Feynman On the Importance of Examples and Diagrams

Below is an excerpt from Richard Feynman's book *Surely You're Joking, Mr. Feynman!* Feynman was a theoretical physicist (and something of a comedian) who received the Nobel Prize in Physics in 1965 for his work on quantum electrodynamics, dealing with the behavior of subatomic particles. He also did important research in other areas of physics. The concepts that underlie what is now called nanotechnology were first described by Feynman in a 1959 Caltech lecture "There's Plenty of Room at the Bottom." Feynman insisted that he needed diagrams and examples in order to understand anything, and he invented what are called Feynman diagrams to represent the mathematical expressions for the behavior of subatomic particles. He became famous among the general populace in the 1980s when he gave a vivid demonstration of the o-ring failure that caused the disastrous explosion of the spacecraft Challenger.

Here's the excerpt from Feynman's book:

That was the first time I was in Japan. I was eager to go back, and said I would go to any university they wanted me to. So the Japanese arranged a whole series of places to visit for a few days at a time.

At all these places everybody working in physics would tell me what they were doing and I'd discuss it with them. They would tell me the general problem they were working on, and would begin to write a bunch of equations.

"Wait a minute," I would say. "Is there a particular example of this general problem?"

"Why yes; of course."

"Good. Give me one example." I can't understand anything in general unless I'm carrying along in my mind a specific example and watching it go. Some people think in the beginning I'm kind of slow and I don't understand the problem, because I ask a lot of these "dumb" questions ....

But later, when the guy's in the middle of a bunch of equations, he'll say something and I'll say "Wait a minute! There's an error! That can't be right!"

The guy looks at his equations, and sure enough, after a while he finds the mistake and wonders, "How the hell did this guy, who hardly understood anything at the beginning, find that mistake in the mess of all these equations?"

He thinks I'm following the steps mathematically, but that's not what I'm doing. I have the specific example of what he's trying to analyze, and I know from instinct and experience [what are] the properties of the thing. So when the equation says it should behave so-and-so, and I know that's the wrong way around, I jump up and say "Wait! There's a mistake!"

This actually happened to *me* one time. Back in the 1990s, after Andrew Wiles proved Fermat's Last Theorem, very famous at the time, three professors from the UA math department gave a public lecture on it. One of them provided background on the theorem and Fermat, another talked about something else, maybe it was about Wiles, I can't remember what, and the third gave a sort of layman's version of the proof. During this last part, I was following the proof with an example in my head. In the middle of some kind of combinatorial argument, I raised my hand and said "Could you go back to that last slide? Something didn't seem quite right." The guy went back, and I asked a question, and I could tell he thought something like "Hah! Some guy who thinks he can do mathematics." So I said "Here's this example, and the argument doesn't seem to work in this example." He started to show why I was wrong, but it just wasn't working. He looked at the other two mathematicians, and they all realized their version of the proof must be wrong. A day or two later I received an email from one of them with the fixed-up version of the proof. (Still not the real proof, of course; that's way too long and difficult.)

Some other math department faculty members were in the audience, so an interesting consequence of this was that I became somewhat well-known in the math department in those days. One of our Econ PhD students was also in the audience. He had taken an advanced theory course from me the semester before, in which I mostly asked the students (who were presenting) questions about the theorems or proofs or examples. He came up to me as we were leaving the lecture and said "When you raised your hand I knew what was going to happen."