**Murmurations** emerged as a project by a community of educators who recognize that education and its results arise from interactions of historical, social, political, psychological, biological and environmental factors. As a U.S. institution, education has most reliably produced inequity. We began *Murmurations* with the intent of dissolving the dynamics that support and re-create inequitable educational outcomes.

*We are not separate from the systems we wish to transform.*

We invite you to reflect with us, examining the relationship between thought, action and the dynamics of the educational systems in which we participate.

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What is Engineering?
A graphic essay of tech and philosophy

Mel Chua
Center on Access Technology, National Technical Institute for the Deaf Rochester Institute of Technology, Rochester, NY 14623
mel.chua@rit.edu
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Abstract

Point of View: I’m a contagiously enthusiastic hacker, scholar, and teacher with an industry background in Free and Open Source Software (FOSS) communities. As a teenager at the Illinois Math and Science Academy, I loved storytelling and cinematography and wanted to major in the arts. That wasn’t an option for my family of immigrants, so I took up electrical and computer engineering at Olin College (BS), where I arrived thinking that a breadboard was for baking (it’s for electronics). I am Deaf and have always been a strong visual thinker; this piece was written and drawn during my first semester as a PhD student in engineering education at Purdue University. I’m intrigued by how multiple interacting curricular cultures in higher education can deconstruct our notions of engineering, education, and just about everything else.

Value: This work is a playful contribution to engineering education ontologies (as a subset of philosophy), which explores questions of reality and being - what “is.” It challenges the high consensus culture of engineering, especially the tendency to seek clearly defined and fixed meanings for terms. In this case, the notion of "engineering" itself is called into question. It also explores what graphical/non-textual scholarship in and about higher education might look like.

Summary: This graphic essay was made when I was a first-semester engineering education graduate student. This past self was naive regarding "scholarly" and "academic" writing conventions, and frustrated both by the limitations of text as a standalone medium and the engineering disciplinary tendency to seek clearly defined and fixed meanings for terms rather than exploring their possibilities. I am now a slightly more seasoned scholar seven years down the line with a desire to engage in discussion and revision of the piece.

Note to readers: This document consists of a comic submission which is meant to be experienced visually: What is Engineering? Each page of the comic is presented separately here, followed by text descriptions for that page. Text descriptions are provided for access.
WHAT IS
ENGINEERING?

A GRAPHIC ESSAY
OF TECH AND PHILOSOPHY

PROUDLY DRAWN
BY AN ENGINEER
ON ENGINEERING PAPER
AT 2AM

MEL CHUA
<mel@melchua.com>
CC-BY-SA 2011
The title, "What is Engineering?: A graphic essay of tech and philosophy" is written across the top. Below it, a realistic line drawing of a pair of ordinary-looking eyeglasses takes up most of the page.

"Proudly drawn by an engineer / on engineering paper / at 2AM" is written in small type below the glasses.

The author’s name, email, and licensing information is also written beneath the glasses:

Mel Chua
<mel@melchua.com>
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The cover is labeled as page 0/5, and is drawn with a black pen on engineering paper. In fact, the entirety of the comic is drawn with a black pen on engineering paper, with hand-lettered words and semi-realistic line drawings throughout. Numbers in brackets (like [0]) refer to notes and references listed at the end of the work, and are shown as small numbered circles in the original drawings.
What does the world look like through this lens?

It depends on the person who wears them and the type of world they see.

Of course, the simple answer is to define it socially. Engineering is what engineers do.°

I define standards for IEEE.
I design and test robots.
I build bridges.
I fixed my board!
I'm in law school now.

I never got a degree, but I'm always inventing electronics in my basement.

I apply math and science to the real world...through research in my lab!

Engineering is problem-solving. "

Sometimes this doesn't help an awful lot with clarity. We want a nice clean answer.°"
Page 1

Panel 1.
The pair of glasses from the cover now rests on a table, with a paper tag labeled "engineering" dangling from it. (This image of engineering as a pair of glasses will recur throughout the piece.) A text box indicating voiceover narration floats on top of the image, beginning: "What does the world look like through this lens?"

Panel 2.
A hand reaches out to take the glasses. It is neatly manicured and appears to belong to a white person. The narration continues: "It depends on the person who wears them and the type of world they see."

Panels 3-6.
This is a series of four images with a similar layout. In each frame, a person wearing the "engineering" glasses stands on the left with their back to the viewer, so it is as if we are looking over their shoulders at the scene. Each scene is overlaid with some kind of engineering diagram.

The first image shows a muscular blond man in an athletic top looking at a pair of ballet dancers balancing each other in a tricky pose. A free-body diagram is superimposed over the dancing pair, showing the angle of tilt, forces acting on their limbs, and so forth.

The second image shows a raven-haired woman in a doctor's coat looking at a young child sitting on an examination table, their arm in a cast. A stress-strain diagram and an image of the fractured bone is superimposed on the wall behind the child.

The third image shows a black man in a t-shirt looking at containers of milk in a refrigerated grocery store display. Superimposed over the rows of jugs and cartons is a recycling symbol and a drawing of the assembly line that manufactured the milk jugs, with tubes and gauges and nozzles descending towards one jug in a demonstration of how it would have been filled with milk.

The fourth image shows a woman with a short bob haircut, pearls, and a formal striped shirt looking at a young bearded man in suit and tie holding up a sales document. A flowchart is superimposed over this image, framing the sales document in one of its boxes; a decision tree of "hold" or "sell" is partially visible within the frame.

Panel 7.
The narration continues, "Of course, the simple answer is to define it socially. Engineering is what engineers do." Seven people are arrayed in a line beneath this narration, all wearing "engineering" glasses and speaking simultaneously. The leftmost speaker is a woman in a dress and heels, holding a folder and saying "I define standards for IEEE." Beside her is a man with a buzz cut in a polo shirt, hands clasped in front of him, saying, "I design and test robots."

Next to him is a little curly-haired girl in skateboarding gear, clutching her deck and exclaiming, "I fixed my board!" Next to her is a man in a sweater and slacks holding his Professional Engineer license, saying "I build bridges." Next to him is a bearded man in a wheelchair wearing a tie, gesturing expansively with his right arm and saying "I'm in law school now." Next to him is a short-haired woman in a "geek" t-shirt, hands on hips, stating "I never got a degree, but I'm always inventing electronics in my basement." Finally, there is a woman with a ponytail in heavy boots and a thick lab smock, holding a beaker full of chemicals in gloved hands. She gestures with her index finger as she says "I apply math and science to the real

world... through research in my lab!"

The narration continues: "Sometimes this doesn't help an awful lot with clarity. We want a nice clean answer. Here's one."

Next to this, "Engineering is Problem-Solving." is written in thick dramatic script across the whole bottom of the page. The period at the end of that sentence is prominent, and labeled "Period! Full stop."

"Or is it?" the narration continues.


WHAT IF WE UNPACK THAT BLACK BOX?

FIRST, THAT THE WORLD IS FULL OF PROBLEMS

IT DOES PRESUPPOSE AT LEAST TWO THINGS

THIS WILL OCCASIONALLY GO HAND IN HAND WITH THE BELIEF THAT WE SEE THE WORLD...

Glare containing H2O equivalent to 60% of its volume.

"OBJECTIVELY."

Problem: small child may break glass.

Problem: waste of glass, do not need such a large vessel.

AND THAT THEY CAN BE SOLVED.

AS IT REALLY IS.

What problem?

Problem: condensation is marred table's wooden finish.

Sometimes your glasses will reflexively tag something as an engineering problem. Sometimes they won't. The things we recognize and categorize are a matter of individual calibration. Sometimes we need to fire without thought...

But we must check to make sure we are choosing our target well.

There is a need to reflect upon our practice while practicing. To "make explicit..."

"Assumptions... that were implicit..."

The ring is Problem Solving.

Because if we don't, others will.

You are very valuable, Mr. Anderson.

You will serve our industry well. Now.

We make powerful pawns.
Panel 1.
"What if we unpack the black box?" continues the narration. A black box sits below it, with "Engineering," "Problem," and "Solving" written across each of its three visible sides.

The narration resumes. "It does presuppose at least two things."

Panel 2.
This panel flows out of Panel 1; there is no border dividing them. The narration continues: "First, that the world is full of problems." A cartoon landscape full of hazards is shown, with a dotted line tracing a path from point A to point B, winding its way past a mysterious dark puddle, a construction hazard sign, a one-eyed monster, a hole in the ground, a safety cone, jagged spikes, and a fire. At the other end of the panel, the narration resumes: "And that they can be solved."

Panel 3.
This panel also flows out of Panels 1-2 with no border dividing them. A glass half-full of water sits on a table, with condensation rings and drops of water near it on the table's surface. A sticker on the glass marks it as a "Glass containing H2O equivalent to 50% of its volume." The narration continues: "This will occasionally go hand in hand with the belief that we see the world... 'objectively.'"

Panels 4-7.
The narration continues: "As it really is." The narration is placed in the middle of these four panels, each of which shows a different image framed by a photographer's viewfinder.

The first image shows a toddler reaching towards the glass on the table, and is labeled "Problem: small child may break glass."

The second image is centered on the empty top half of the glass, with the label "Problem: waste of glass, do not need such a large vessel."

The third image is centered on the droplets and condensation rings from Frame 3, and is labeled "Problem: condensation is marring table's wooden finish."

The fourth image shows the glass without the viewfinder markings, and is labeled "What problem?"

Panel 8.
The narration continues. "Sometimes your glasses will reflexively tag something as an engineering problem. Sometimes they won't. The things we recognize and categorize are a matter of individual calibration. Sometimes we need to fire without thought..."

As we pull back, we see the narration is written on a plume of smoke trailing behind a missile sailing towards the "Engineering is Problem Solving" portion at the bottom of the previous page. It is bracketed by the same viewfinder markings as the previous four panels, and we abruptly realize the camera viewfinder is also a target lock.

The narration continues, "There is a need to reflect upon our practice while practicing."

7. ibid.
To 'make explicit... assumptions... that were implicit... But we must check to make sure we are choosing our target well. Because if we don't, others will.' Beside the soaring missile, two agents from the movie "The Matrix" confront a frightened Thomas Anderson, prior to his transformation into Neo. "We make powerful pawns," the narrator says.

Legitimization has historically been a powerful driving force... The theoretical need for more concrete experience in the job market.

We see this in MIT's motto: *Mens et Manus* — *Mind and Hand*.

"And creativity, and design, and global thinking, and teamwork skills, and math and so on... The feature creep gets worse. Family, community, social, formal, informal, business savvy, and physics theory..."

"And I belong to me, 32?"

"Let me answer this, 

"Take anything off the syllabus list.

"Professional certification? Rigorous quantitative analysis? And the ability to learn?"

I don't know the way to success, but the key to failure is trying to please everybody..."

"Que le mieux..."
Panel 1.

Narration continues. "Legitimization has historically been a powerful driving force... in multiple directions, from multiple sources." A parade of engineers throughout history marches left to right across the page, parodying an image of monkeys evolving into humans and then back down again into hunched computer users. The leftmost engineer crouches with a toolbelt over a bridge strut; then a half-upright engineer bends over a motor, and then a fully upright engineer in academic regalia clutches a diploma while wearing a mortarboard. After this, a half-upright engineer shuffles papers over a podium, and then an engineer sitting at a desktop workstation turns to the viewer and asks "wait a moment, didn't I use to make things?"

The narration picks up again: "One is theory vs. practice. (I choose to express this as a dichotomy, but they can coexist.)"

Panel 2.

"We see this in MIT's motto, 'Mens Et Manus.' "Mind and Hand," continues the narration. The Latin motto is chiseled as if out of stone, and a disembodied hand and brain are drawn next to it.

The narration continues, as if chiseled on a monument wall that spans the entire left column of the page. This chiseled text stands next to a huge statue of Superman, wearing the engineering glasses and peeling open his suit jacket front to reveal not an emblazoned 'S' for Superman, but 'E' for engineer: "And creativity. And design. And global thinking. And teamwork skills. And math and... business savvy. And physics theory. And lifelong..."

Some of this text is obscured by another set of narration boxes floating above it. "The feature creep gets worse from there." (The chiseled monument text continues peeking out in the background: "Well-rounded... professional... certification... quantitative...") "I mean, you can't take anything off this list, right?"

A small girl wearing a school backpack stares up at the Superman Engineering statue, dwarfed by its massive shoes. "Wait," says the girl, "I have to be WHAT when I grow up?"

"Right?" says the narrating voice, still streaming over the chiseled text in the background. "Can you?"

"I don't know the key to success, but the key to failure is trying to please everybody," says a picture of Bill Cosby.

"Dit que le mieux est l'ennemi du bien / The perfect is the enemy of the good," says a picture of Voltaire.

Panel 3.

On the right side of the page not occupied by the Superman Engineering monument, two white men in 1900's formal garb with mustaches and slicked-down hair to match are arguing on either side of a swinging pendulum labeled the "curricular pendulum." "These kids..."
can’t PROVE anything! Pile on the theory!” cries one. "These kids can’t MAKE anything! Pile on the practice!” cries the other. Between them, an engineering student sitting at a desk piled haphazardly with papers looks frantically back and forth between the two as the pendulum swings between them.

Below this image is a voice-over narration box. “The PARTICULAR balance of mind and hand one should have been a subject of debate for quite some time now. But as any engineer knows, design and fabrication are not the same... ultimately, the maker determines the making.

A woman wearing sneakers, a dress, and engineering glasses gazes thoughtfully upwards, one hand tapping her chin as the other rests upon a canvas on an easel. We can see the woman is partially finished with a self-portrait, and is pausing to think in the middle of the work.

The narration continues: "And an engineer’s first project is to make themselves. From where they are, with what they have... What, did you think we were magically gifted with these features?"

A whole variety of glasses - square frames, round frames, thick and thin frames, shaded, goggles, etc. - tumbles out of the page towards us, its variety notable in contrast to the uniformity of the “engineering glasses” worn by all the engineers in the panels to date.

The narration continues. “Every product has a process, and regardless of how we’ve tried to standardize that process... we end up with as many ways of doing engineering as there are engineers. Some whimsical, some mathematical, some waterproof for deep sea work, some with magnification for fine detail operations...”


16. The most common phrasing of this thought is “decisions are made by those who show up,” or the open-source phrasing variant, “those who do, decide.” No canonical source has been tracked down.

17. Nel Noddings, Philosophy of education (New York: Routledge, 2018). (Specifically, the section on Dewey and his theories.)

18. Dominique Vinck et al., Everyday engineering: An ethnography of design and innovation, ed. Dominique Vinck (Cambridge, MA: MIT Press, 2003). (They have, of course, the people as well as the objects around them.)

We try to draw these categories and these lines because that’s how we’re trained to think; we spend our time turning mess into models, fuzziness into at least mathematically defined gradients if not boxes and arrows. It’s our job to make the world comprehensible so we can do something about it.

I mean, we can’t just leave it like that.

When we put the glass on and see,

Why else would they show us? We must...

Remember: “I propose to...”

Here: Outside the lens, they frame reality, but just because peripheral vision outside the lens is fuzzy doesn’t mean it isn’t.

We do what we must because we can for the good of all of us.

Except the ones who are dead.

Taking them off sometime is not a bad idea.

There are so many other ways of being one can try.
Panel 1.
A hand reaches towards a contact lens case. Cursive text scrolls by it in the background, partially blocked by the hand and contacts: "Went to get my MBA. Took a gap in the Peace Corps. Teaching high school chemistry... management... dancing... fabricating..."

Narrator: "...some who might not look like engineers at all to us...

Panel 2.
Narrator: "Or to themselves."

This narration textbox is superimposed on a complex Venn diagram with overlapping circles labeled things like "students," "degree," "certified," "practicing," and "hobby." Parts of each set of overlapping circles are shaded dark, with a key indicating that the shading indicates people who self-identify as engineers. Most of the students/practicing/certified areas are shaded; some but not all of the degree/hobby circles are shaded, and the diagram continues off the edge of the page.

Panel 3.
We see the same array of engineers from Page 1, Panel 3; they are now all arguing with each other. The woman in a dress and heels is telling the skateboarding girl "You're not really a engineer yet." The girl glares back, hands in fists defiantly on her hips. "Am too!" she retorts. The woman looks skeptical, and indicates the man in the buzz cut and polo shirt next to them: "He is." The man in the buzz cut replies, "Actually, I studied physics, so I see myself as a scientist instead."

Next to them, the man holding his Professional Engineer license says, "I'm an engineer." He turns towards the bearded man in the wheelchair, adding "and so are you! We went to school together!" The bearded man replies, "I used to be, but then I went into law school, so now..."

Next to them, the woman in the "geek" t-shirt is in mid-retort: "What? My business card and job title say so..." She is talking to the woman holding the beaker, who replies, "I know you build more things than I do, but you need the degree! Without ABET, how would we have any standards?"

"Or even to each other," the narration concludes.

Panel 4.
We see the engineering glasses held by a pair of hands and coming towards the viewer as if we are putting on or taking off the glasses ourselves. Above this floats voiceover text: "We try to draw these categories and these lines because that's how we're trained to think; we spend our time turning mess into models, fuzziness into at least mathematically defined gradients if not boxes and arrows. It's our job to make the world comprehensible so we can do something about it. A missile streaks across the page under this text, the words "DO SOMETHING!" in bold block font streaming behind it. "With great power comes great responsibility" is written in much smaller text nearby.

Voiceover text continues. "I mean, we can't just LEAVE it like that. Once we put the glasses on and see. Why else would they show us?" We can see block diagrams with boxes and arrows within the frames of the glasses, as if these neat diagrams were only visible through their lenses. There are words written in the boxes of the block diagrams, and they piece together

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21. Sam Raimi, Spiderman, Sony Pictures Entertainment, 2002. (Quote by Uncle Ben to soon-to-be-superhero Peter Parker, a.k.a. Spiderman.)
to read "Remember that the world exists..."

And then the text continues in varied styles of free-flowing script immediately outside the lens: "Here / here/ here / here outside the lens. They frame reality, but just because peripheral vision outside the lens is fuzzy doesn’t mean it isn’t there. Taking them off sometimes is not a bad idea."

In the peripheral vision of the glasses, outside their frames, is a display shelf of other kinds of clothing: a fedora labeled “anthropology,” a collared shirt labeled “politics,” a pair of sneakers labeled “art,” a necktie labeled “law,” and a vest labeled “journalism.” The narration flows over it, partially obscuring the journalism vest: "There are so many other ways of being one can try (not mutually exclusive)"

In the corner, the GLaDOS robot from the video game "Portal" sings: "We do what we must / because we can / For the good of all of us / except the ones who are dead"

**Things We Have Touched Upon**

- Engineering is a way of seeing the world—how things can change, how you can do it.
- Among many other possible definitions.
- Engineering depends on the engineer's human, subjective, and emotional qualities and history. Perspectives vary, including what is and isn't an engineering problem.
- Seeing is not the same as knowing or being right. Enhanced perception does not foster the sees with godlike fixing process.
- These lenses are built through many years of effort.
- Engineers are recruited by industry, their power upgraded by science, and must maintain a sense of self through the whole process.
- These lenses carve boundaries, including the duality of eliteness vs inclusiveness. Watch out for loss of peripheral vision.

You might have come here looking for an answer. You don't get one. Sorry.

I refuse to wrap up with a nice neat "and therefore, engineering is..." conclusion that you can skip to the end for and re-read for comfort every time you wonder. Because we are too good at that.

I'll give you a few highlights, though. Here's the thing.

**ENGINEERING**

G is the brain. Well, it's your turn. What will engineering be for you?
Panel 1.
Narrator: "You might have come here looking for an answer."

There is a gap, and then the narrator again: "You don't get one."

Outraged speech bubbles pipe in from off the page's right side. "What?!" "No, tell me!" "What's the point?" "What are you trying to say?"

"Sorry," says the narrator. "I refuse to wrap up with a nice neat 'and therefore, engineering is...' conclusion that you can skip to the end for and re-read for comfort every time you wonder. Because we are too good at that."

Panel 2.
Here is a series of three images. In the first, a human figure wearing engineering glasses stands anxiously behind a snarled black tangle labeled "MESS." In the second, the same human figure swabs vigorously at the edges of the tangle with a sponge, as if erasing a blackboard. In the third, the "MESS" has been contained within a rectangular box, with neat arrows labeled "in" and "out" on either side of it. The human figure crosses its arms, looking very satisfied, and exclaims "Done forever!"

Voice over narration: "Doesn't work that way."

Panel 3.
Narrator: "I'll give you a few highlights, though." This text leads to an arrow that leads to a long column of text running down the left side to summarize some points. It reads as follows:

"Things we have touched upon: - Engineering is a way of seeing the world - how things can change, how you can do it. - Among many other possible definitions. - Engineering depends on the engineer's human, subjective, and emotional qualities and history. Perspectives vary, including what is and isn't an engineering problem. - Seeing is not the same as knowing or being right. Enhanced perception does not bestow the seer with godlike fixing powers. - These lens are built through many years of effort. - Engineers are recruited by industry, their powers upgraded by science, and must maintain a sense of self through the whole process. - These lens carve boundaries, including the duality of eliteness vs. inclusiveness. Watch out for loss of peripheral vision."

Panel 4.
This shows a vision test, beginning with a large 'E' at the top, then continuing with a slightly smaller 'NG' underneath, then the rest of the phrase "ENGINEERING IS..." followed by nonsense letters that keep filling out the eye chart until they are too small to follow.

Narrator: "Here's the thing. These are my glasses. Mine, not yours. Mel's." We see this text wound over and around the pair of glasses from the cover image. "My prescription will not work as well for you. Heck, I constantly adjust them so they'll work for me."

Panel 5.
A desk is shown, viewed from the perspective of its user. A laptop set to administrative settings stands in the middle of the desk, atop a pile of papers that show writing, graphs, and drawings of various kinds. A ball of yarn and knitting needles are on the right; a cup holding pens and pencils is on the left along with a swing-arm lamp. A light switch is on the wall behind the laptop, and a bookshelf with books is overhead. The desk has a window view overlooking a pastoral scene with a tree, another house, a grassy field, a sky dotted with clouds, and a lake and city in the distance.

23. The pound (#) sign indicates that the computer is being used by "root," the superuser who has the highest administrative privileges on the platform.
Mel Chua

Narrator: "You know how we talked earlier about building your own views, your own skills? Well, it's your turn. What will engineering be for you?"

On the right bottom corner of the page is a small text box that reads: "END."

Mel Chua, 2018

References


