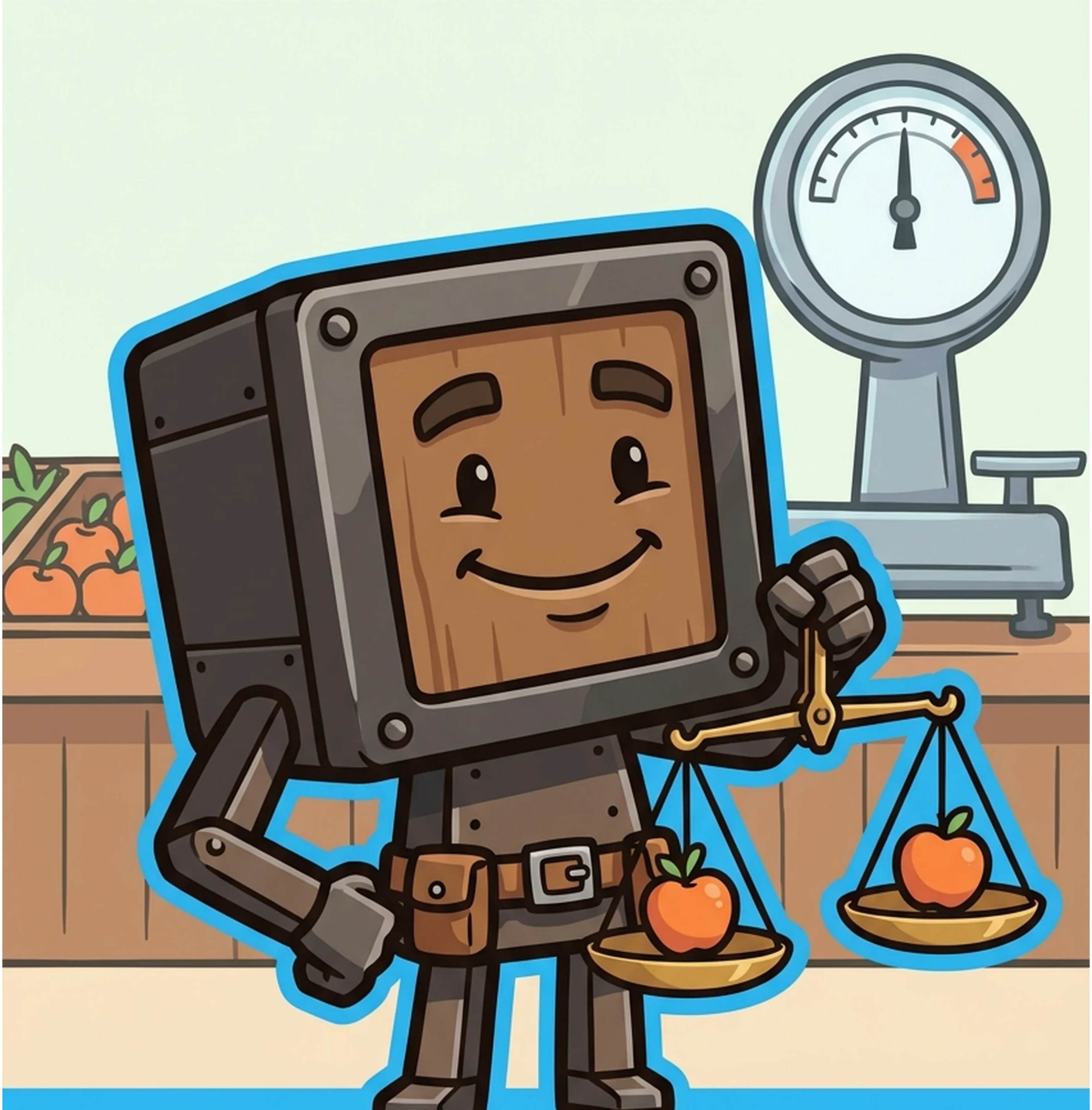

EquationQuest

Meet the Cast

STANDARD EDITION

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This book collects 6 chapter books from the EquationQuest cast — each character embodies a different curricular primitive; together they teach the full subject.

Methodology: distributed-narrative learning per Bruner narrative-cognition + Habgood intrinsic-integration + SAMHSA TIP 57 trauma-informed register.

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##

For everyone who learns by hearing a story first.

Contents

Introduction

The EquationQuest cast was authored to embody the curriculum, not decorate around it.
Each of the 6 characters you'll meet in this book teaches a specific primitive —
a particular tactic, a particular technique, a particular way of seeing.
Together they form an ensemble: the cast IS the curriculum.

Read in any order. Each chapter stands alone.
Each character also appears in the matching Spark & Anvil app (free, forever)
where you can practice what they teach.

— The editors at Spark & Anvil

Flipper

RECIPROCALS — turning a fraction upside down. Multiplying by 1/x undoes multiplying by x. The flipping principle.

Flipper grew up by the sea.

She did not grow up *near* the sea, in the way some children grow up in towns a few miles from the coast. She grew up *on* the sea — her family lived in a small whitewashed house that backed directly onto a harbour wall, and the harbour was full of fishing boats, and the fishing boats had sails, and the sails were made by Flipper's mother, who was the local sail-maker.

Flipper's mother's sail-workshop was attached to the house. It was the largest room in the building — large enough to lay out a full sail flat on the floor and walk around it. Flipper grew up in this room. She learned to read sitting on a half-finished sail. She learned to count by counting grommets along a sail's edge. She learned, very early, that sails come in pairs of decisions: *which way they catch the wind, and which way they release it.*

This is the story of how Flipper became the reciprocal teacher she became.

Sails, Flipper's mother taught her, are *adjustable* in a particular way. When the wind shifts from one direction to another — which it does often, near a coast — a sailor has to *flip the sail* to the other side of the boom. The wind that was pushing the sail to the *right* now pushes it to the *left.* The boat keeps going. The sail does the work in the opposite direction.

This is, technically, a *change of orientation.* It is also, Flipper learned by watching, exactly how a sailor *uses* the new wind. The sail does not have to be *different.* It only has to be *flipped.*

When Flipper was thirteen, her mother let her go out with a fishing boat for the first time. She sat near the boom for the whole trip — six hours, mostly quiet. The wind shifted three times. Each time, the captain (a quiet woman named Reef) called out: *"Coming about!"* — and the deckhands flipped the sail to the other side.

Each time, the boat kept moving forward.

Each time, the sail was *the same sail.* It had just been turned over.

Flipper, who was thirteen and quietly thoughtful, said to Reef on the way back: *"The sail did not change. We just used it the other way around."*

Reef said: *"That is one of the great pleasures of sailing."*

Flipper went home and wrote it in a small notebook her mother had given her. The notebook page said:

"Sometimes you do not need a different tool. You only need to flip the one you have."

She did not know yet that this principle had a name in mathematics. She did not know that the principle was called *reciprocals.* She did not know that *multiplying by 1/x is the same as dividing by x*, or that *flipping a fraction* — turning 2/3 into 3/2 — was a tool that algebra used to undo multiplication.

She learned all of this later, when she was nineteen, at a small mathematics evening class her uncle had insisted she attend. The teacher wrote on the board: *"To divide by 2/3, multiply by 3/2."* Flipper raised her hand. She said: *"Like flipping a sail."* The teacher looked at her, slightly confused. Flipper explained. The teacher laughed for a long time. Then the teacher said: *"That is the best explanation of reciprocals I have ever heard."*

Word got back to the EquationQuest academy. Flipper was invited to come and teach reciprocals. She accepted.

She still carries a small piece of folded canvas in her pocket — a scrap from one of her mother's sails, kept for sentimental reasons. She uses it in class. She unfolds it. She refolds it the other way. She says, calmly: *"This is reciprocal multiplication. The sail is the same. The orientation is different. The maths is the same."*

Children find this surprisingly intuitive. Children draw little sails in their notebooks.

She still goes home to the harbour twice a year. She still helps her mother stitch sails. She still does not negotiate with the wind.

(Reef, the fishing captain, retired ten years ago. She still drops by Flipper's mother's workshop occasionally for tea. She has, on three separate occasions, attended Flipper's classes at the academy as a guest visitor. Children are very impressed by a fishing captain. Reef tells them stories about coming about.)

If you ask Flipper what reciprocals are, she will reach into her pocket and pull out the canvas. She will unfold it. She will refold it the other way. She will say: *"Same canvas. Other side."*

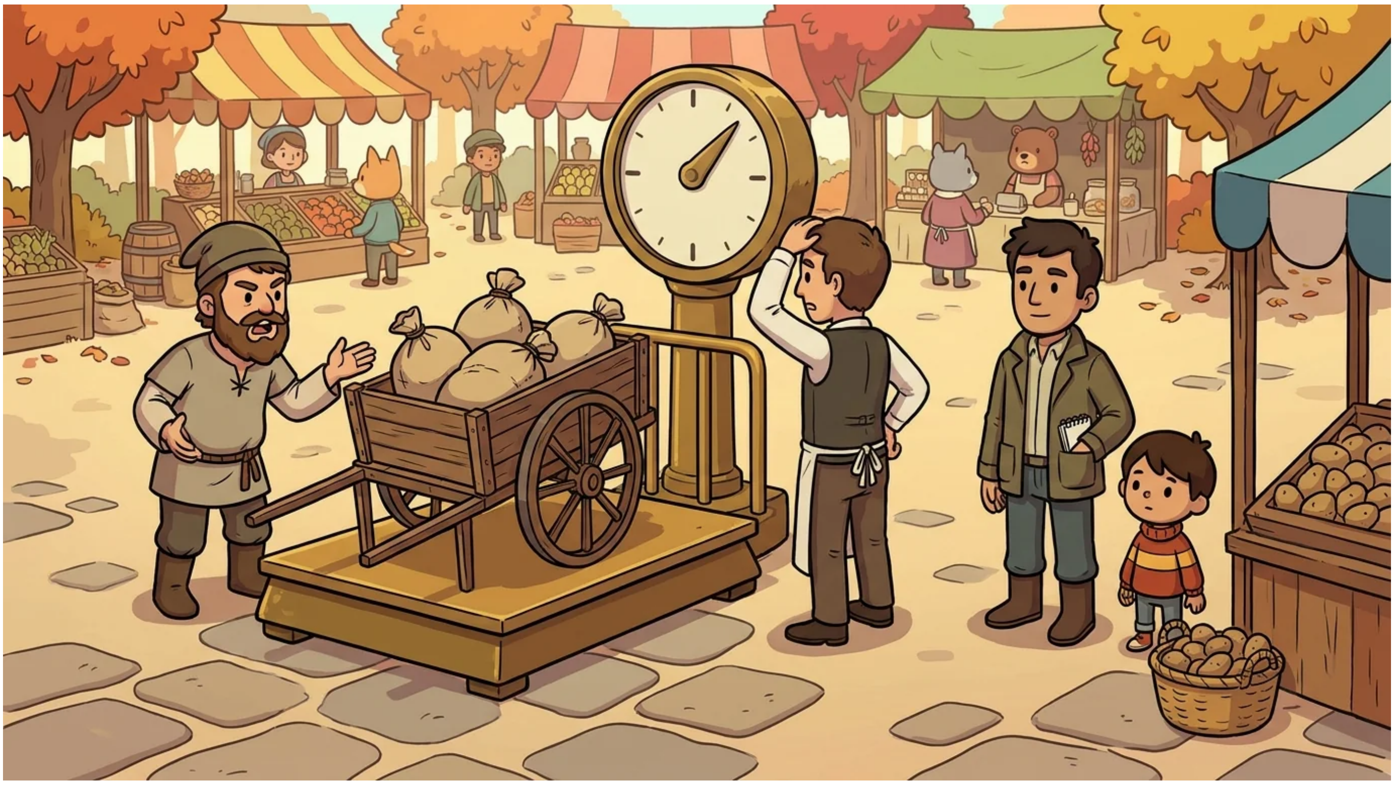
That is, for Flipper, the whole lesson.

Listen along + meet more of the cast at:

https://spark-and-anvil.com/cast/equationquest/flipper

Lever and Solo

BALANCE-AND-ISOLATE — solving any equation requires (a) keeping both sides balanced as you transform it AND (b) moving every other term away from the variable until the variable stands alone. Two operations. One single, shared idea.



A peculiar thing happened at the Pivot market one autumn morning.

A traveling miller arrived at the front gate with his cart. The cart was old — Lever had seen this cart before, perhaps thirty times over the years — and was loaded with sacks of milled flour. The miller wheeled it onto the market's enormous brass scales and waited politely while the clerk took the reading.

The clerk leaned in. He squinted. He wrote a number in his ledger. He looked again. He shook his head.

He said to the miller: *"My friend, your cart weighs five hundred and twenty pounds."*

The miller said: *"That cannot be correct. My cart is forty pounds empty. I loaded twelve sacks of fifty pounds each. That is six hundred and forty pounds total. The cart should read six hundred and forty."*

The clerk said: *"It reads five hundred and twenty."*

The miller said: *"Then your scales are broken."*

The clerk said: *"My scales are never broken."*

This was the moment Lever stepped over from the booth where he had been quietly buying potatoes. He set down his basket. He said, with the particular calm he reserved for scale disputes: *"May I look?"*

The clerk, who knew Lever, said: *"Please."*

Lever opened a small leather notebook and wrote three lines:

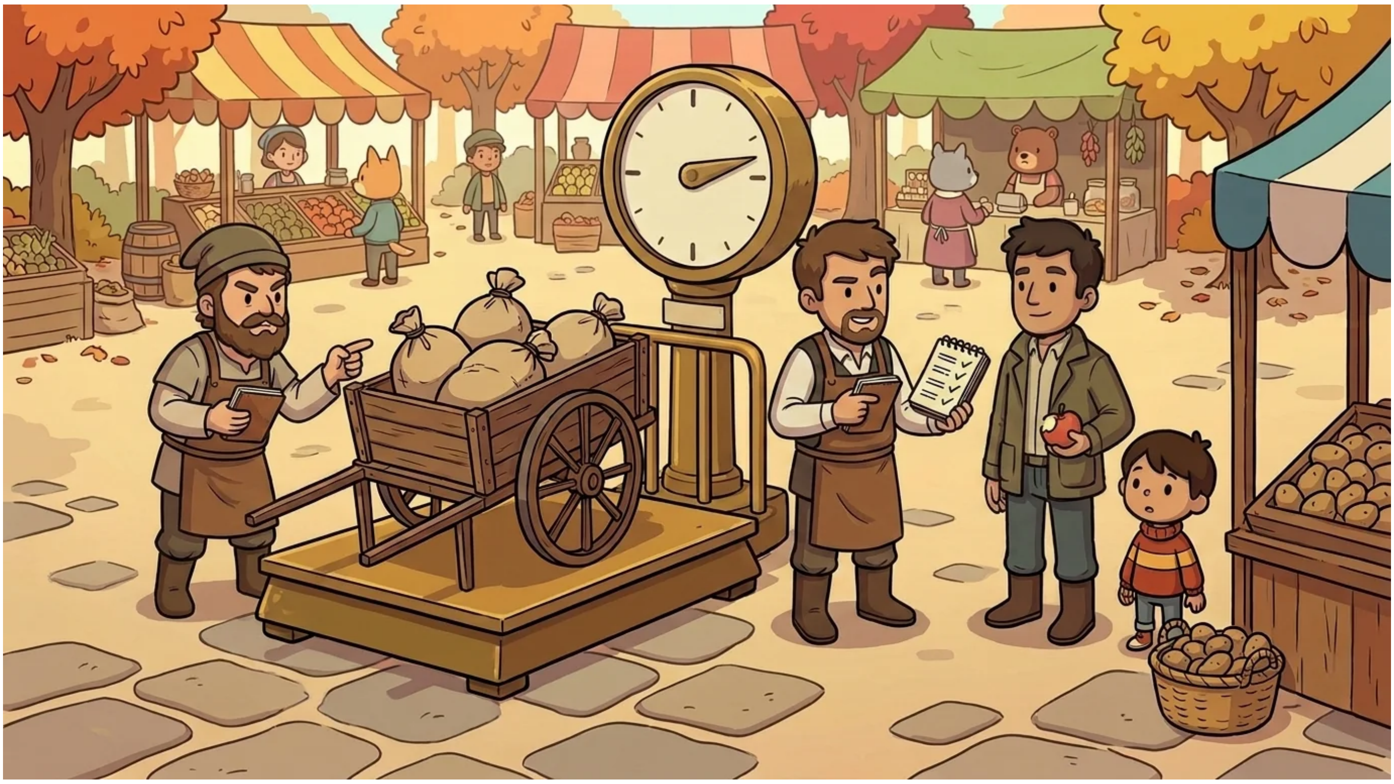
Cart empty: 40.
Twelve sacks at 50 each: 600.
Expected total: 640.

He then wrote: *Actual reading: 520.*

He underlined the difference. *120 pounds missing.*

He looked at the miller. He looked at the cart. He looked at the scales.

"Solo," he said quietly, "I think this is one of yours."



Solo had been browsing the apple-stall across the way. He heard his name and came over. He had a half-eaten apple in one hand.

"What's the problem?" Solo asked.

Lever showed him the notebook. *Expected 640. Actual 520. Missing 120.*

Solo studied the page. He took another bite of the apple.

"So somewhere," Solo said, "the equation does not balance. The miller's side says six-hundred-and-forty. The scale's side says five-hundred-and-twenty. Those are not equal. Something has to account for the difference."

"That something is a variable," Lever said. "We do not yet know its name. We do not yet know its size. We only know its effect. Let us call it *x.*"

Solo nodded. He liked it when Lever called things *x.* It meant they were about to do real work.

Lever wrote on a fresh page in the notebook:

Empty cart (40) + sacks (12 × 50) − x = scale reading (520).

He read it aloud. "Forty plus six hundred minus x equals five hundred and twenty. Solve for x."

The miller, who had been listening, raised both eyebrows. He had not expected algebra to be performed on his cart at nine in the morning. He had expected to be paid for flour.

"Watch this," Solo said to the miller, not unkindly. "It will take fifteen seconds. Lever has done the balancing. I will isolate the *x.*"

Solo set down the apple on the edge of the scale. He took the notebook from Lever. He worked through it out loud, the way he always did in class.

"Start with the whole equation," he said. "Forty plus six hundred, minus x, equals five hundred and twenty. First step: combine the friendlier numbers on the left side. Forty plus six hundred is six hundred and forty. So now we have: *six hundred and forty minus x equals five hundred and twenty.*"

He wrote the new equation on the page.

$640 - x = 520.$

"Now," Solo said. "I want x by itself on one side. So I have to move the six-hundred-and-forty away from x. The six-hundred-and-forty is being added on the left. To move it away, I subtract six-hundred-and-forty. But — and this is the part Lever cares about — *I have to do the same thing to the other side.* Whatever I do to the left, I must do to the right. Otherwise the equation stops being a balance. And the equation stopping being a balance is *Lever's worst nightmare.*"

The miller, despite himself, smiled.

Lever did not smile. But his eyes warmed.

Solo wrote:

$640 - x - 640 = 520 - 640.$

He simplified.

$-x = -120.$

"Now," Solo said, "I have negative-x on the left. I want positive x. So I multiply both sides by negative one. Or — equivalently — I flip every sign. Lever will allow either."

He wrote:

x = 120.

He held up the notebook. "There. The missing weight is one-hundred-and-twenty pounds. The equation balances. The miller's side and the scale's side now agree, *provided we can account for a hundred-twenty-pound something that we have not yet found.*"

The miller said: *"What could weigh a hundred-twenty pounds and be missing from my cart?"*

Lever and Solo looked at the cart.

Then, almost together, they looked at *the back wheel.*

The back wheel was a brand-new wheel. The miller had replaced the old wheel three days ago. The wheel itself was not the problem.

But the old wheel — the one he had taken off — had been a *heavy* solid-oak wheel. The kind of wheel that weighed *about a hundred-twenty pounds.*

"You used to have a wheel that weighed a hundred-twenty pounds more than the one you have now," Lever said. "Your home scales were calibrated with that old wheel on the cart. You weighed twelve fifty-pound sacks against the *six-hundred-forty figure* you've used for a decade. You expected the same six-hundred-forty here. But the new wheel is lighter. The cart-empty figure is now forty pounds, not a hundred-and-sixty. The math works out."

The miller stared at the cart. Then at Lever. Then at the notebook. Then at his own fingers.

"Oh," he said. "*Oh.*"

He laughed. It was a slightly embarrassed laugh.

"I owe you fifteen pounds," he said. "I have been undercharging for flour for three days. The cart was lighter. The flour was the same. The customers got more flour per coin than they should have."

"Don't undo it," Lever said. "Customers always remember a baker who gives them a little extra. Recalibrate tomorrow."

That evening, Lever and Solo walked back together along the road from the market toward the academy.

"That was a fun one," Solo said.

"It was," Lever agreed. "Two principles. One cart."

"The miller didn't even know he was solving an equation," Solo said. "He just thought he was weighing flour."

"All trade is equation-solving," Lever said. "Every cart that comes onto the scale is a balance problem. Every transaction has an unknown until someone names it. Once you can name the unknown — once you can call it *x* — you can move every other term out of the way and find it."

"Balance," Solo said.

"And isolate," Lever said.

"That's it," Solo said. "That's the whole job."

"That's the whole job," Lever agreed.

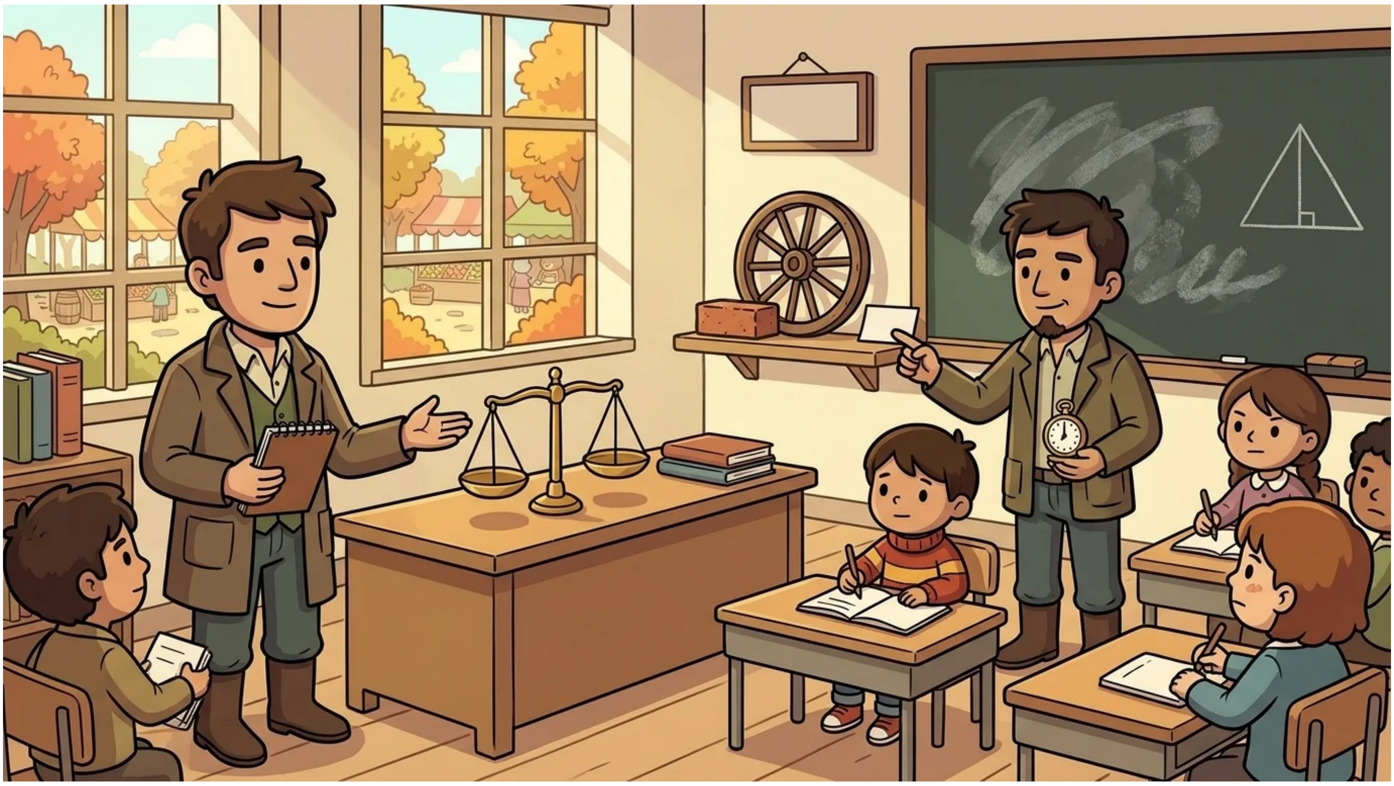
They walked on for a while.

"Lever," Solo said, after a moment. "Do you ever think we should put this on a poster for the classroom? *Balance both sides. Isolate the variable.* Something the kids can stare at while they're stuck."

"I have tried," Lever said. "Three times. Every time I write it on a poster, the poster looks *flat.* The principle is alive when you do it. On a poster it looks like a rule. And kids don't trust rules. They trust *stories.*"

"Then we keep doing stories," Solo said.

"Yes," Lever said. "We keep doing stories."



The next morning, in Lever's classroom, the brick that had started his teaching career sat as always on its shelf. *The equation is a balance.*

Lever had added something new beside it.

A small wooden wheel-spoke. Picked up from the miller's discarded old wheel, carried home in his pocket, set carefully on the shelf next to the brick. A small handwritten label underneath:

A hundred and twenty pounds. Once you can name what is missing, you can find it.

The kids would ask about it that afternoon. He would tell them the cart story. He would tell them about Solo arriving with half an apple. He would tell them that the miller had walked away laughing because the scale had told the truth, and Solo had isolated *x*, and the truth turned out to be a wheel.

He would, at the end of the story, set a small pair of brass balance-pans on his desk.

He would say: *"Balance both sides. Isolate the variable. That is the whole job."*

The kids would copy it into their notebooks. Some of them would believe it. Some of them would not believe it yet. By the end of the year, all of them would.

Listen along + meet more of the cast at:

`https://spark-and-anvil.com/cast/equationquest/lever-and-solo`

Lever

BALANCING — the foundational principle that an equation is a balance, and whatever you do to one side you must do to the other.

Lever is a small, square, sturdy character who carries a balance scale with him almost everywhere he goes. The balance scale is, by his own admission, not strictly necessary — he could explain everything he teaches without it — but he likes carrying it. He says it reminds him *why he started.*

Lever grew up in a town called Pivot, on the kingdom's central plain. (Pivot is, as the name suggests, named for a kind of mechanical joint. The townspeople have, over generations, mostly stopped finding this funny.) His family did not run a mill, or a forge, or a farm. His family ran a *fruit-and-vegetable market*, the largest in the central plain, with twenty-three stalls and one very large set of weighing scales at the entrance.

The scales were enormous. They had two flat brass pans, each about the size of a large dinner plate, hanging from a wooden beam that pivoted on a brass pin. The beam was four feet long. The pans were the heaviest things in the market. The whole assembly weighed about as much as a small pony.

Lever grew up watching customers weigh fruit on those scales.

He spent, by his own count, approximately ten thousand hours watching people put apples on one pan and brass weights on the other. He watched until he was eleven years old, by which time he had noticed something his family had stopped noticing.

What Lever had noticed was this: the scales were *honest.* You could not cheat them. You could not, by tilting your head or by hoping very hard, make them say something untrue. If you put two pounds of apples on one pan, you needed two pounds of brass weights on the other pan to balance them. *Exactly two pounds.* Not one and a half. Not three. The scales did not negotiate.

This was, to Lever, the most interesting thing in the world.

He was, at eleven, given his own small set of scales by his grandmother. They were a beautiful set — wooden, palm-sized, with little tin pans. Lever weighed everything in his house. He weighed his shoes. He weighed his lunch. He weighed his cat (who did not enjoy this). He weighed feathers, and stones, and coins, and once, memorably, his sister's hair-ribbon. He kept a small notebook full of weighings. He thought of himself as a *honest-numbers detective.*

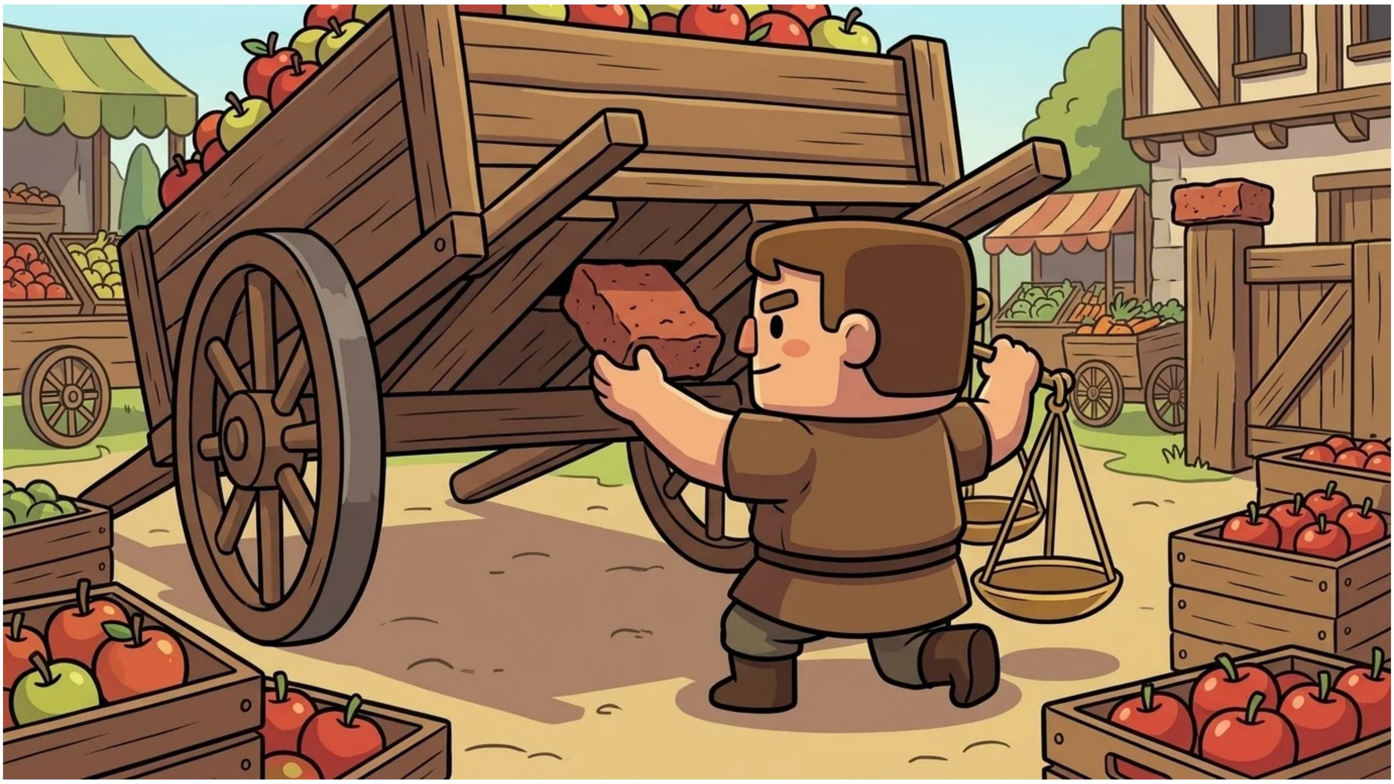
One spring afternoon, when Lever was twelve, an event occurred at the market that he has never forgotten.

A customer arrived at the front gate with a cart full of apples. The cart had been weighed at his orchard before he left. The cart weighed, according to his own scales, two hundred and forty pounds.

He arrived at the market scales. The scales said two hundred and fifty pounds.

The customer was annoyed. The market clerk was confused. The customer said he had been cheated somehow. The clerk said the market scales were honest. Lever, who was watching from a stall, did not say anything. He had been thinking.

After about a minute, he walked over to the customer's cart. He looked at it. He walked around it. He looked underneath it.



There was a brick under the cart.

Somebody — probably a child, somewhere on the road from the orchard — had wedged a brick into the underside of the cart, between two of the wooden slats, as a joke. The brick weighed ten pounds. The cart weighed two hundred and forty pounds. The brick weighed ten pounds. The total weighed two hundred and fifty pounds.

The customer's scales were right. The market's scales were right. The brick was the difference.

Lever pulled the brick out. He showed it to the clerk. The clerk laughed. The customer laughed. Both sides paid for the apples — by weight — *minus the ten pounds of brick.* Everybody went home happy. The brick was placed on the gatepost where it could be seen by future cart-drivers, as a kind of friendly warning.

This was the day Lever understood what would later become his job.

The day's lesson was: *the scale told the truth.* The scale could not have *known* the brick was there. But because the scale *did not negotiate*, the brick had to be accounted for. You could not just *decide* the cart weighed less. If you wanted the apples-only weight, you had to remove the brick. From both sides of the problem. From the cart. From the count.

This is, in algebraic terms, *isolating a variable by doing the same thing to both sides.*

When the EquationQuest academy invited Lever to come teach the balancing principle to children, Lever brought the small wooden scales his grandmother had given him. He still uses them in class. He still uses the brick story. The brick itself — the actual brick, from the gatepost — is now on a shelf in his classroom, with a small label that says *"the equation is a balance."*

He is, as you can probably tell, a patient teacher.

He still goes home to Pivot once a year to help with the harvest weighings. He still does not negotiate.

Listen along + meet more of the cast at:

`https://spark-and-anvil.com/cast/equationquest/lever`

Solo

ISOLATING A VARIABLE — getting x alone on one side of the equation by patiently moving every other term to the other side.

Solo grew up in the largest family in the town of Quint. The town of Quint is small. Solo's family was, by official town-records count, *nine children*, *two parents*, *one grandmother who lived in the back room*, *two dogs*, *one cat*, and *one tortoise who is technically still alive at the age of fifty-three.* That is, in total, sixteen heartbeats under one roof.

Solo was the seventh of the nine children.

He learned, very young, that there was no such thing as *finding somebody* in his house. There was only *moving everything else out of the way until you found them.*

If you wanted to find your mother, you did not call out *"Mother!"* (You did not call out anything in the house, because if you called out, every other person in the house would hear you, and at least three of them would think you were calling *them*, and you would suddenly have a queue.) Instead, you walked through the kitchen, looked. Walked past the playroom, looked. Walked around the cousin who was sleeping in the hallway, looked. Walked up the stairs, looked. Eventually, in the linen cupboard or the garden shed or the bench by the well, you would find your mother.

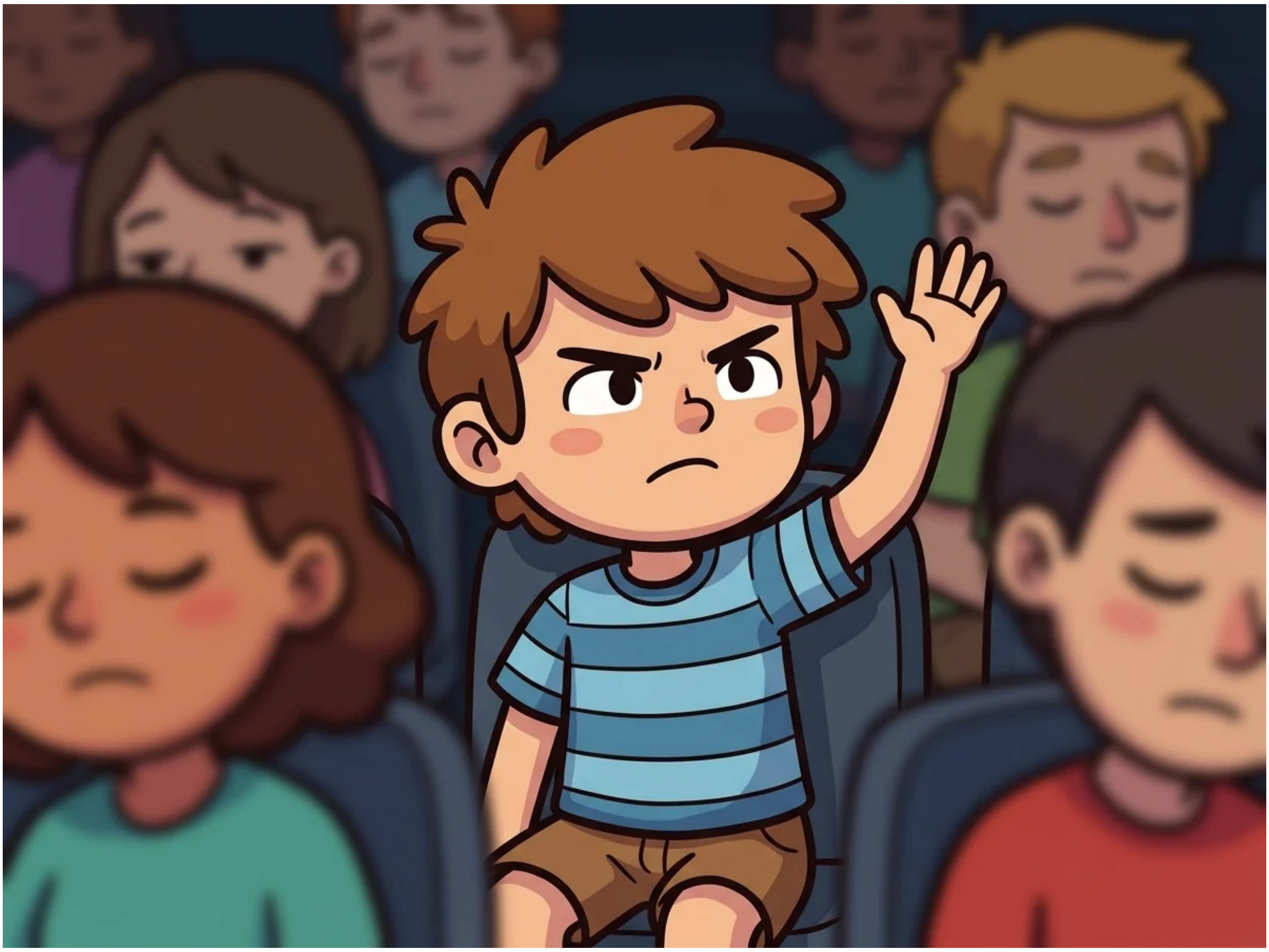
This took, on average, six and a half minutes.

Solo had figured out, by the age of nine, that *finding* anybody in his family was the same as *removing everything else.* You did not search for the person. You eliminated the non-persons. When everything else had been moved aside, the person remained.

This was, although Solo did not know it yet, *the principle of isolating a variable.*

In algebra: you do not search for x directly. You remove every other term from x's side of the equation, one at a time, by doing the opposite operation. You add or subtract constants. You multiply or divide coefficients. You unbuild the layers. When everything else has been moved away from x, x is left, *alone* — and you have your answer.

Solo found out that this had a name when he was sixteen. A travelling algebra teacher came through Quint giving a free lecture in the town hall. (Quint was small enough that any travelling lecturer attracted approximately the entire town.) The algebra teacher wrote, on a small chalkboard, the equation: $2x + 7 = 19$. She said to the audience: *"How do we solve this?"*



Most of the audience did not raise their hands. They were tired. They had come for entertainment, not algebra.

Solo, who was sitting in the back row, raised his hand.

The algebra teacher said: *"Yes?"*

Solo said: *"You move the seven away from x. By subtracting seven from both sides. Then you move the two away from x. By dividing both sides by two. Then x is alone. And x is six."*

The algebra teacher said: *"That was extraordinarily quick. Where did you learn that?"*

Solo said: *"I have eight siblings."*

The algebra teacher laughed. She thought he was making a joke. He was not making a joke. He was telling her exactly where he had learned it.

She walked over to him after the lecture. She asked him a few more questions. Then she said: *"Have you considered teaching mathematics?"*

Solo said: *"I have considered leaving my house."*

The algebra teacher, who was wise, understood that these two desires were, for Solo, the same desire.

He came to the EquationQuest academy six months later, at seventeen. He arrived with one small suitcase. He had, by his own count, the first private bedroom he had ever had in his life.

He has been teaching at the academy for twenty-two years.

He still goes home to Quint twice a year, for Midsummer and Midwinter. He still loves his family. He still has eight siblings (everybody is alive; the tortoise is too). He still finds people by eliminating non-people.

When children come to his class for the first time and ask, nervously, whether the technique of *isolating a variable* is hard, Solo always says the same thing:

"You don't search for x. You move everything else away from x. One step at a time."

He adds, after a small pause:

"It also helps if you don't shout."

(Children find this confusing. Solo, after another small pause, sometimes explains. Sometimes he just lets them wonder.)

Listen along + meet more of the cast at:

`https://spark-and-anvil.com/cast/equationquest/solo`

Spread

DISTRIBUTIVE PROPERTY — multiplication distributes over addition: a(b+c) = ab + ac. The expanding principle.

Spread worked, for fifteen years, at the central printing press of the capital city. The printing press was — and still is — the largest in the kingdom. It printed books, broadsheets, school texts, and the occasional poster announcing royal proclamations. It was a busy place. It smelled, faintly, of ink and damp paper and warm metal.

Spread's job was *inking the type.*

This was a specific job. The printing press worked by setting metal letters into a frame — *typesetting* — and then pressing inked paper down onto the frame. For the letters to print clearly, every letter had to receive the same amount of ink. Too little ink and the letter came out faint. Too much ink and the letter smudged.

To ink the type, Spread used a *roller.* It was a large roller, about the size of a forearm, made of a particular kind of soft rubber that held ink well. She would roll it across a pad of ink to load it, and then roll it across the typeset frame — once, twice, sometimes three times — until every letter in the frame had received its share.

This was the magical part, to Spread: *one roll of the roller distributed ink to every letter at once.*

Whether the frame held four letters or four hundred, the roller did the same thing. It rolled across. It deposited a thin even layer of ink. Every letter got its fair amount. The roller did not have to *think about* which letter was which. The roller did not have to *aim.* The roller just rolled, and the ink *spread* across all of them.

Spread thought about this for fifteen years.

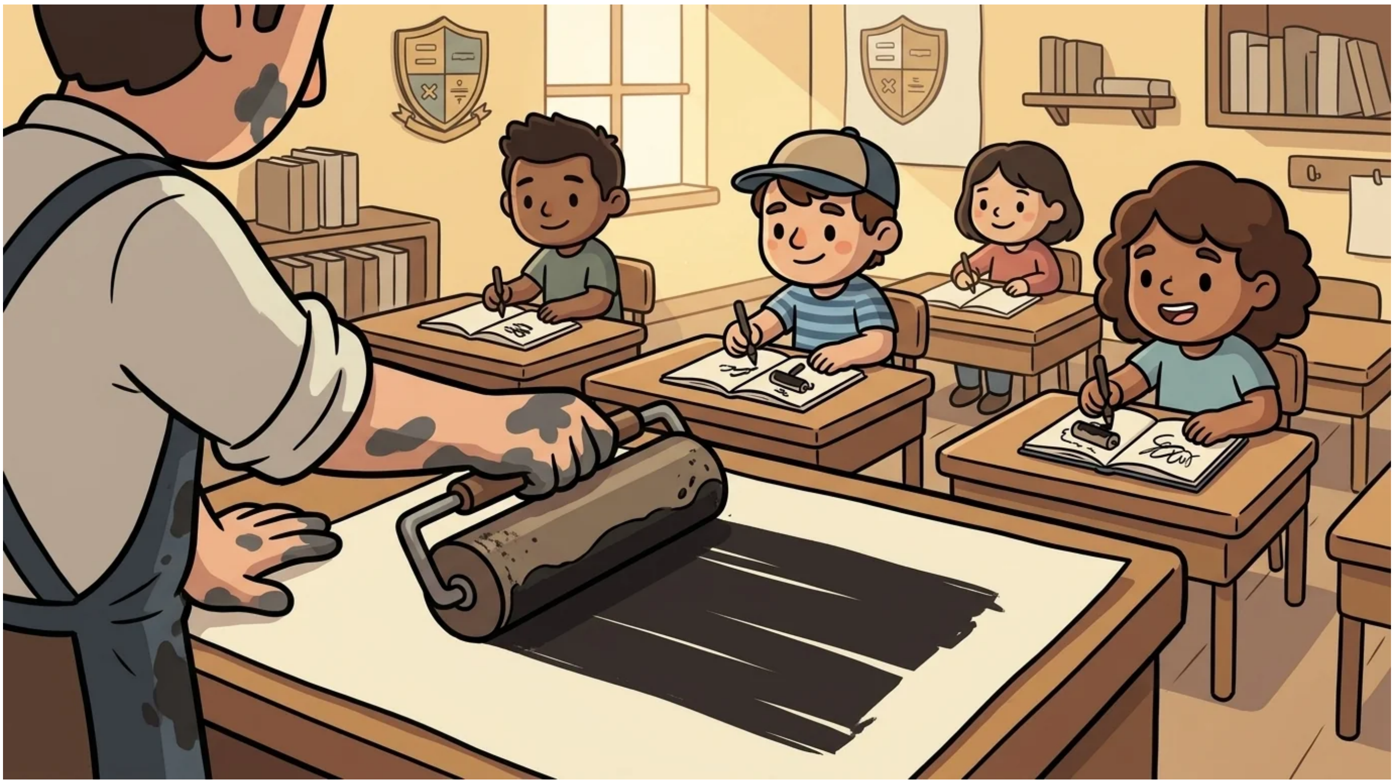
What she eventually realised — and she realised it in a particular evening in winter, when she was thirty-three, sitting at her workbench drinking tea after the day's print run — was that the rolling-the-ink operation was *deeply parallel.* The roller did the same thing to every letter simultaneously, with no extra effort for additional letters. If she rolled across a single letter, she used a small amount of ink. If she rolled across a hundred letters, she used a larger amount of ink — but she did the same *single* motion. The ink was distributed *uniformly* across whatever was in front of the roller.

This was, although Spread did not yet know it had a name, *the distributive property.*

In algebra: when you multiply a quantity by a sum — say, $3 \times (5 + 7)$ — you can *distribute* the 3 across the 5 and the 7. You get $3\times5 + 3\times7$. The multiplication "rolls across" each term. The result is the same whether you compute $3 \times 12 = 36$, or $15 + 21 = 36$. The distributive property says these two are equal.

When Spread realised the connection between her roller and algebra, she set down her teacup. She sat for several minutes. Then she stood up, walked to her workbench, and wrote a small note to herself:

"The roller does what the parenthesis does. Multiplication rolls across each term inside."



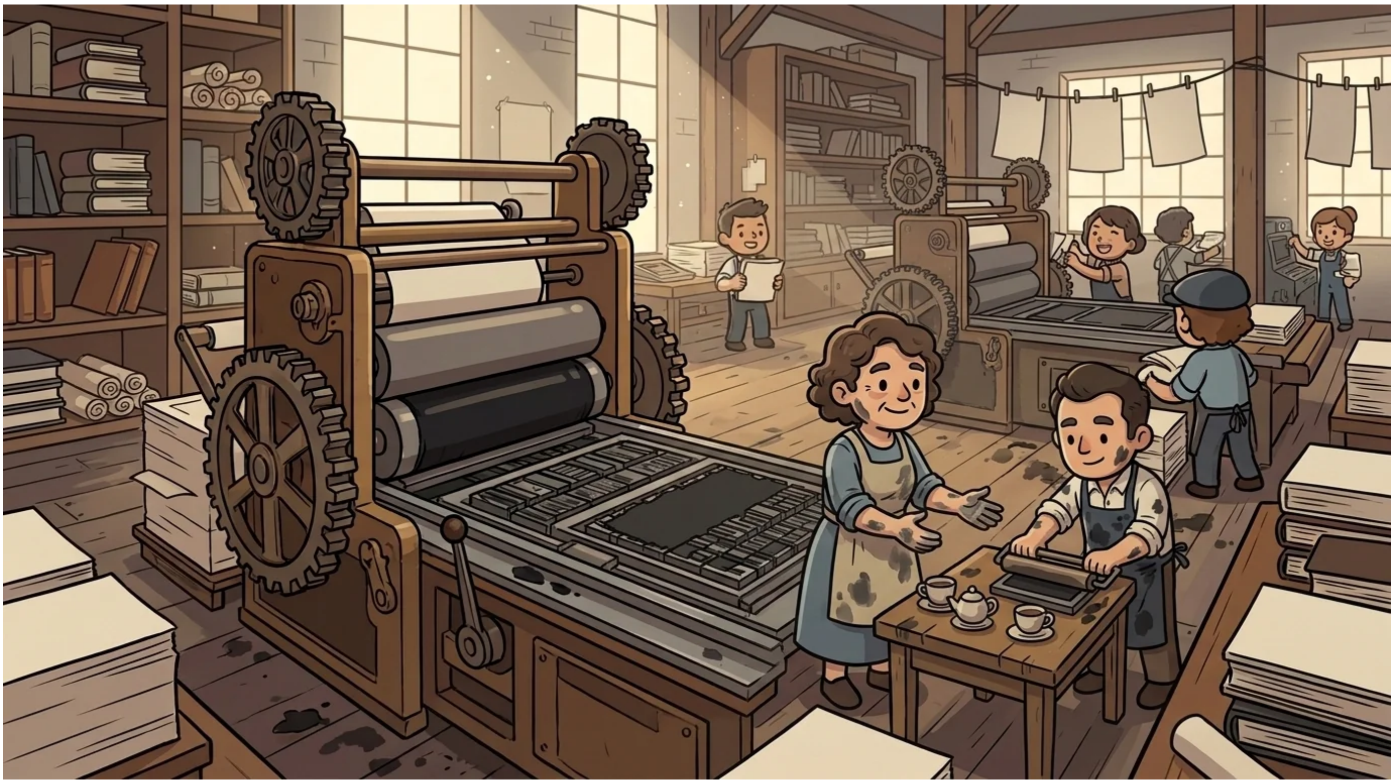
She kept the note. She still has it. It is taped to the inside of her classroom door.

A year later, when the EquationQuest academy was looking for someone to teach the distributive property to children, a printer who knew her by reputation mentioned her name. The academy master wrote her a letter. Spread, who was thirty-four and ready for a slight change of pace, accepted.

She arrived at the academy with her old roller (her colleagues at the press had given it to her as a leaving gift). She still uses it in class. She rolls it across a sheet of paper with five large letters written on it. She watches the children watch the ink land. She says: *"The roller rolled once. Every letter got ink. That is multiplication distributing across addition."*

Children find this unusually clear, which is exactly the effect Spread intended. Children draw little rollers in their notebooks.

Spread's hands are still slightly inky, fourteen years after she left the press. The ink, her colleagues used to joke, *takes about a generation* to fully come out. Spread does not mind. She likes the small grey stains. They remind her, every time she looks at her hands, of the principle she teaches.



She still visits the press once a month. She has tea with the new chief inker, who was apprenticed under her. The new chief inker is also patient. The new chief inker is also slightly inky.

When children come to Spread's class for the first time and ask, nervously, whether the distributive property is hard, Spread always says the same thing:

"It isn't hard. It's just the roller. You multiply across each term inside the parentheses. The roller does the same thing to every letter, all at once."

She holds up her hands. They are slightly grey.

She adds: *"It also helps if you don't mind a little ink."*

Listen along + meet more of the cast at:

`https://spark-and-anvil.com/cast/equationquest/spread`

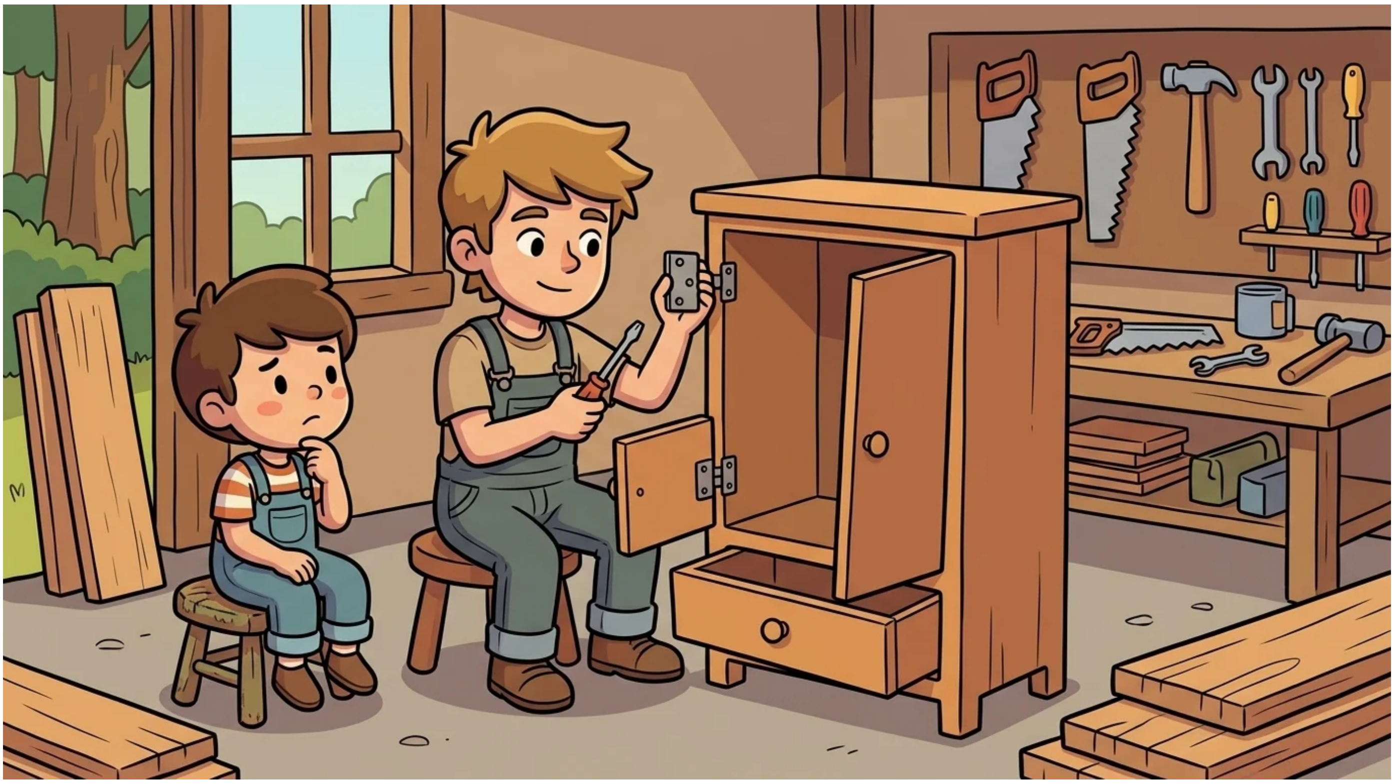
Undo

INVERSE OPERATIONS — every operation has an undo. Addition undoes subtraction. Multiplication undoes division. Squaring undoes square-root.

- "MATH"
    - "LAB"

Chapter 2 — Undo and the Cabinet That Wouldn't Open

Undo grew up next door to Lever, in the town of Pivot. They have known each other since they were three years old. They walked to school together. They walked home together. They were, in the way that close childhood friends sometimes are, *partly the same person* in their own thinking, though they each grew up to be very different teachers.



Lever — as you have already heard — grew up watching the brass scales at his family's market. Undo grew up watching her brother build cabinets.

This is the story of how she became the kind of teacher she became.

Undo's brother, whose name was Joist, was a carpenter. He was nine years older than Undo. From the time Undo was small, she would sit on a little stool in Joist's workshop and watch him build. He built chairs, tables, shelves, doors. His favourite things to build, though, were *cabinets.* Cabinets with drawers. Cabinets with hinges. Cabinets with doors that swung and latched and stayed shut and opened cleanly when you wanted them to.

Joist's cabinets were beautiful. Customers came from three towns over. He was, the local carpenters' guild had told their mother, *"unusually patient."*

What Undo noticed, sitting on her little stool, was that Joist did something at the end of every cabinet that no other carpenter she had watched did.

He *unbuilt* it.

Not completely. Not destructively. He would, after spending two weeks building a perfect cabinet, take it almost entirely apart again. He would pull each drawer out and slide it back in. He would unscrew each hinge and screw it back on. He would test every joint by pulling on it in the opposite direction it was meant to hold. He would, in short, *undo* every piece of his own work, and then put it all back together.

Undo, who was seven, asked him why.

Joist said: *"I do not trust a joint I have not undone."*

She thought about this for the rest of the day.

What she eventually understood — and she understood it slowly, over several years of watching — was that every step in building a cabinet was the *opposite* of some step in taking one apart. If you nailed a board, the opposite was *pulling the nail.* If you glued a joint, the opposite was *separating the joint with a thin blade.* If you screwed in a hinge, the opposite was *unscrewing the hinge.* For each action, there was an action that *exactly reversed* it. And Joist insisted on knowing all of them.

This was, Undo realised much later, *exactly the principle of inverse operations.*

In algebra: if you added five to one side of an equation, the operation that exactly reverses it is subtracting five. If you multiplied one side by three, the operation that exactly reverses it is dividing by three. If you squared a quantity, the operation that exactly reverses it (for positive numbers) is taking the square root. Every step has an undo. *Every step.* If you do not know the undo, you cannot trust the step.

When Undo arrived at the EquationQuest academy at nineteen — with a small toolbox her brother had given her containing six different small implements, each of which was a *reverse* of some carpentry action — the academy master watched her for a few minutes and said, *"You will be teaching inverse operations. Welcome."*

Undo has been teaching ever since. She still keeps the toolbox in her classroom. She uses it as a demonstration. She holds up a hammer. She says: *"This puts a nail in."* She holds up the back end of the hammer, which has a small claw. She says: *"This takes a nail out. They are the same tool. They are the same idea, in two directions."*

Children remember this. Children draw little hammers in their notebooks.

There is a story she tells, every year, in kit 8. It is a true story. Joist built a cabinet for a customer once — a beautiful corner cabinet — and the customer, after taking it home, sent a letter back saying the cabinet's main door *would not open.* Joist was, briefly, panicked. He could not understand. He had tested the door. He had opened and closed it a hundred times. He went to the customer's house. He looked at the cabinet.

The customer had put it in a corner. The door, when fully open, was supposed to swing out to the *left.* The wall on the left was four inches away. The door could not open more than a quarter of the way.

The cabinet was fine. The *room* was the problem. Joist suggested moving the cabinet six inches to the right. The customer did. The door opened cleanly.

Undo tells this story when teaching kit 8. She uses it to explain that *sometimes the equation is fine, but the situation is wrong.* Sometimes you have to step back and check that the *room around the equation* makes sense — that the variable can actually take the values you are letting it take. (Mathematicians call this *checking the domain.* Undo calls it *moving the cabinet six inches to the right.*)

Listen along + meet more of the cast at:

`https://spark-and-anvil.com/cast/equationquest/undo`

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Methodology

Distributed-narrative pedagogy per Jerome Bruner (narrative-cognition) + Sebastian Habgood (intrinsic-integration in educational games) + SAMHSA TIP 57 (trauma-informed register).

Trauma-informed-design framework per Eggleston et al. (2025) and Stoltenburg et al. (2024).

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