effort and time preparing my notes and lectures, thinking about the best ways to explain difficult concepts. However, I quickly discovered that this method did not work well. Even after my preparation and my carefully planned lessons, at the end of the class, many of my students still did not fully understand the concepts we had covered.

How could these high school kids fail to see what I was trying to show them? How could it be that something I could so clearly explain, and draw their attention to, was still beyond their grasp? Well, if at first you don't succeed, try again, they say. And I did. I would repeat the lesson, going through the entire process of explaining the concept all over again, only to discover that the problem had persisted. Many students were still unable to see their way to the solution. Maybe some could to a certain extent, but, for most of them, a deep understanding of the concepts discussed and the ability to use them again in a different context, the holy grail of education, remained elusive.

Research on human learning by then had already developed a solid understanding about why we fail to understand when we are taught in this way. I unpack the major problems of learning in Chapter 1. Except at the time, I did not know about this research. I was at once frustrated and curious why my students could not see what I was trying to show them.

As you can imagine, teaching too didn't work out.

By now I was touching 30. Massively lost and confused and having spent my entire twenties trying and failing to figure out what I should do with my life, I decided to focus on my curiosity, and it was perhaps my curiosity stemming directly from my failure as a teacher that finally drove me to my fifth-choice career, in academia, searching for a scientific explanation for why teaching math was so hard and how it could be made easier. My close friends and colleagues often call me a reluctant academic. After all, academia was never in the cards, and when it happened, it was only after several tours and detours as a fifth-choice career.

Venturing into Academia

I enrolled in a doctoral program at Teachers College at Columbia University, majoring in the learning sciences – the science of human learning, how we learn, and how we can design better learning environments. I was immediately drawn to research into how best to teach new concepts. As I poured through scientific journals, I did not at first find the answer, but I started to notice a pattern across the research in my new academic field that echoed my experiences in the classroom. I had an epiphany, and I ended up writing a thesis on the science of learning from failure.

For a reluctant academic, I must say my years at Teachers College, Columbia University, were by far intellectually the most stimulating of my life. The formal training was of course rigorous and useful, but so was the informal experience beyond the confines of the formal courses, where encounters with diverse ideas challenged my thinking and broadened my perspectives in profound ways. Regardless of whether these interactions were planned or spontaneous, they formed the fertile ground from which new insights emerged and flourished. I claim these insights as my own, but in many ways they were the product of the collective experience.

A big part of this experience was reading and discussing what we read, and making sense of it. My focus was on how we learn new concepts, and how best to teach those concepts. Many of the studies I encountered described researchers who went into the classroom to observe how teachers taught their students. The teachers were almost always selected carefully: they were not just experts in their domains but also good at teaching. The researchers often found their lectures to be well-structured, engaging, and clear. Their students usually agreed and reported that they had learned a lot from the experience.

Yet, in study after study, when the researchers probed the extent to which students actually understood the concepts covered in the lectures, by giving them problem-solving tasks based on these concepts, they found that the understanding was largely superficial. Most students did not really understand the material, even though they felt like they did and reported that they had. I bet if you asked my high school math students, they would tell you I was a good teacher. Yet, as kind a judgment as that may be, I would bet doubly that chances are my well-structured and well-delivered lectures merely gave them the illusion of learning without actual deep understanding.

Almost everyone who has gone to school is familiar with this method of teaching. The teacher first teaches, then we practice, and, week in/week out, we learn new things and in a largely predictable manner. This is the "Direct Instruction" model, the standard approach for decades, and both the articles I had been reading and my own experience suggested that it was not effective, even if applied by excellent lecturers. The problem was not that we learn poorly from bad lectures, rather that we learn poorly from excellent ones.

Not learning well from bad lectures is understandable and explainable. Not learning well from good lectures is perplexing, even shocking. One can think of several reasons why. Maybe the material was not pitched at the right level. Maybe students needed to be supported better. Maybe students were only partially engaged with the material. Maybe more interactive learning was needed, and so on. And there are lots of studies in the literature that explore these explanations. No doubt these additional measures sometimes lead to incremental improvements, but they do not solve the problem of bad learning from good teaching.

To solve the problem, we need to know the cause.

Finding the Cause and Its Solution

Imagine you are watching a movie, a delightfully engaging and entertaining film. Now imagine that the person sitting next to you is an acclaimed director, an expert at making movies. Will you see the same movie as the director? In a sense, you will: the same sequence of images will appear before each of you. But what you will notice out of those images, the patterns you will see, the significance you will give to various elements of the movie, even the things you will see and will remember seeing – these are likely to be different unless you are an expert director yourself.

As we will see later in this book, decades of research on the difference between experts and novices has clearly demonstrated that experts see different things than novices. Novices tend to see superficial features, but experts see what is essential, the deep structure and critical features. It is seeing the deep structure that leads to understanding and powerful learning.

It turns out seeing is not simply a perceptual exercise but a cognitive one as well. We don't just see with our eyes, but with our minds: seeing is a function of what one knows. And herein lies the paradox (and challenge) of teaching a novice. A novice, by definition, does not have the knowledge to see what is critical. Yet, the novice needs to somehow be able to see the critical features to be able to develop expertise.

The solution to the paradox lies in realizing that the first job of teaching is actually not to teach. The first job of teaching is to prepare the novice to see with an expert's eyes. Indeed, my mistake as a math teacher was in assuming that my students could understand the principles I was trying to show them. Instead, I needed to activate my students' ability to see the critical features of the problem before I could expect them to fully grasp the solution.

How could I do that?

I realized that the best way to really teach something is to engage students in problem-solving activities specifically designed for them to productively struggle and even fail, and only then give them the correct explanation or lecture. Instead of waiting for failure to happen, I wanted to intentionally design for failure and then bootstrap it for learning from subsequent instruction, turning the initial failure into deep learning; that is, Productive Failure.

Since I made the realization, I have discovered by failing – and beginning to understand the reasons why they were failing – students could start to approach a problem in a way that enables them to see the critical features for success. They are then prepared to learn from subsequent explanation, instruction, or expert feedback.

In Chapter 2, I describe how I conceptualized Productive Failure, and designed the initial set of experiments to test its effectiveness, as well as the larger body of evidence that has accumulated over the years. As a teaser, let me just say that Productive Failure students have invariably demonstrated significantly deeper conceptual understanding as well as a greater ability to transfer what was learned to novel problems than students who had received Direct Instruction.

The bottom line: when learning something new, it is much too easy to find the path of least resistance. It is most natural to seek the easy way out. However, my research on Productive Failure shows that making learning easy does not always ease learning. If not intentionally designed to leverage failure in the initial stages, learning tends to be shallow and inflexible. But with it, learning is deep, flexible, and adaptive. Productive Failure suggests that making initial learning more difficult and challenging, where you may struggle and even fail to solve a problem or perform a task, can be beneficial for learning.

The Productive Failure model is in many ways simple yet paradoxical. Simple, because it turns the traditional mode of instruction on its head. Paradoxical, because it intentionally designs for and leverages failure in initial problem solving as the path to longer-term success; that is, deeper learning.

To be clear, the proposition of *Productive Failure* is not simply that failure, if and when it happens, should be seen and used as an opportunity to learn. Of course all of us make mistakes from time to time, we falter and fail. Everyone can relate to such experiences, and I do believe some of our deepest lessons can come from our failures.

In *Productive Failure*, the question I ask is: If failure is indeed such a good teacher, why do we wait for it to happen? Why not intentionally design for it? Take solar or wind energy as an analogy. We know these are natural sources of energy. Do we just wait for them to generate energy by chance? No. We intentionally design tools and technologies to tap the energy for our use.