

CHAPTER VI

Fidelity

“Give the pupils something to do, not something to learn; and the doing is of such a nature as to demand thinking; learning naturally results.”

John Dewey, Democracy and Education

🥥 The Coconut Stall

Picture a street market in a Brazilian city in the early 1980s: crowded, loud, hot. A nine-year-old boy runs a stall selling coconuts. A customer wants three, at 40 cruzeiros each, and some lemons too, and she'd like a better price for buying so much. The boy haggles, settles on a total in his head, takes her large bill, and counts back the change, all while keeping an eye on the rest of the stall. He does this all day, accurately, transaction after transaction.

In 1985, Terezinha Carraher, David Carraher, and Analúcia Schliemann watched children like him at work and recorded the arithmetic they did: addition, subtraction, multiplication, all of it correct. Then they took the same problems, with the same numbers and the same operations, and wrote them out school-style, as bare numbers on paper. No coconuts, no customer. Forty times three.

The children struggled with the very problems they had just solved, effortlessly, at the stall.

Arithmetic is supposed to be universal. Forty times three is a hundred and twenty whether you're counting coconuts or looking at ink. The children hadn't forgotten how to multiply. Human minds don't store knowledge as context-free data. At the stall, the numbers were attached to coconuts, coins, and a customer waiting for her change, and the setting carried part of the thinking. On paper, all of that was gone, and the same arithmetic became a different, harder task.

This chapter is about that difference. It's about **fidelity**, the third of the four core engagement drivers.¹ Fidelity is how directly the learner contacts the real structure of what's being learned: real materials, a world that answers back, the learner's own body and senses at work.² The real world supplies fidelity by default. A classroom or a simulation has to choose it. And more fidelity is not always better. Good fidelity is fitted to the learner and to the goal, and the part that matters most is the world answering back on the thing being learned.

The Drift From Reality

Over the last century or so, schooling moved learning onto paper. I mean paper broadly: worksheets, textbooks, screens, multiple-choice tests, training modules you click through. Corporate onboarding and professional training followed the same path.

Both systems can now run entirely on symbols. Inquiry becomes questions about a textbook passage. Practice becomes drills on a worksheet. Every metric can be met while the learner never touches the thing itself. You can earn top marks in biology by memorizing a diagram of a cell without ever focusing a microscope, or dealing with a slide someone prepared badly, or touching soil.

The vendor study shows the cost, and the cost runs in both directions.

Street knowledge can stay stuck in the street. The boy at the coconut stall calculates change perfectly, and can't pass the written test that might open the door to more schooling.

School knowledge can stay stuck on paper. Think of the analyst with every finance certification, who builds flawless real-estate models in a spreadsheet, cells color-coded, returns projected thirty years out. Close the laptop and sit her across a table from a seasoned landlord to negotiate one real lease, and she may freeze like the children with the pencils. The spreadsheet was her paper test; the negotiating table is the street market. Or the physics graduate who can't work out why his car won't start.

Knowledge tends to stay in the medium where it was learned. So fidelity alone doesn't guarantee that learning travels. What lets it move is the two systems working together: contact with the real thing in Practice, and Inquiry into its structure.³ We'll come back to that at the end of the chapter.

What Fidelity Is

The definitions in Chapter 2 both point outward. Inquiry meets “the real structure of what's being learned.” Practice answers to standards “that exist in the world.”² Fidelity measures how directly a learning encounter touches that structure.

Learn to ride a bicycle on a real street and the structure is simply there: gravity, momentum, balance, the grip of tires on pavement. Lean too far and you fall. Move the learning into a classroom, a seminar, or a training module, and that contact disappears unless someone builds it back in.

Fidelity comes in degrees, and in more than one kind. The field that has studied it most closely is simulation-based medical education, where the gap between a good simulation and a bad one can decide whether a patient lives. It distinguishes three dimensions.

Physical fidelity is how much the materials look and feel like the real thing. Does the skin on the training mannequin have the texture of skin? Is the synthetic blood the right red?

Functional fidelity is how much the encounter behaves like the real thing: whether the world answers back. Give the simulated patient a dose of epinephrine. Does the heart rate jump when it should, by as much as it should?

Contextual and emotional fidelity is the setting, the stakes, and the feeling of the real situation. Are you practicing CPR in a quiet, bright, air-conditioned classroom, or with alarms going, a clock running, and an actor shouting at you?

The Cardboard Box and the Replica

Physical and functional fidelity come apart. Suppose you're learning to fly a jumbo jet, and you're offered two simulators.

The first is a cardboard box in an empty room. You sit inside on a folding chair, holding a cheap plastic joystick. The screen shows a crude wireframe. But the software behind it reproduces the aerodynamics of the real aircraft exactly. Pull back a hair too far on takeoff and you stall. A crosswind shoves the stick in your hand.

The second is a full-scale replica of the cockpit, every dial and leather seat a perfect copy. It even smells right. But the software is broken. The stick feels loose and toylike, the plane banks like an arcade game, and however badly you fly, you can't make it stall.

If the goal is to fly a real plane safely, the cardboard box wins easily. The replica is worse than useless: it trains your hands to believe that sloppy inputs carry no cost. The box, ridiculous as it looks, makes you grapple with the real demands of flight.

Stanley Hamstra and his colleagues (2014) made this argument for medical simulation: functional alignment with the task matters more than physical resemblance. Institutions tend to do the opposite. They pay for polish, which looks good in a brochure, and skimp on function. Think of the beautifully produced training module, with professional narration and handsome graphics, where all you actually do is click Next, and answer a quiz

you can retake as many times as you like. Plenty of physical fidelity. No world answering back.

The real world supplies fidelity by default. Consequences arrive whether or not anyone designed them. A classroom or simulation has to choose fidelity, and most decline to.

Fidelity and Worth

Fidelity and worth both involve real consequences, so they blur together easily. Here's the line. **Fidelity is the world answering back. Worth is someone using the result.**⁴

When Nora's doubled loaf collapsed in Chapter 2, that was fidelity: the chemistry of the dough answering back to what she did, indifferent to her intentions or how hard she'd worked. The feedback was disappointing, and structurally exact. When the family ate the loaf that rose, and asked for seconds, that was worth.

A learner can get plenty of one without the other. A student who writes a derivative essay that follows the rubric and earns an A has received worth of a sort, in the form of a teacher's approval. Whether the essay could persuade anyone was never tested; nothing in the world answered back.

What a learner needs first is a world that answers back

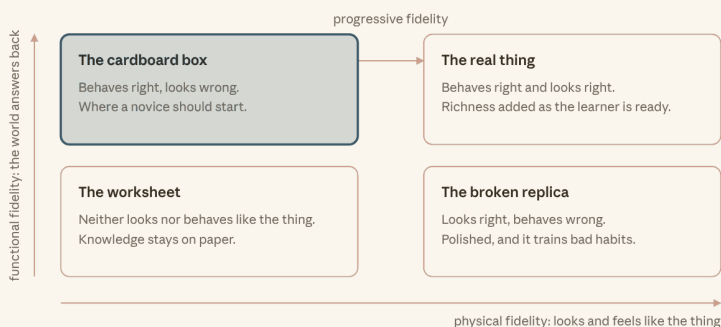


Figure 6.1 · physical and functional fidelity

Start in the upper left, where the world answers back on the thing being learned, and move right as the learner can handle more.

✿ Why Fidelity Works: The Body in Learning

Why should touching the real thing matter so much? We have large, capable brains. Why can't we simply read about it?

The picture of the mind behind most schooling is a brain in a jar: a biological computer, carried from room to room by a body whose only job is transport. Learning, in that picture, is a data transfer. Information goes in through the eyes, gets stored, and the job is done. Plug in the cable and you know kung fu.

Cognitive science, developmental psychology, and neuroscience have spent the last few decades taking that picture apart. Four lines of work point the same way.

Embodiment. Richard Mayer and Logan Fiorella's embodiment principle, in its 2021 form, holds that people learn better when they engage in task-relevant sensorimotor experiences, such as gesturing or handling objects, whether by doing the movements themselves or by watching others do them. An earlier version of the principle concerned only on-screen teaching agents that gesture. The 2021 version extends it to the learner's own body.

Hands on the material. Kira Carbonneau, Scott Marley, and James Selig (2013) pooled 55 studies comparing mathematics taught with concrete manipulatives (blocks, tiles, objects a child holds and moves) against mathematics taught with symbols alone. The manipulatives won, with small to moderate effects overall, moderate to large effects on retention weeks or months later, and smaller effects on problem solving and transfer.

Meaning built from the body. Julia Penn Shaw's Meaning-Events framework (2026) proposes that meaning is organized from the body up, starting in infancy: tracking a moving object with the eyes, the shared timing of a glance between parent and baby and then toward a toy, orienting the body, coordinating eye and hand, reaching for a goal. A baby who grabs a

wooden block, mouths it, and bangs it on the floor is learning that objects have weight, edges, permanence, consequences. Shaw builds on Fischer's dynamic skill theory, in which advanced skills grow out of sensorimotor ones,⁵ and on Erik Erikson's psychosocial stages, and she writes for parents and teachers. In her account, the body stays part of how meaning is made through adulthood, long after abstract thought arrives.

The philosophical root. A century earlier, John Dewey made the same case without any of the instruments. In *Democracy and Education* (1916) and *Experience and Education* (1938), he argued that learning grows from **doing and undergoing**: you act on the world, and then you live with what the world does back. Doing alone is activity. Undergoing alone is passivity. The connection between the two, felt and then understood, is where learning happens.

Dewey's phrase is a good one-line definition of fidelity. The world has to do something back.

The Tension: More Is Not Always Better

Push the argument to its extreme. If minds need contact with the real thing, and the world answering back is what matters, then the best learning tool for anything should be the most realistic replica money can buy. To teach a five-year-old addition, skip the plain wooden blocks and buy perfectly painted, lifelike fake apples.

It seems to follow. The evidence says otherwise.

Realism adds little past a point. Geoffrey Norman, Kelly Dore, and Lawrence Grierson (2012) reviewed studies comparing high- and low-fidelity medical simulators. Both beat no training. And the high-fidelity simulators, with realistic skin and blood and all the expense that implies, added little over the low-fidelity ones when it came to transferring skills to real clinical practice. Their review points toward **progressive fidelity**: simpler simulations for novices, richer ones for experts.

Richness can distract. The same manipulatives research that favored blocks over symbols found that perceptually rich objects can hinder mathematical problem solving. Plain objects let learners focus on the idea the object stands for. And manipulatives were least effective of all for children aged three to six, with very small and sometimes negative effects.

Two Things at Once

Why would a more realistic object teach worse? Because a realistic object is two things at once. It's a thing in its own right, and it's a stand-in for an idea. The more interesting the thing, the harder it is to see through it to the idea.

Sit a five-year-old at a table with two superhero action figures. "If this hero joins that hero, how many heroes are there?" She's looking at the capes and remembering last night's cartoon, one plus one far from her mind, and within ten seconds the two heroes are fighting across the table. The object's richness hijacked the lesson.

A plain gray cube has no cape and no backstory. It's one thing only: a placeholder for a number. It offers little to play with, and it invites her to think with it.

A beginner can be swamped by the full complexity of the real thing. That's the tension: the body needs contact with the world, and too much world at once overwhelms the beginner.

The Resolution: Fit the Fidelity

Fidelity has to be fitted, like challenge.⁶ Nobody hands a beginner a hundred-and-fifty-pound barbell on day one, and nobody should drop a novice into a hyper-realistic, chaotic, high-stakes simulation on day one either.

Functional fidelity comes first. The world should answer back on the part being learned, and only that part, with the rest of the noise stripped away. That's the cardboard flight simulator. Physical richness and full context come in as the learner can handle them: once the core is automatic and working memory has room, add the realistic cockpit, the alarms, the crosswinds. It's

the same logic as the expertise reversal effect from Chapter 5. What helps a novice and what helps an expert differ.

A fair objection: if I'm a medical student practicing an IV on a beige plastic tube that looks nothing like an arm, won't I check out? Won't the fakeness kill the stakes?

Simulation educators answer with what they call the **fiction contract**: an implicit agreement in which learners suspend disbelief and engage as if the situation were real. It's the same agreement you make in a movie theater, where you know perfectly well you're watching light on a screen and cry anyway, as long as the story keeps its own logic. As long as the plastic tube resists the needle the way a vein does, the student commits. When the contract holds, modest realism is enough.

What makes a simulation work is engagement. Give a learner a task with real problem-solving and real consequences, and the mind fills in the visual gaps readily. Give them a rote task without consequences, and no amount of graphics will make them care.

Box: Real Tasks and Representational Objects

"Hands-on" covers two different things.

Real tasks bring the learner into contact with the thing itself: pouring water, setting the table, carrying groceries, making change at a stall. This is high fidelity in this chapter's sense.

Representational objects are physical stand-ins for ideas: beads for numbers, blocks for fractions. They're concrete, and they're models of the structure. The structure itself lies elsewhere, so their fidelity is lower than it looks.

*Representational objects ask for **dual representation**: seeing an object as a thing and as a symbol at the same time. Judy DeLoache's research found this ability still forming in early childhood. Children around two and a half couldn't use a scale model of a room to find a toy hidden in the real room; three-year-olds could. And letting children play with the model first made them worse at treating it as a symbol*

(DeLoache, 1987; 2000). That may explain why manipulatives worked least well for children aged three to six.

Montessori. *Montessori materials look designed around exactly this problem. They're plain. Each varies one quality at a time. They're self-correcting, so the material itself answers back: the cylinder fits its hole or it doesn't. The child chooses them, uses them over long periods, and moves through them in sequence from concrete toward abstract. Those are close to the conditions under which manipulatives work. And Montessori's practical life work (pouring, washing, sweeping) belongs with real tasks.*

Egan. *Kieran Egan's stages point the same way.⁷ In his account, young children's strongest tools are first the body, then story, binary opposites, rhythm, and imagination. They handle abstractions readily when the abstractions arrive as story. A bead standing for a place value is a formal symbol, which draws on tools Egan places later.*

For the youngest learners, then, fidelity likely means full-body contact with real things, carried by story. The age finding comes from comparisons across studies with relatively few young children, so treat it as suggestive for now.

✿ Fidelity in Inquiry and in Practice

Fidelity in Inquiry

High-fidelity Inquiry asks its question of the real thing, and the real thing answers back, often with surprises no textbook would think to include.

An eight-year-old notices that the tomato plants in the garden droop every afternoon, around the hottest part of the day, and look fine again by evening. He forms a perfectly sensible guess: they're thirsty.

He could ask his father, or look it up, and the inquiry would end there. He tests it instead. At noon he waters one plant thoroughly and leaves the one beside it alone. A few hours later both plants are drooping.

The plant's answer overturns his guess. A gardening book might have told him to water plants when they droop. The garden told him something more interesting: water isn't the whole story. Now he has a better question. Is it the heat? The sun? Or is the plant doing something on purpose, folding its leaves in the afternoon to lose less water?

That last possibility is close to what many plants actually do. He got to the edge of it because the real plant pushed back on his first idea.

Fidelity in Practice

High-fidelity Practice answers to a real standard. The reps count because the world checks them.

A ten-year-old helps out at a family farm stand on weekends. Real customers line up holding real vegetables and hand her real bills. She has to total the items, subtract, and count back the change, with the line waiting. Nobody stands over her with a red pen. At the end of the day the adults count the cash box, and it balances or it doesn't. Her arithmetic has consequences, and the world audits it.

The adult beside her is also tuning the fidelity. Early on, the prices are round: a dollar for a tomato, two for a squash. The adult stands close and checks each transaction. That's low cognitive load with high functional fidelity, the farm stand's version of the cardboard flight simulator. As she gets faster and the arithmetic becomes automatic, the prices get messier (\$1.35 a pound, three for \$2.50) and the adult steps back, until one Saturday she's running the box alone.

She's doing exactly what the boy at the coconut stall did. The difference, as the next section shows, is what happens afterward.

Setting Fidelity

If you're designing learning, for a child, a team, or yourself, five rules follow.

1. Start from the goal. Ask which part of the real structure the learner needs to contact, and make sure the world answers back on that part.

Teaching a new employee an inventory system, the core is logging a shipment through the right screens in the right order. The feedback should land on those choices, and on little else.

2. Functional before physical. A cardboard model that behaves right beats a beautiful replica that behaves wrong. A plain black-and-white spreadsheet that correctly calculates the load on a bridge beam teaches more than a photorealistic animation of a bridge that ignores gravity.

3. Progressive fidelity. Begin simple, and add richness, stakes, and context as the learner shows they can handle the core. The farm stand does this: round prices first, messy prices and impatient customers later.

4. Bring consequences in. Where the real thing is available and safe, use it. Let the loaf collapse, let the tomato plant droop, let the code fail to run. Where the real thing is dangerous or costly, simulate the part that answers back. A medical student shouldn't learn on a patient who can die. She needs a monitor whose readings fall when she gives the wrong drug.

5. Connect it back. Contact with the real thing needs Inquiry into its structure before it can travel beyond its setting. You can fix engines in a garage for ten years, with all the fidelity anyone could want, and know nothing about thermodynamics. The knowledge stays in the garage.

The vendor children show what happens without that connection. So that evening, the girl from the farm stand sits down at the kitchen table with her mother, and they look at what she did. She grouped the quarters in fours in her hand to make dollars. Her mother writes it down: $4 \times 25 = 100$. The change she counted back up from \$3.65 to \$5 becomes a subtraction on paper. Practice with the world answering back, then Inquiry into its structure, while the experience is still fresh. That's how what she knows gets out of the cash box and onto the page, and from the page into the next place she'll need it.

The two systems together are what let learning travel. Contact with the real thing anchors the symbols. Inquiry into the structure frees the skill from the place where it was learned.

Try it on something you're learning now. Find one place where you're learning on paper: a tutorial you're clicking through, a leadership book you're highlighting on the couch. Then find a way to let the world push back, even a little. Write the small program from memory and watch it fail. Start the slightly difficult conversation and watch how it lands. Go find the collapsed loaf.

As more of daily life becomes smooth, virtual, and free of consequence, that may take deliberate effort. Minds learn the world by meeting its resistance.

🍷 Open Questions

- How low can fidelity go before engagement drops, and does the floor differ by age?
- What helps learning travel from a real context to an abstract one, and back?
- Does the advantage of real tasks hold for the youngest children, and at what point does the ability to treat objects as symbols make representational materials help?
- Where do virtual and AI-generated simulations fall? Can they supply functional fidelity without physical contact?

🍷 Notes

1. See Chapter 4.
2. See Chapter 2, “What Inquiry Requires” and “What Practice Requires.”
3. See Chapter 3.
4. See Chapter 7.
5. See Chapter 13, “Why Each Line Must Be Raised on Purpose.”
6. See Chapter 5.
7. See Chapter 14.

Sources

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