Searching for Justice in Programming Language Design

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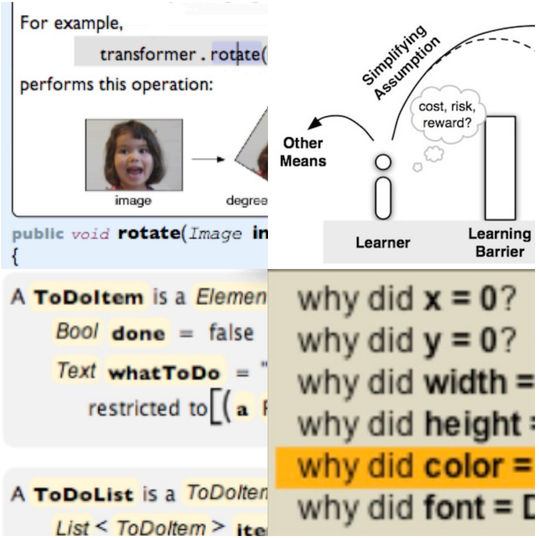
It’s great to be back!

Thank you so much for the time to visit, reminisce, and reconnect with Pittsburgh. It’s been a joy!

It’s reminded me a lot of my doctoral work on **human-centered programming tools**, and how much I’ve missed building things.

But I set building aside for good reasons…



For example,

```
transformer.rotate(
```

performs this operation:

```
public void rotate(Image in
{
```

```
A ToDoItem is a Elemen
    Bool done = false
    Text whatToDo = "
        restricted to[( a f

A ToDoList is a ToDoIten
    List < ToDoItem > ite
```

```
why did x = 0?
why did y = 0?
why did width =
why did height =
why did color =
why did font = D
```

A decade of computing education research

Back in ~2010, I saw a world that was increasingly computational, but also increasingly **complex**, **centralized**, and **colonial**, “eating” the world in both powerful and oppressive ways.

I wanted to help create a different world where a more **critical computing literacy** was equitably available to everyone.

Public education is the biggest lever we have, and so I joined the global CS for All movement to help broaden participation, dismantle barriers, and address inequities in CS education.

From learning to justice

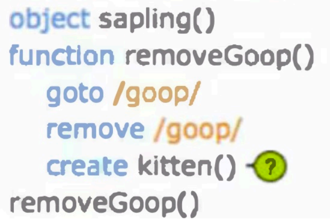
As my lab’s work progressed, my perspective shifted from the **neoliberal** goals that dominate computing to one that centered **justice**:

- Our world is built to reinforce what Patricia Hill Collins called the **matrix of oppression** — the social systems that entrench power hierarchies by erasing intersecting identities.
- Computing and computing education reinforces this matrix, framing computing and learning as tool of corporate profit.
- Justice, in my view, is **dismantling** this matrix, and creating one that equitably works for everyone, instead of just those with power.

We’ve worked toward justice on many fronts

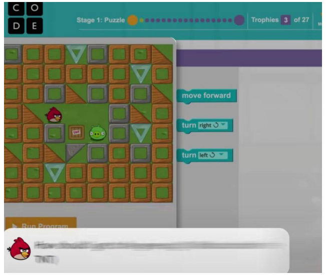
A justice-focused K-12 **teacher education** program that frames CS concepts sociotechnically (w/ studies of how this shapes teacher identity)

Books that prepare students and teachers to see computing through the lens of justice, and discover their own “limiting situations”



```
object sapling()
function removeGoop()
    goto /goop/
    remove /goop/
    create kitten() ?
removeGoop()
```

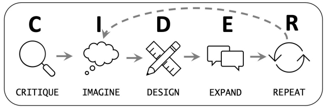
Teaching methods that improve learning and self-efficacy in programming by resisting authoritative framings of compilers.



Studies of how **bias** hides in CS assessments, creating structural forms of gatekeeping of CS literacies.

“There's ACM guidelines that sort of tell you what you should be covering… I've not looked at those guidelines in a while, but I doubt that [it is].”

Studies of **norms** and **fears** that deter CS teachers from teaching about diversity, equity, inclusion, accessibility, and ethics.



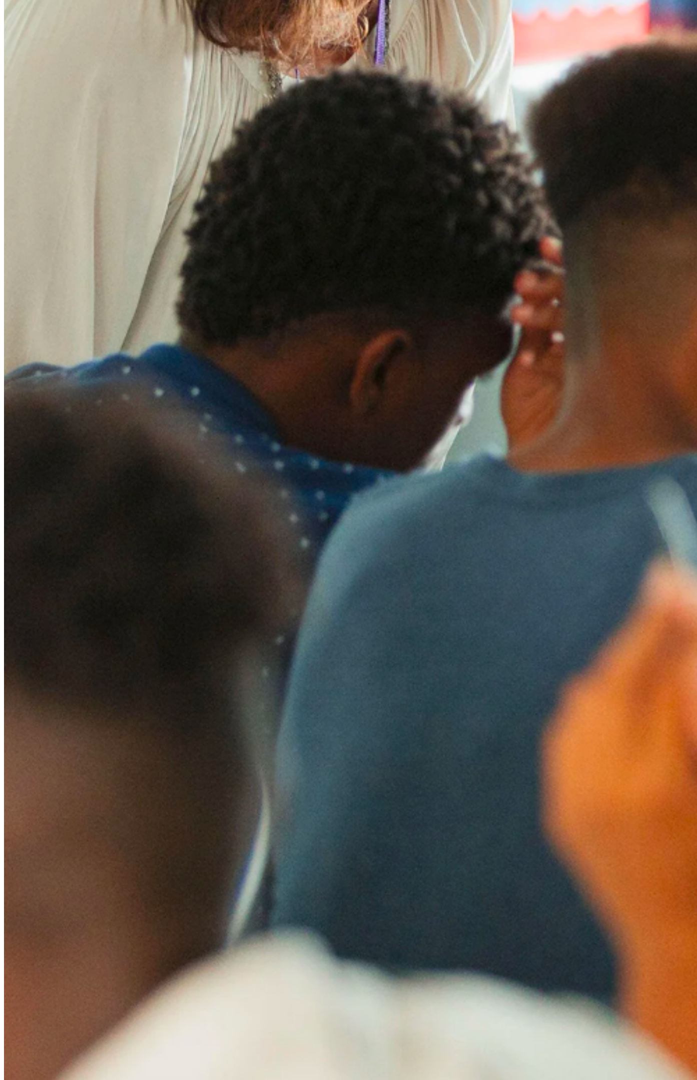
Teaching methods for surfacing **assumptions** about identity and ability in algorithms and data.

My lab and I take these discoveries into the world, shaping state and federal policy, curricula, learning technologies, and teacher education pathways. Our work has reached millions of youth through **curriculum**, **policy**, and **learning technologies**.

Despite all of this work, however, the **tools** of computing still stand in the way of literacy.

I was in a south Seattle math classroom last Spring. Most were refugees, most were learning English, and many had disabilities, including dyslexia, blindness, low vision, and motor impairments. The 25 kids spoke 17 different languages.

(stock photo)



The teacher had completed some equity-centered CS professional development and wanted to integrate CS in some of her algebra lessons in culturally sustaining ways. She had many questions…

(stock photo)

What platforms would work for my **blind**, **low vision**, and/or **motor impaired** students?

What would work for the **17 different languages** in my classroom, and for English-language learners?

What platforms can center my student own languages and cultures, instead of **Western**, **American** ones?

What platforms seriously engage **math and computing**, but make aren’t boring?

I had no answer.

This is because most of our educational programming languages and tools are designed with the same set of assumptions…

- Students can read English
- Students can see
- Students can use a mouse
- Students are interested in CS
- Students will persist

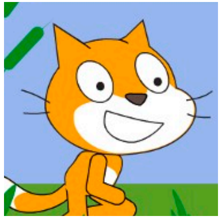
Most of these were not true for her students. And of course, these aren’t true for most students in the world. They’re really only true for the tiny sliver of English-speaking, normatively abled people who fall in love with computing itself.

None of these structural forms **ability**, **culture**, **language**, and **identity** exclusion are surprising.

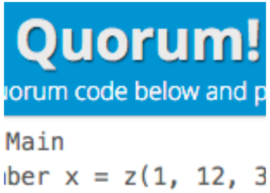
They are the consequence of **ableist**, **colonizing, hegemonic** decisions made by computer scientists from 1960’s to today, centering white, Western, ability-normative ideas of who CS is for in our programming languages and tools.

The computing ed community is just starting to make progress on breaking these assumptions.

Bootstrap has deep integration with algebra, and some focus on accessibility, but assumes English and makes little room for identity work.



Scratch centers expression and is localized in many languages, but requires use of a mouse and isn't screen readable.

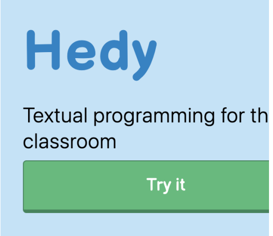


Quorum!

orum code below and p

```
Main
ber x = z(1, 12, 3
```

Quorum was designed to be screen readable and keyboard accessible, but assumes English and de-centers student culture, language, and identity.



Hedy

Textual programming for th classroom

Hedy embraces dozens of natural languages, even down to the syntax level, but segregates them, and leaves little room for expression.

Where are the creative coding platforms that celebrate the beauty of computing, but also center **disability justice** and **decolonization**?

I decided to make one

- **Sabbatical** gifted me ~1,000 hours over ~15 months to build
- I’ve approached the work as **art therapy, not design** (because academic leadership, pandemics, and gender transitions are stressful)
- I’ve had **so many ideas** about programming languages that I haven’t had time to explore in the past 20 years. This was my chance!
- As a typography nerd, I was excited about the new **Noto font**, which supports nearly all of the languages in Unicode. It was my muse.
- I explicitly deferred **evaluation**, and so view the work as generating new questions, not answers.

My aesthetic goals

🌍 **Global** — Celebrate the diversity of the world’s languages

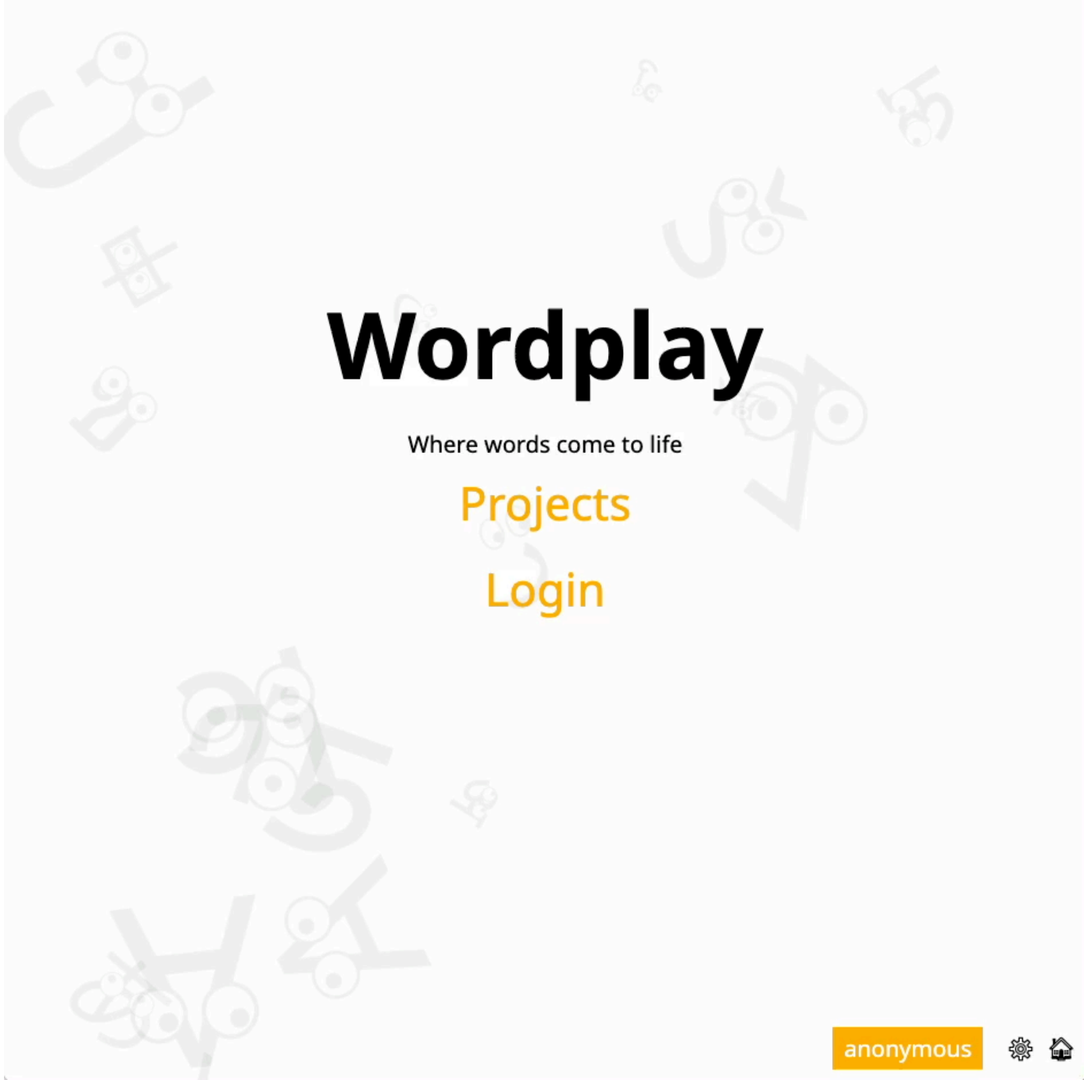
⌨️ **Accessible** — Center ability diversity and neurodiversity, and their tensions

🤪 **Playful** — Embrace the silliness of adolescence, not CS seriousness.

🤗 **Simple** — Ruthlessly avoid complexity

wordplay.dev

A web-based creative coding platform for creating interactive typographic experiences with the world’s languages. **Unicode is the palette, code is the brush**.



examples

This is a glimpse of **what** can be made. Now let’s discuss **how**, and what it has to do with justice, and why justice is so hard to achieve.

global

embracing the
world’s languages

problem: English all the way down

Most programming languages are designed to mimic **English**. English keywords, English grammar, English concepts. They aren't designed to be translated, and have no built-in support for translating their output.

This is not an accident: it is the direct result of winner-takes-all **settler colonialism.**

```
var bookshelf = require('../lib/db-connection');
var _   = require('underscore');
_.str = require('underscore.string');
_.mixin(_.str.exports());
_.str.include('Underscore.string', 'string');

module.exports = bookshelf.Model.extend({

    co      tor: function() {
             odel.apply(this, arguments);

              this.in      amps
              this.u
```

idea: translation all the way down

Linguistic justice (e.g., Baker-Bell 2020) might mean that all languages are supported, and none privileged.

Wordplay operationalizes this by:

1. Only using abstract **symbols** for the syntax — no words (e.g., ~~`function`~~, ~~`for`~~)
2. Viewing **names**, documentation, and output as a set of language tagged aliases

30 symbols/pairs that aspire to be **global**

It’s hard to choose symbols that don’t have deeply situated culture meaning. e.g., `false` often translates to “lie” or “deception”. Choosing symbols (⊤, ⊥) helps avoid cultural assumptions, at the possible expense of clarity.

( )   [ ]   { }   ⌈ ⌋   < >   ⦅ ⦆   ,   /   \   _

f   ?   ø   ⊤   ⊥   “ « 「   ←   →   ↑   ↓

^   #   • | &   .   :   Δ   …   ` `

all other symbols are names

infix operators can be any non-emoji character in the **symbols** category, e.g.:

+ − × ÷ √

ϟ ↘ ♲ ⌘ ✗

✾ ▶ ◉ ☞ ␣

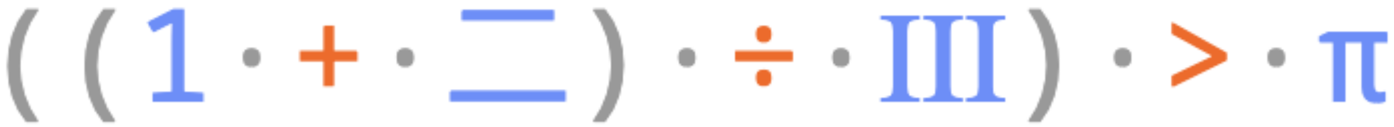
names can be **any** sequence of non-reserved, non-operator characters.

حصيلة אָבֵד

😀😀😀 pony

玉明 अभय

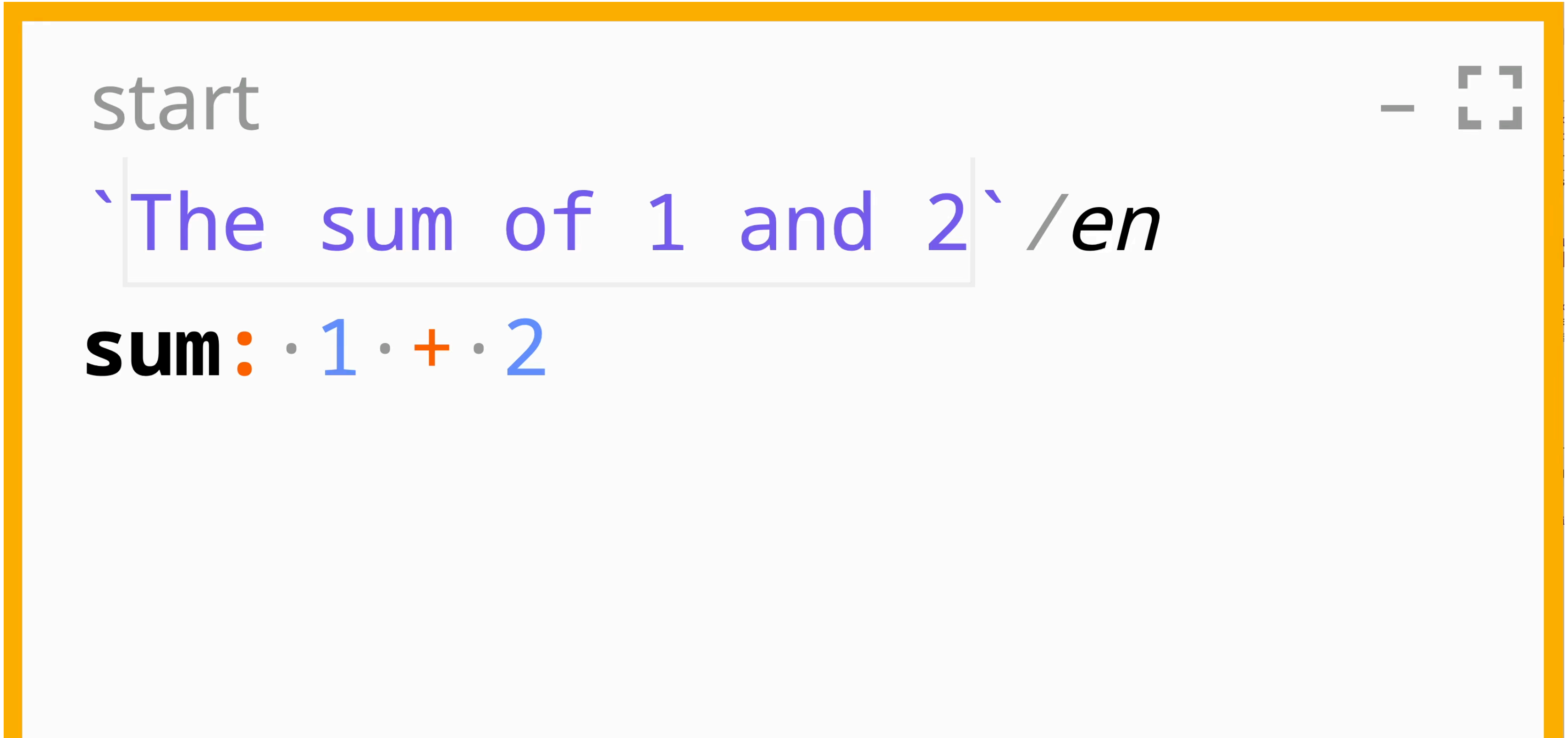
numbers from across the world, intermingled



```
((1·+·二)·÷·Ⅲ)·>·π
```

Arabic, Japanese, Roman, Greek, and more — Wordplay embraces all of the world’s number systems and numerals and allows them to be mixed together.

names and documentation are **translations**



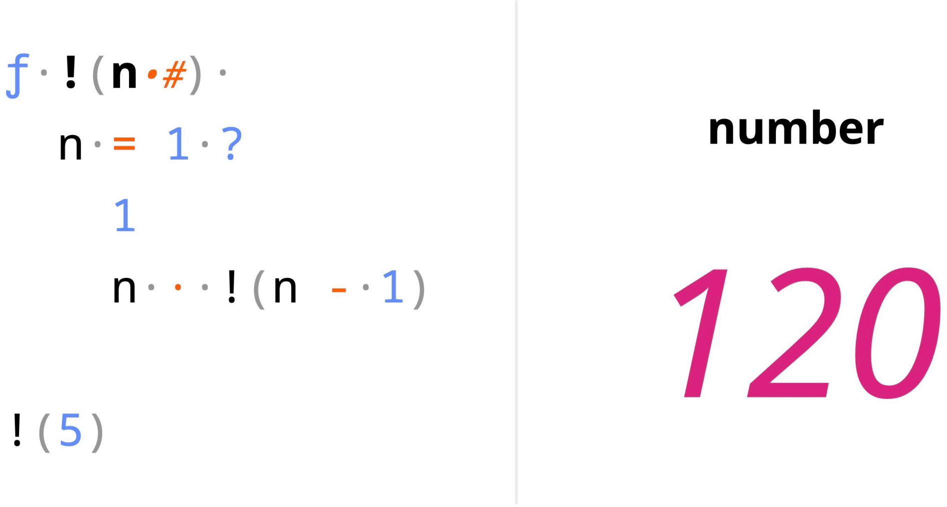
```
`The sum of 1 and 2`/en
sum: 1 + 2
```

data structures are typographically spare, avoiding culturally bound keywords

```
nothing: ø
list: [1·2·3·4·5]
set: {'cat'·'dog'·'pig'}
map:·{'Amy':·⊤·'Dr.Ko':·⊤·'yo':·⊥·}
•Kitty(name•''·breed•'') (
  ƒ·hello()·"Hi, my name is \name\ and I'm a \breed "
)
```

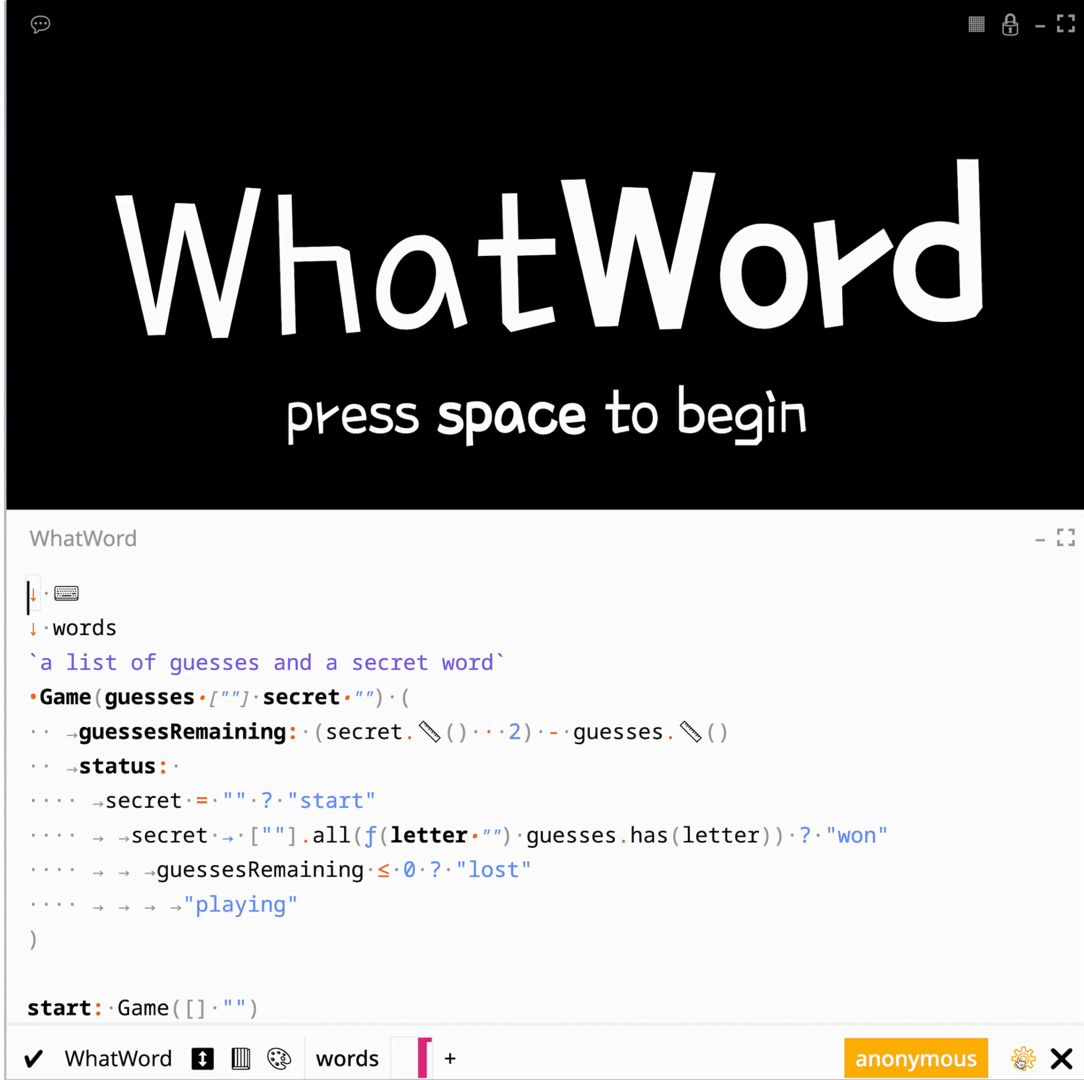
a functional grammar

Wordplay blends Smalltalk’s love of **objects**, Lisp’s love of **parentheses**, APL’s love of **symbols**, and functional programming’s love of **expressions**, while avoiding natural language mimicry to avoid privileging a grammar.



```
ƒ !(n•#)
  n = 1 ?
    1
    n · !(n - 1)

!(5)
```

All of these ideas enable 1) **instant localization** of code and output and the use of 2) **multiple languages** in code.



```
↓·⌨
↓·words
`a list of guesses and a secret word`
•Game(guesses•[""]·secret•"")·(
··  →guessesRemaining:·(secret.📏()···2)·-·guesses.📏()
··  →status:·
····  →secret·=·""·?·"start"
····  →  →secret·→·[""].all(ƒ(letter•"")·guesses.has(letter))·?·"won"
····  →  →  →guessesRemaining·≤·0·?·"lost"
····  →  →  →  →"playing"
)

start:·Game([]·"")
```

questions about being global

- What is gained and lost with this **“deep” localization** of a programming system, in learning, teaching, play (e.g., shared language for concepts)?
- What are the opportunities for 1) student **translanguaging**, and 2) teacher facilitation with English-language learners?
- What can be taught about **localization** itself by building concepts of localization directly into a language?
- How do **English learners’** perceptions of CS change when they see CS concepts in their languages instead of English?

Is this justice?

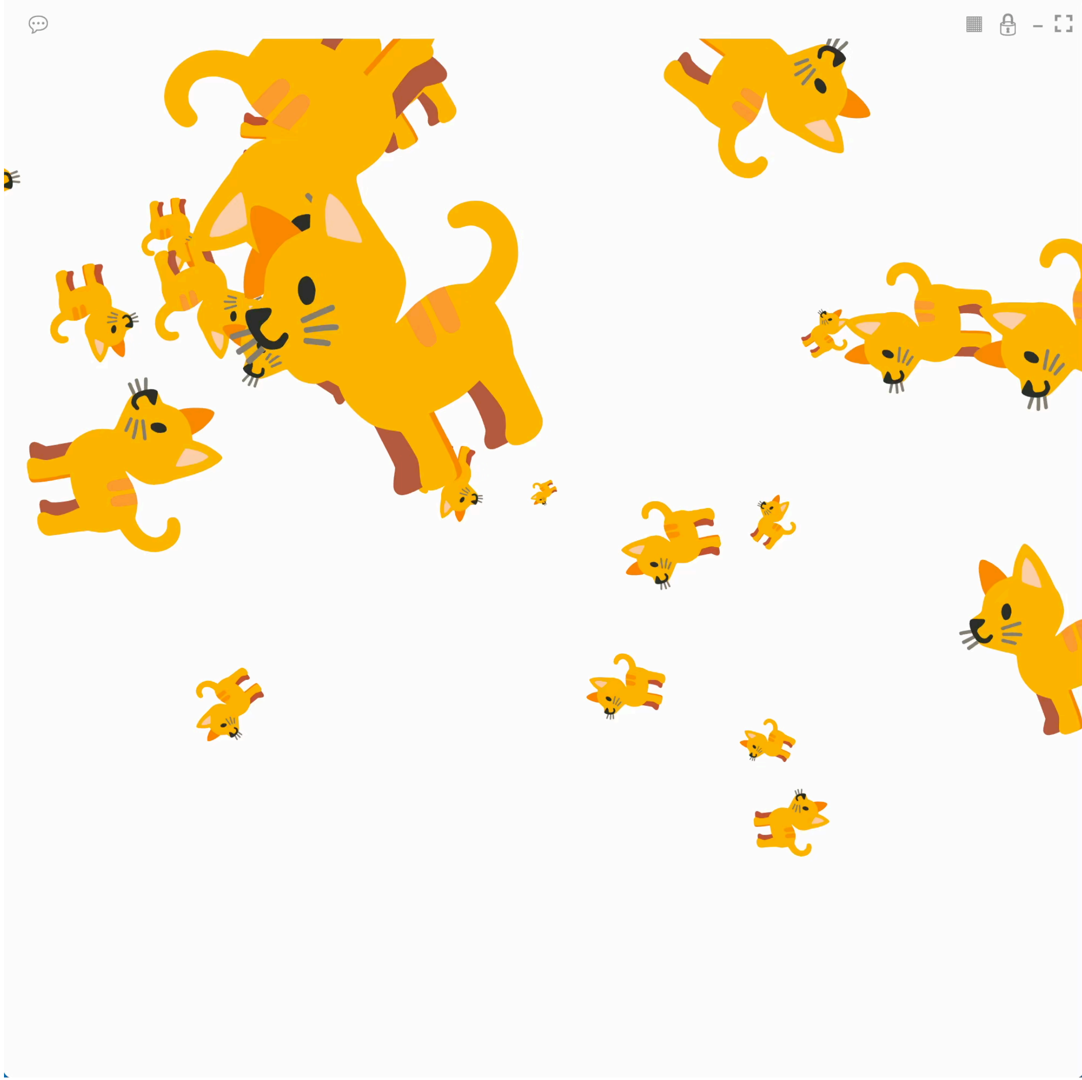
Perhaps in a mundane way. It feels to me like the **least** programming languages could do.

In particular, it leaves a mountain of **translation labor** to do, in the language and documentation, but also in every program.

It leaves intact the broader forces that privilege English and western civilization, including those in the very machine translation tools that might help address these gaps.

playful

centering
silliness



problem: PL indirectly out-groups

Community is often the first thing that learners experience — it's signaled in tooling, documentation, learning materials, and more, and conveys group membership in ways shape who codes and how they do it.

This is not an accident: dominant groups in CS uphold an epistemic hegemony that privileges **western rationality** and rejects **subjectivity**.

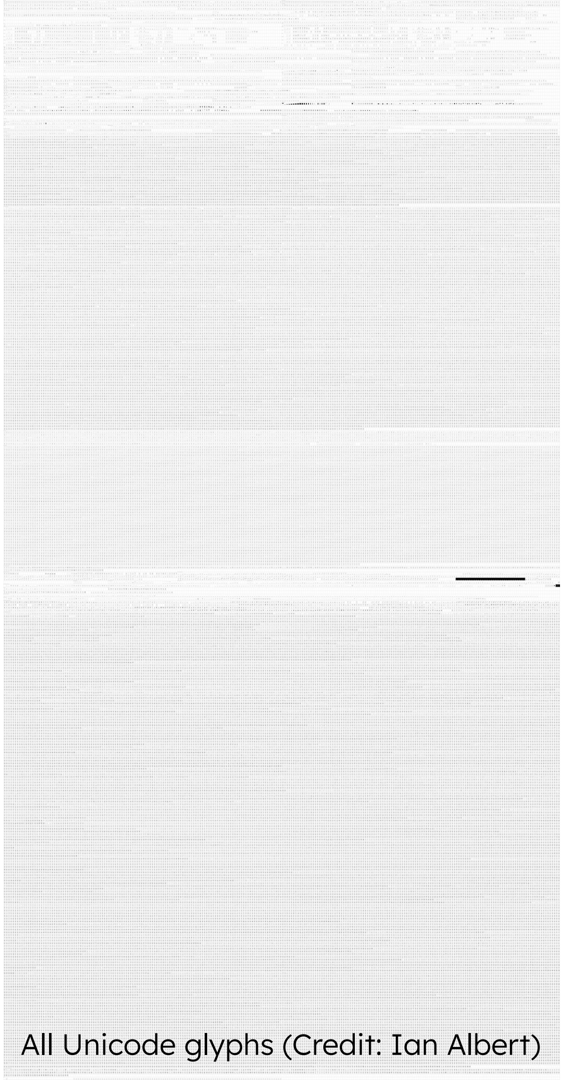
idea: computational ideas as social beings

Epistemic justice (Fricker 2007) might mean actively resisting the idea that programming languages and their designers are the sole sources of authority, truth, and objectivity.

Wordplay operationalizes this by anthropomorphizing computing concepts through **lore**, offering building a world in which computing concepts interact, have conflict, and collaborate.

A **community** of characters

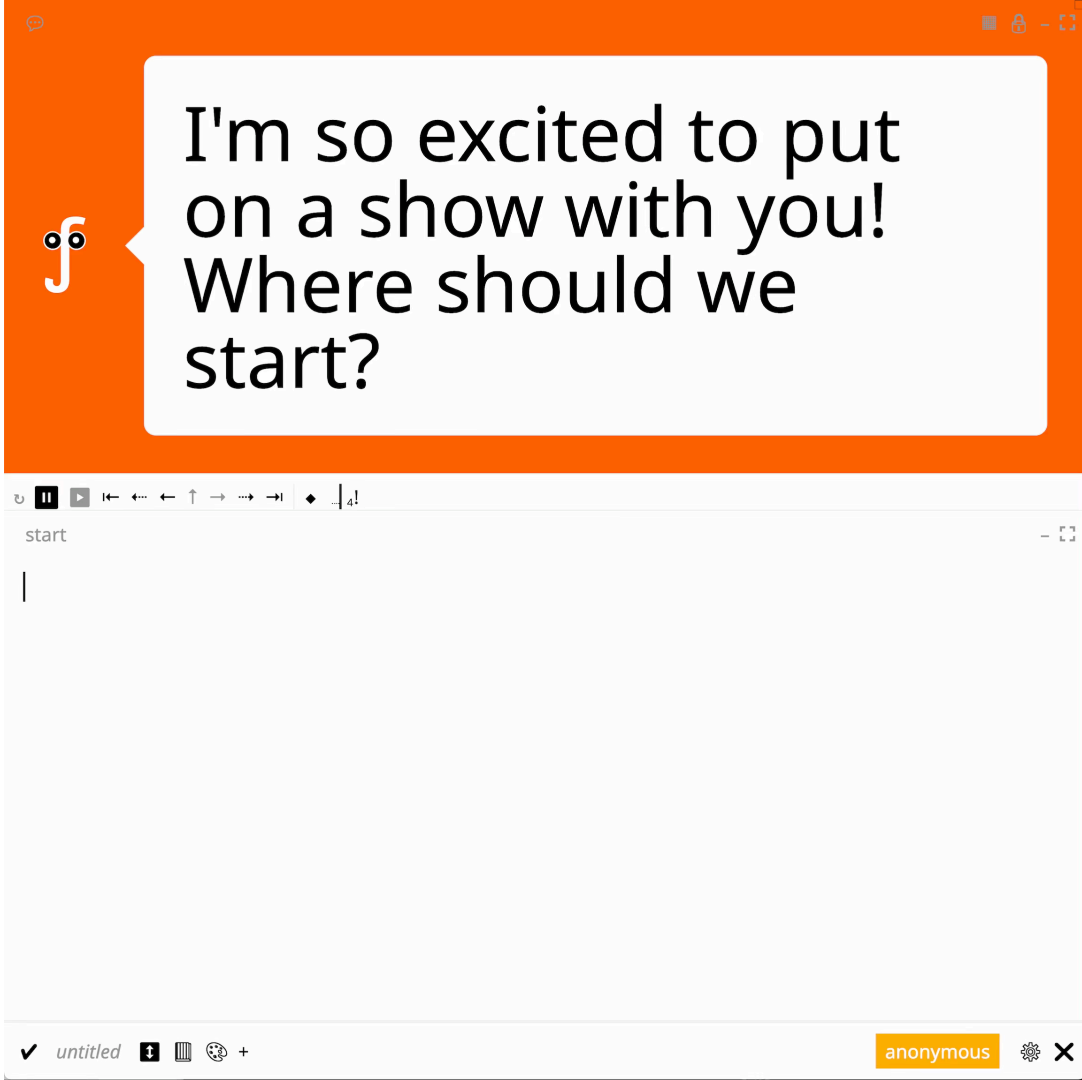
- The **verse** is a place with ~150,000 residents, spanning 161 scripts.
- Each resident is a **character**, corresponding to a Unicode code point.
- Characters like to put on elaborate **performances** (programs) in collaboration with **choreographers** (programmers)
- Some characters like to be on **stage** (output), but some like to choreograph (code), doing set design, controlling lighting, etc.



All Unicode glyphs (Credit: Ian Albert)

Every character has a **personality** and **positionality**.

Program nodes, for example are presented by ***ƒ***, who is always excited about planning a performance.

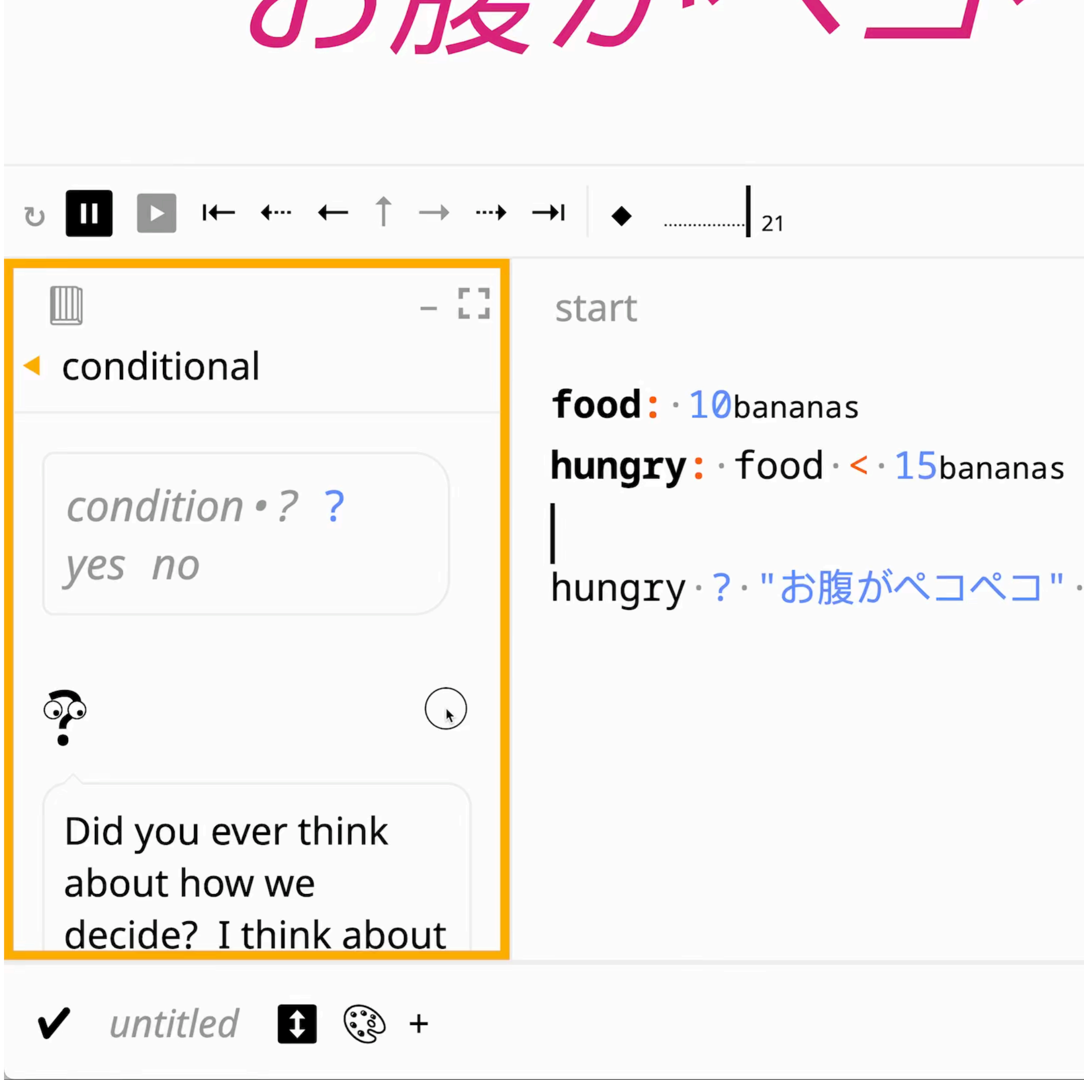


I'm so excited to put on a show with you! Where should we start?

Some characters convey **epistemic struggles** with their computational purpose.

These are conveyed in **diaries** (documentation), where language concepts project their purpose, values, and concerns.

Here, **conditional** (represented by **?**) wrestles existentially with binary decision making and their skepticism of dichotomous truth values.



お腹がペコ

21

conditional

condition • ? ?

yes no

Did you ever think about how we decide? I think about

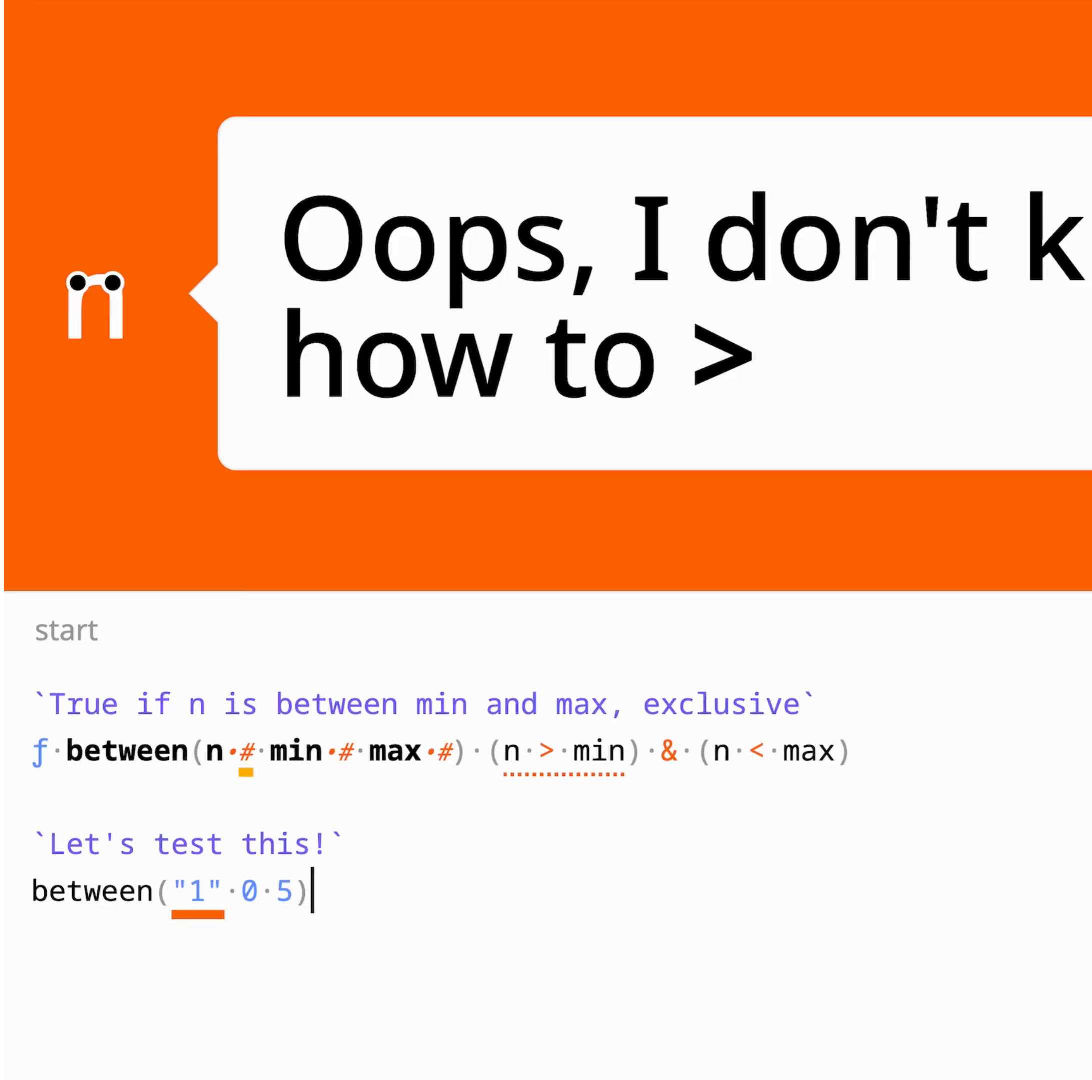
start

```
food: 10bananas
hungry: food < 15bananas

hungry ? "お腹がペコペコ"
```

untitled

Wordplay frames “errors” as **conflicts** between characters that need to be resolved before a performance can proceed.

Here, a function definition and a function evaluation have a conflict about the type of an input, and it’s up to the choreographer to resolve it.



Oops, I don't k
how to >

start

```
`True if n is between min and max, exclusive`
ƒ·between(n·#·min·#·max·#)·(n·>·min)·&·(n·<·max)

`Let's test this!`
between("1"·0·5)
```

questions about being playful

- What effect does **anthropomorphization** of programming language concepts have on learning, self-efficacy, theory of intelligence?
- How might lore be written to align with different cultural **values** and **ideas**?
- What effect does silliness have on how youth perceive computer science as a discipline?

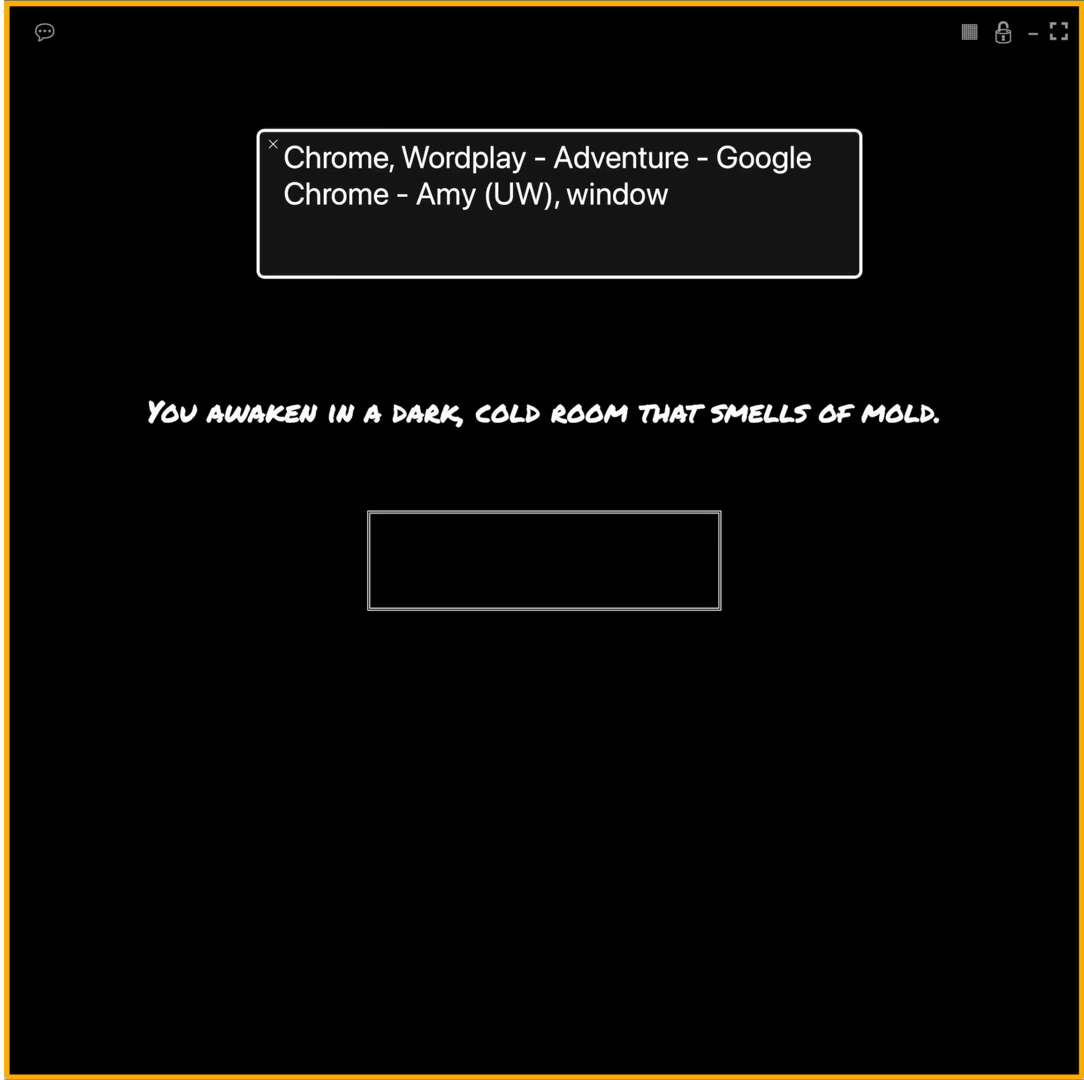
Is this justice?

It is certainly **resistance**. It is one language amongst thousands, and perhaps the only one that explicitly questions the epistemic claims of computing directly inside a computing medium.

But justice might mean **all** programming languages and their communities centering humility about computing and its uses, even advocating for refusal (e.g., not building).

accessible

all abilities, no exceptions



Chrome, Wordplay - Adventure - Google Chrome - Amy (UW), window

You awaken in a dark, cold room that smells of mold.

problem: PL stacks are inaccessible

People are immensely diverse in their abilities and cognition, but programming languages tend to work for a narrow band of human ability, forcing mouse or keyboard use, visual output, complex language.

A
B
C
$this->
run() void
Age int
basicCompletion() void
Name string
veryLongFunctionName() void
Press ↵ to insert, ⇥ to replace Next Tip

This is not an accident: PL is just one example of the broader **ignorance** and **disregard** for disability in computing and the world, and one that is now self-reinforcing.

idea: multiple representations of code and output

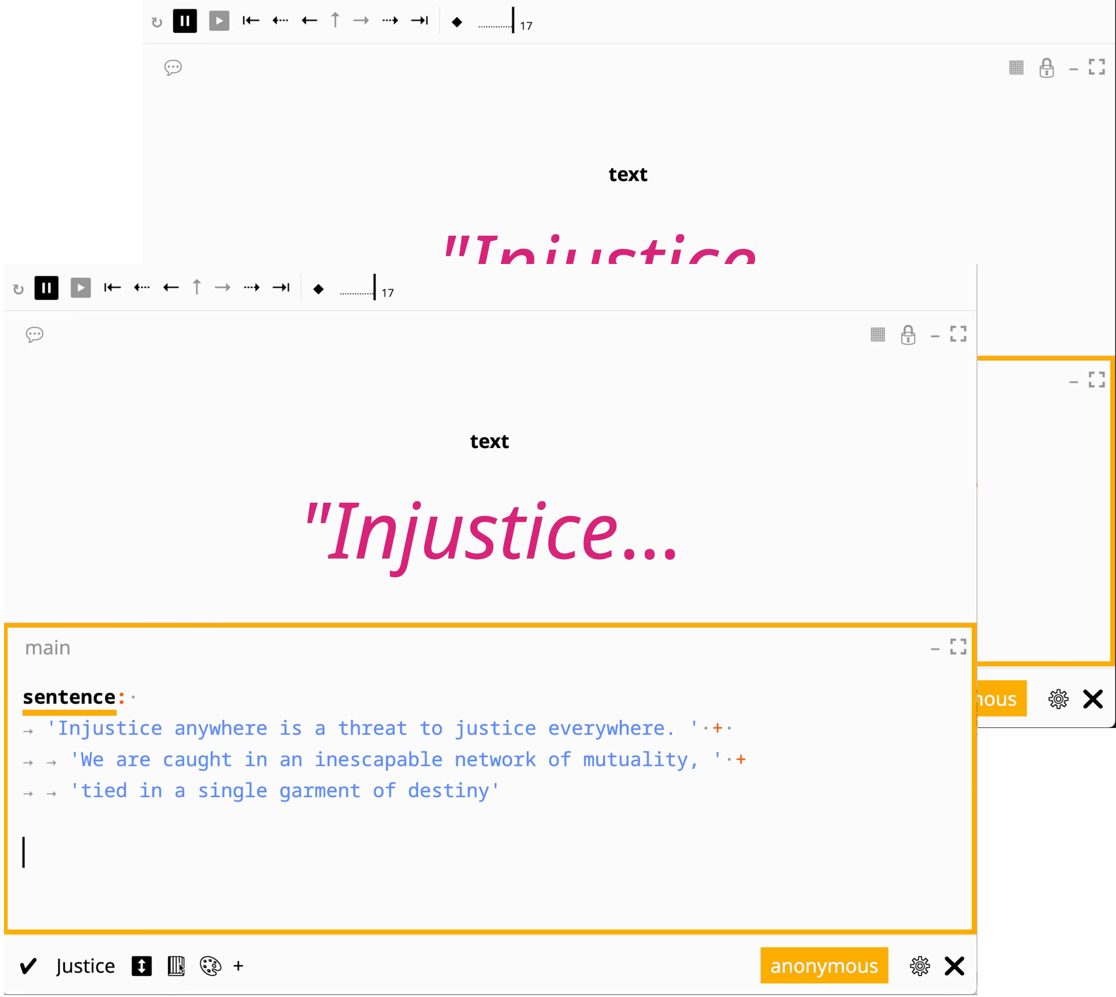
Disability justice means many things (e.g., Berne 2018), but particularly **agency** amidst broader ideas of collective access, interdependence, cross-disability solidarity.

In Wordplay, this might mean **flexibility**: multiple modalities for input, output when reading, writing, and evaluating code, but also control over time, color, and other details typically under the control of a computer, runtime, or designer.

Wordplay offers the world’s first **hybrid text and block-based editors**, providing options:

- Quick but error prone typing
- Slow but error preventing drag and

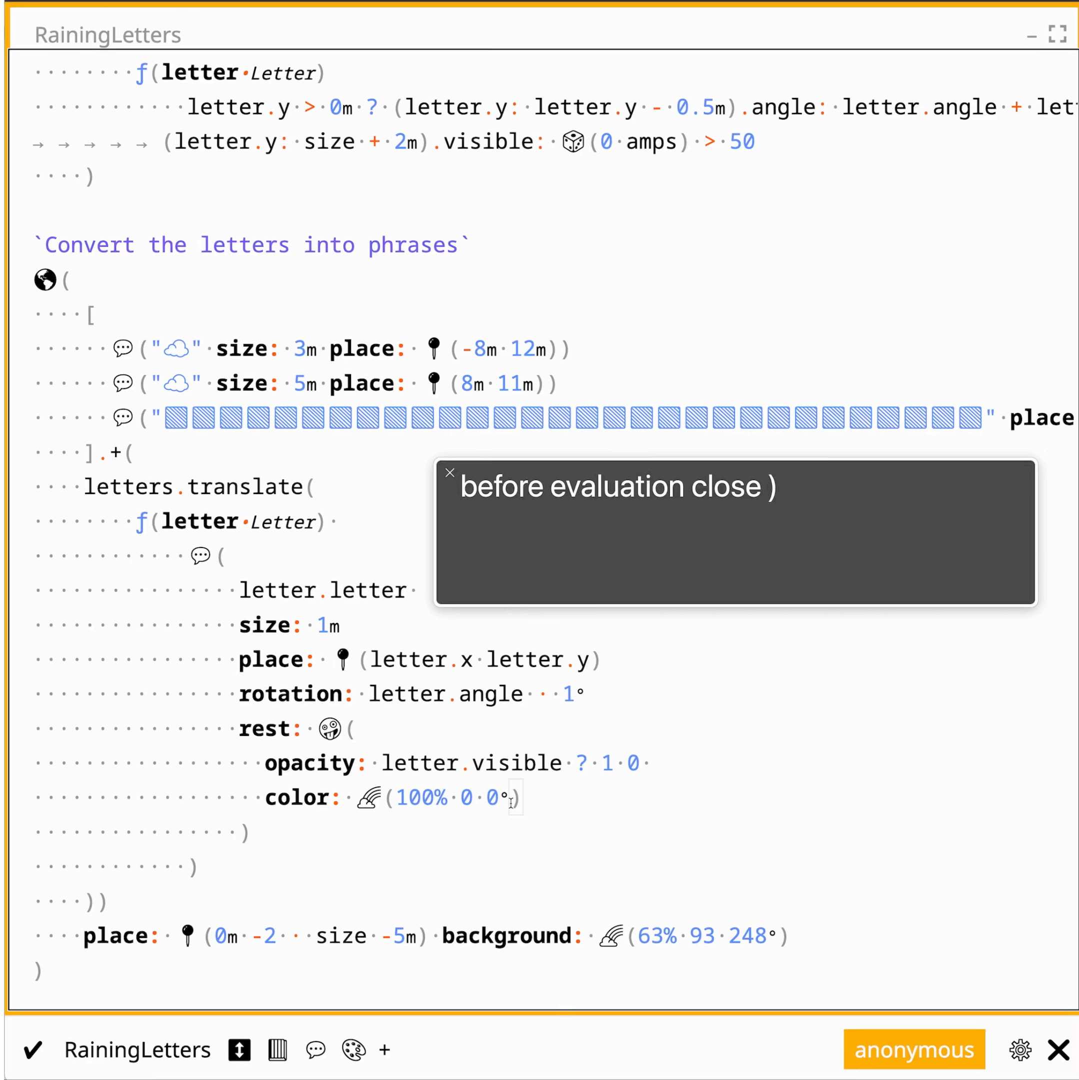
Creators can choose how to edit based on their abilities, knowledge, and risk aversion, without the stigma of **segregation**.



```
sentence:
→ 'Injustice anywhere is a threat to justice everywhere. ' +
→ → 'We are caught in an inescapable network of mutuality, ' +
→ → 'tied in a single garment of destiny'
```

The editor allows for visual and audio navigation of **program structure** via keyboard, climbing the tree, moving to siblings and children.

The screen reader reads a **localized description** of each node in this abstract syntax tree instead of reading program text verbatim.



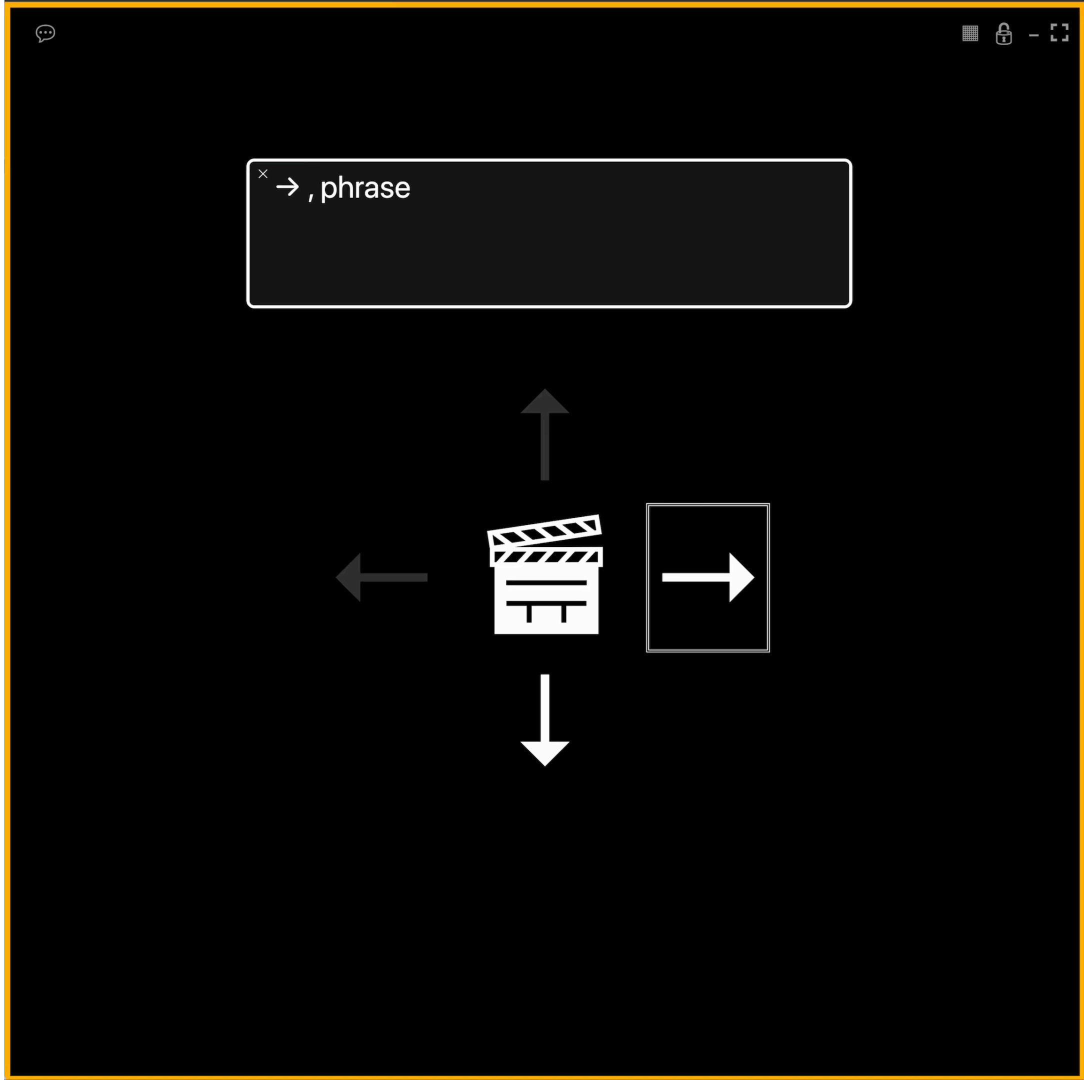
```
        ƒ(letter•Letter)
            letter.y > 0m ? (letter.y: letter.y - 0.5m).angle: letter.angle + let
→ → → → → (letter.y: size + 2m).visible: 🎲(0 amps) > 50
    )

`Convert the letters into phrases`
🌎(
    [
      💬("☁" size: 3m place: 📍(-8m 12m))
      💬("☁" size: 5m place: 📍(8m 11m))
      💬("▨▨▨▨▨▨▨▨▨▨▨▨▨▨▨▨▨▨▨▨▨▨▨▨▨▨▨▨▨▨" place
    ].+(
    letters.translate(
        ƒ(letter•Letter)
            💬(
                letter.letter
                size: 1m
                place: 📍(letter.x letter.y)
                rotation: letter.angle · 1°
                rest: 🤪(
                  opacity: letter.visible ? 1 0
                  color: 🌈(100% 0 0°)
                )
            )
    ))
    place: 📍(0m -2 · size -5m) background: 🌈(63% 93 248°)
)
```

before evaluation close)

Output is a scene of **phrases** that enter, change, and exit stage.

Phrases are both **visual** and **textual**, as are changes to phrases.

The declarative nature of functional code enables a kind of live captioning.

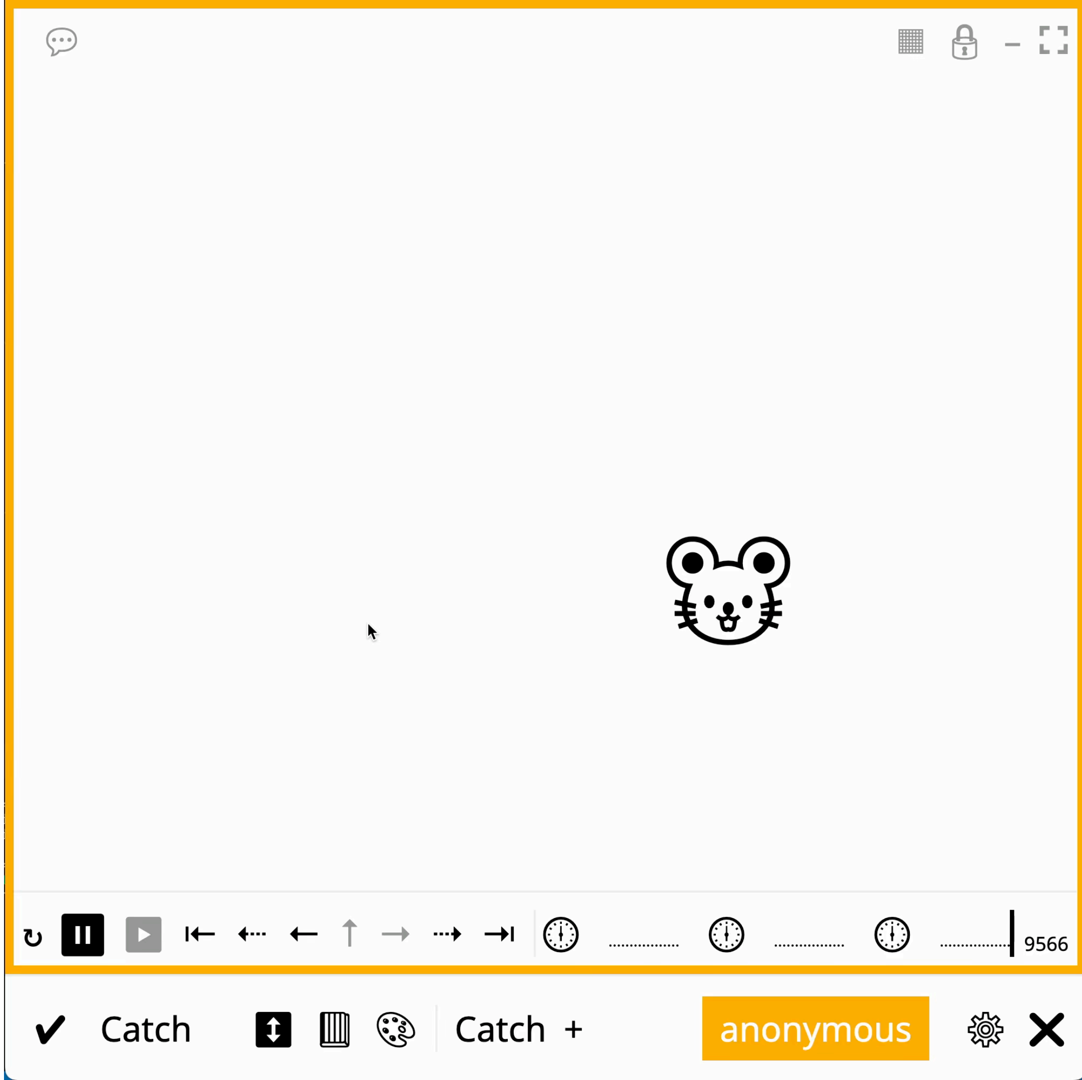


× → , phrase

Timing and animation are **globally configurable** — without requiring program-level support.

Here, a catch-the-mouse game moves a bit too fast, but slowing down time can make the game more tractable.

Turning off animations altogether can address motion sensitivity.



questions about accessibility

- What **tradeoffs** does Wordplay's accessible hybrid editor pose to complexity, scalability, error-proneness?
- What might students learn about **accessible computing** by creating programs that are accessible by default?
- What are **other forms** of input and output are possible with multiple representations? (e.g., speech input, tactile output?)

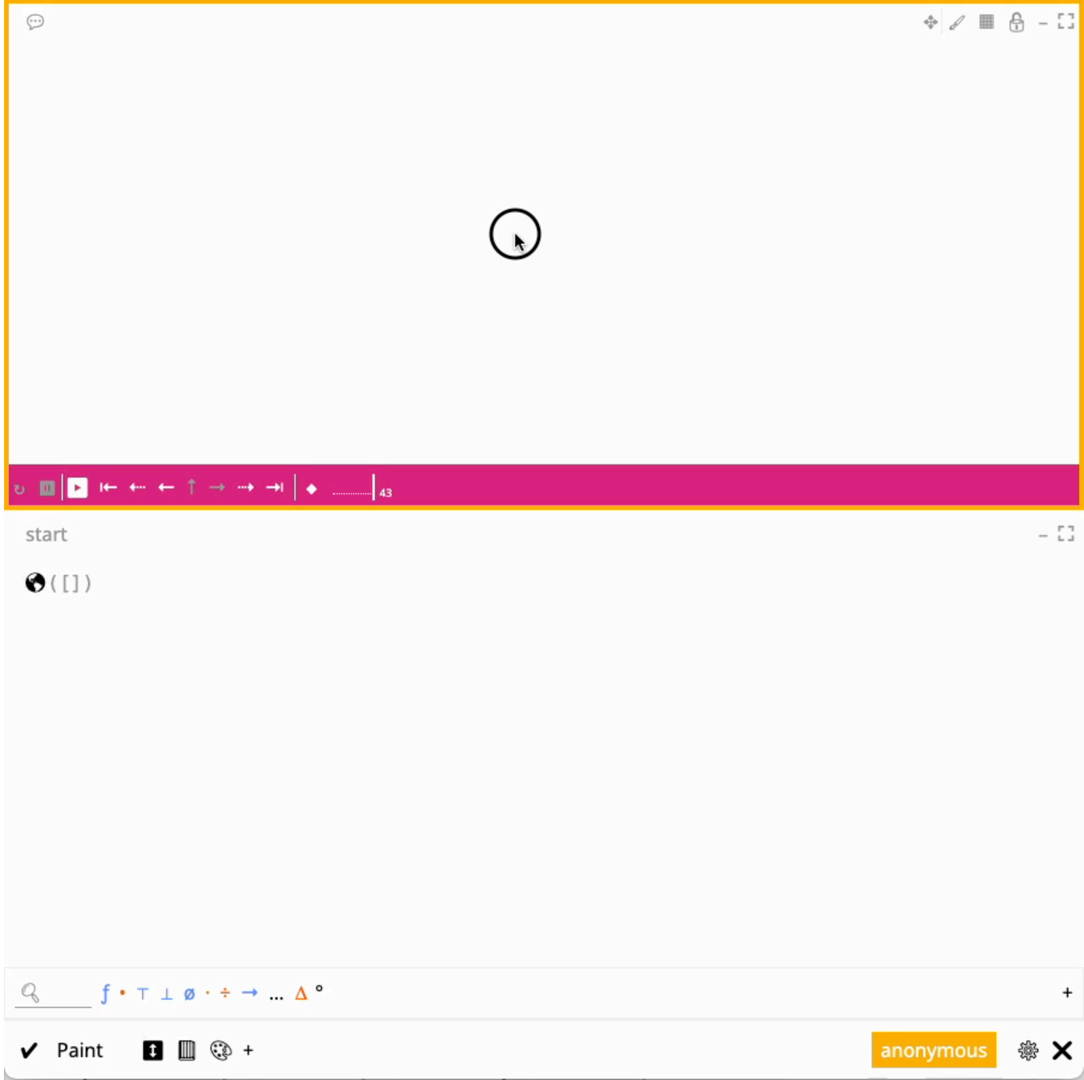
Is this justice?

Only in the most prosaic sense. It is the **bare minimum** of access, opening up input, output, and code to more abilities, and not yet all, and only for this one language.

True disability justice would mean not only having all of these features be standard in all programming languages, but also centering intersectional disabled communities in envisioning these standards. We are far from that.

simplicity

reducing complexity



problem: complexity causes difficulty

Understanding and **debugging** code has always been the central difficulty, and much of this stems from language features such as mutability, but also a lack of tool support, exacerbating language and accessibility barriers.

This is not an accident. Computing has long prized **performance** over comprehensibility, as part of a broader project of capitalism, burdening programmer's with cognitive labor to buy speed. Educational programming languages inherit these priorities, placing learners in the same bind, limiting participation in computing.

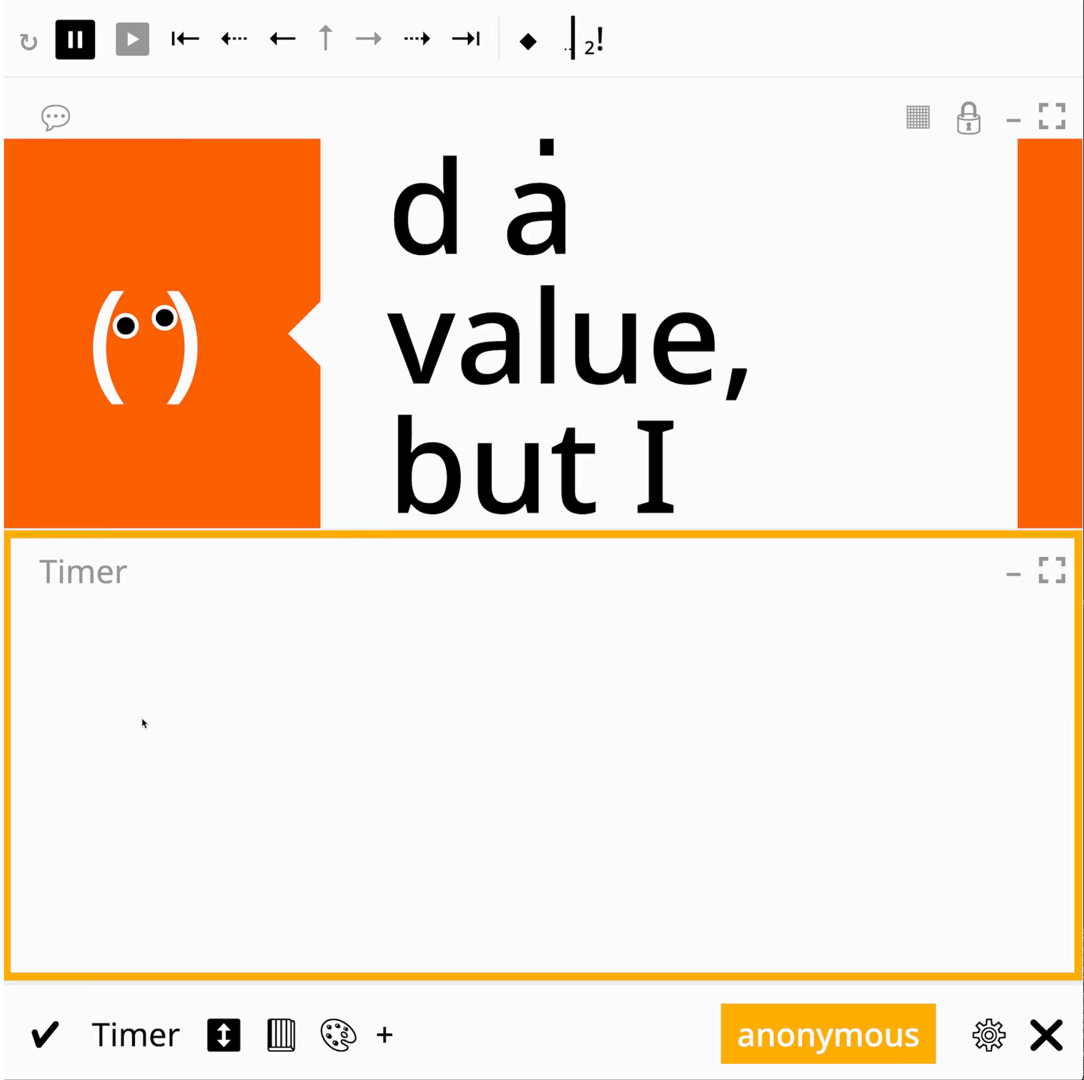
idea: A purely functional, stream-based design

An anti-capitalist (e.g., Tormey 2013) programming language might mean liberating learners from these capitalist cognitive burdens, at the expense of speed.

Wordplay operationalizes this with **pure functions**, **immutable data**, and **stream-based reactions**, in an attempt to simplify program comprehension. These features mean only one source of change in program behavior, **input**, and that program output is completely determined by code, not runtime state.

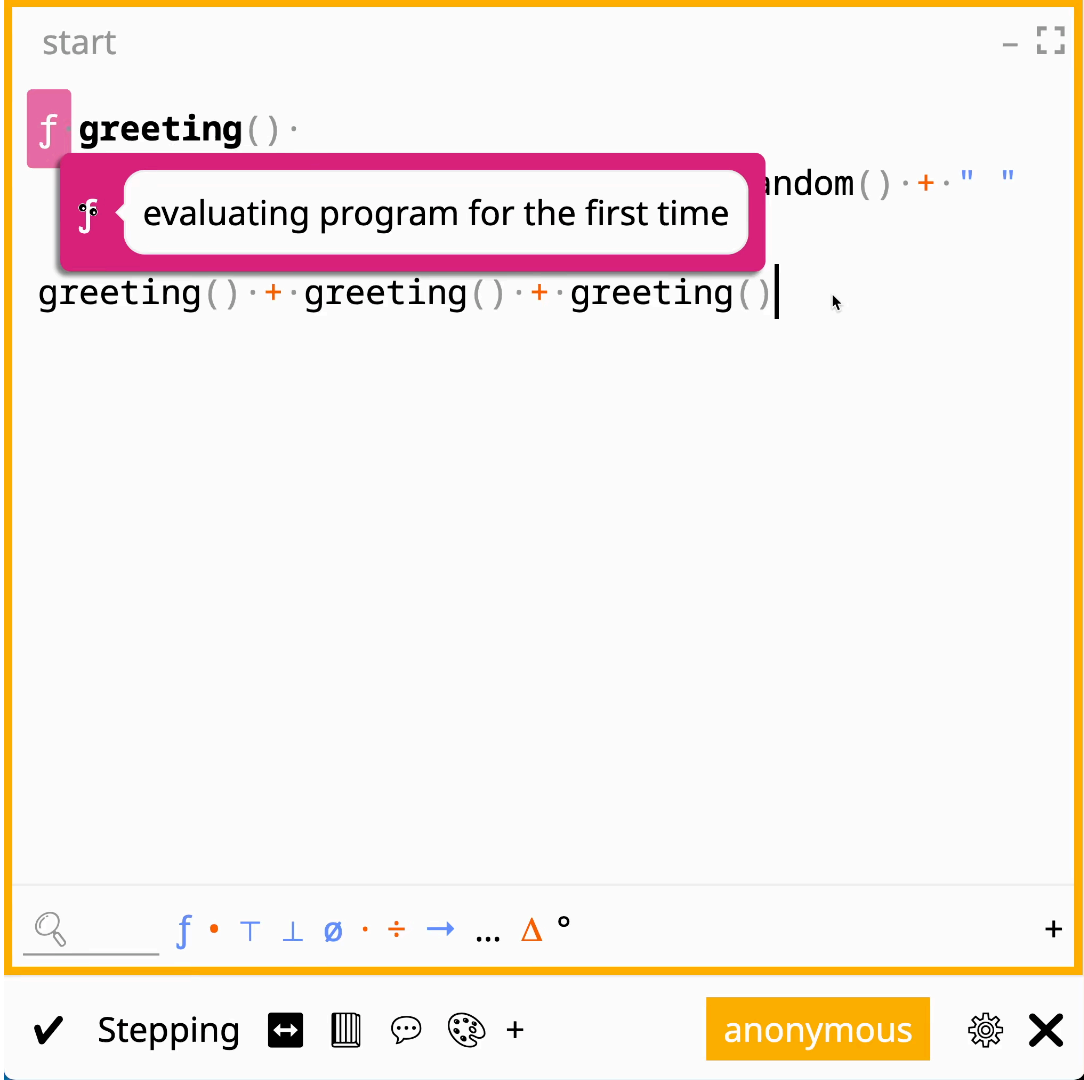
Programs can make and react to **streams** of input that trigger program re-evaluation each time they change. This means that every program is therefore a **recurrence relation** on stream input and prior values.

Here, we use a time stream to create different kinds of timers.



Because program evaluation is just function evaluation, we can step through evaluation one expression at a time, seeing how the program is **translated** into a value.

Here, we create a list of greetings in different languages by appending a **greeting** function's random value three times.

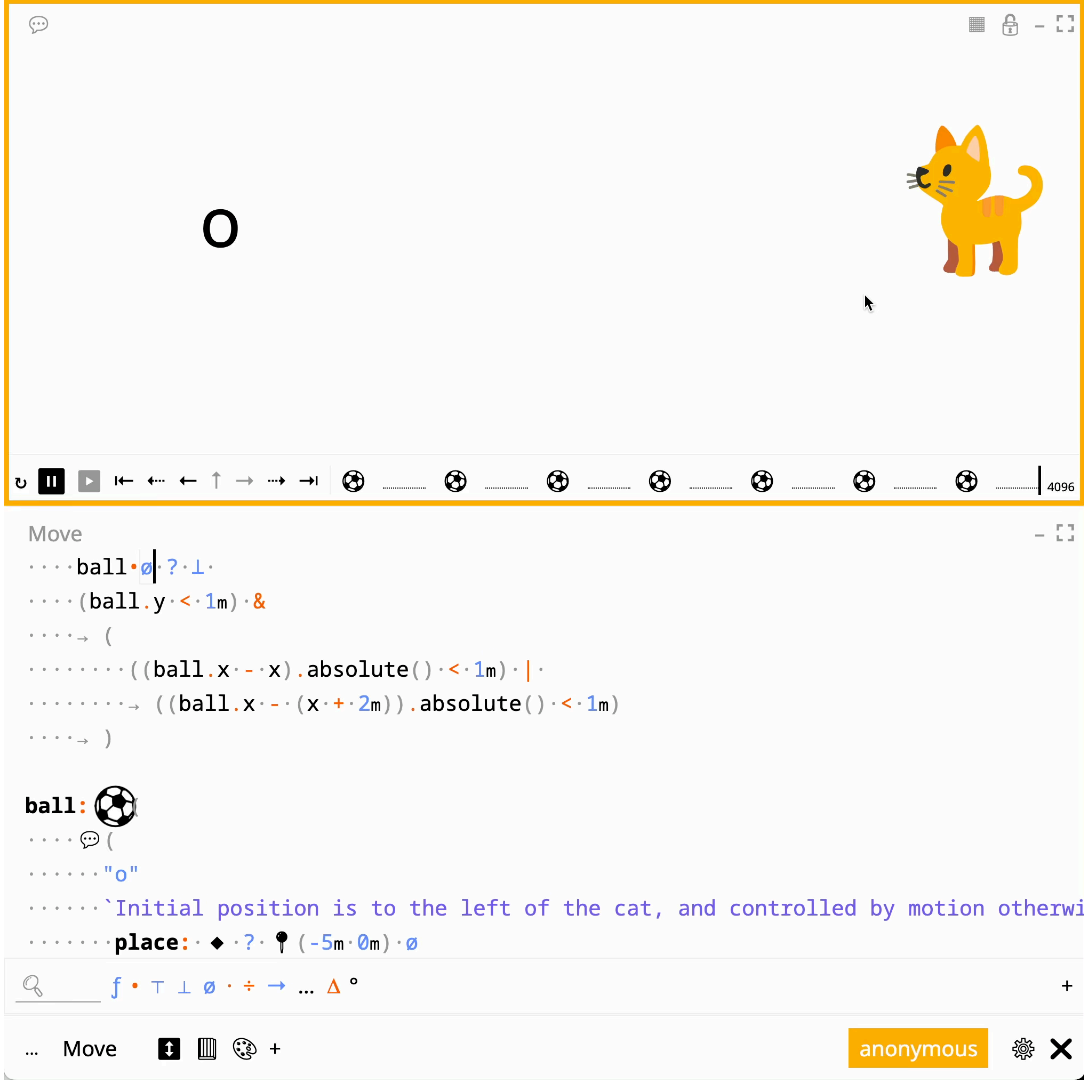


evaluating program for the first time

```
greeting() · + · greeting() · + · greeting()
```

But program output is just a time series of values, and we can recreate any program state from the stream history. This makes **time travel** trivial.

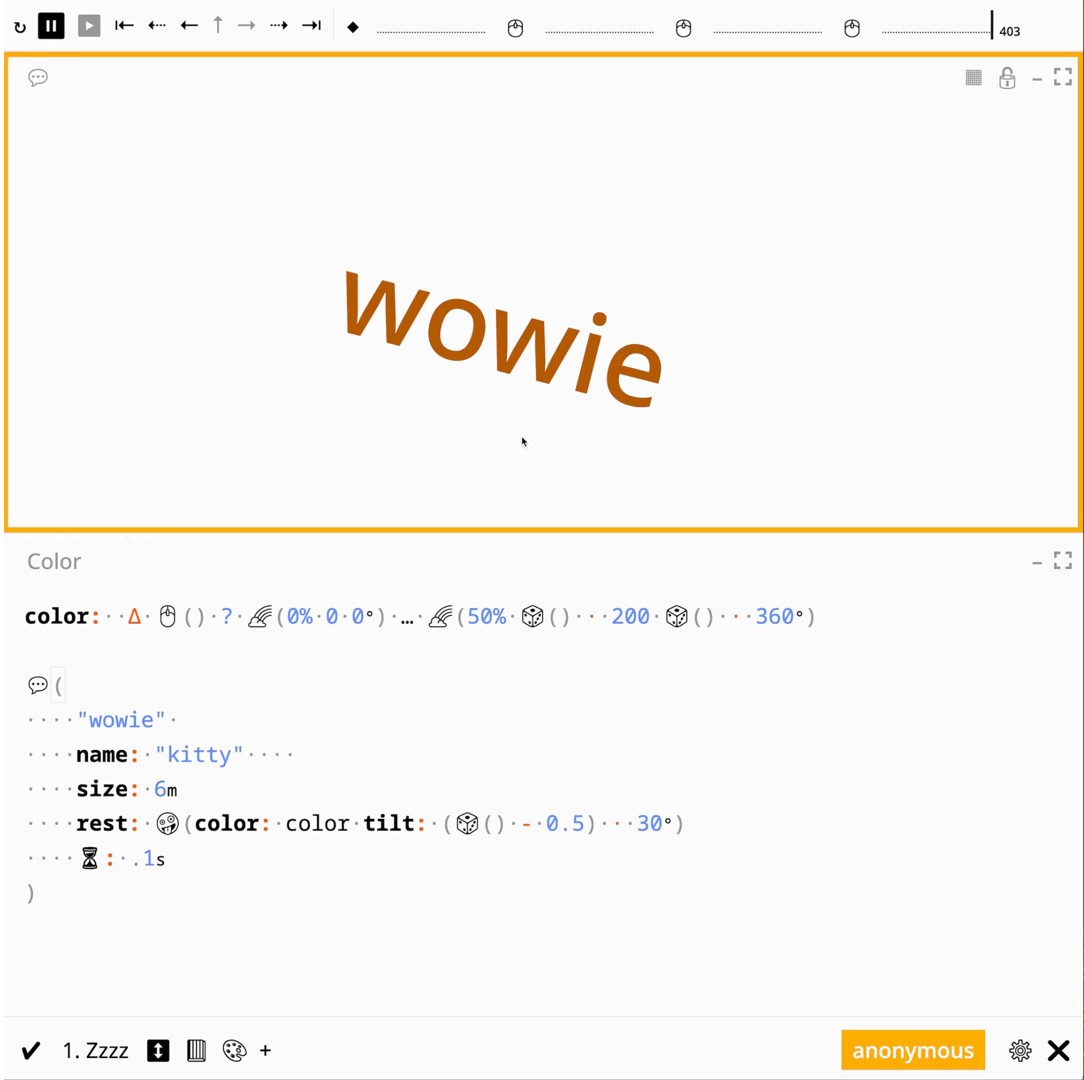
Let’s find each time the cat collides with the ‘o’ by stepping backwards to time, by **scrubbing**, stepping to prior **inputs**, and stepping to prior expression **evaluation**.



```
    ball ø ? ⊥ 
    (ball.y < 1m) &
    → (
        ((ball.x - x).absolute() < 1m) | 
        → ((ball.x - (x + 2m)).absolute() < 1m)
    → )

ball: ⚽(
    💬(
      "o"
      `Initial position is to the left of the cat, and controlled by motion otherwi
      place: ◆ ? 📍(-5m 0m) ø
```

Wordplay retains value **provenance**, linking values to the expressions that created them.

This, and the declarative nature of functional code, enables bidirectional editing, enabling direct manipulation of output, despite the lack of mutable state.



```
color:··Δ·🖱()·?·🌈(0%·0·0°)·…·🌈(50%·🎲()···200·🎲()···360°)

💬(
····"wowie"·
····name:·"kitty"····
····size:·6m
····rest:·🤪(color:·color·tilt:·(🎲()·-·0.5)···30°)
····⌛:··.1s
)
```

questions about complexity

- Is the **lack of mutable state** in functional programming an inherent difficulty, or just a property of poor tooling and lack of interactivity in classic functional languages?
- How does the ability to **manipulate time** change the difficulties of debugging?
- Does **stream input** add complexity relative to stateful event-based interactivity, or reduce it, relative to event-based or constraint-based models?

Is this justice?

Hardly. It is the smallest form of liberation from capitalist obsession with productivity, and does little to change these broader systems. It is an equitable refuge, surrounded by inescapable forces of labor exploitation.

A broader goal might be **economic justice** (Hahnel, 2005), where programming languages are tools of liberation, creativity, and community, and a source of empowerment for learners to demand and make change.

Wordplay is many things

A purely functional, stream-based, reactive programming language

A new medium for creating interactive, multilingual, accessible typographic media

A fantasy world in which characters collaborate with people and resolve conflicts to create typographic performances

A cultural mashup of language, typography, interactivity, and logic

A small form of resistance to the overwhelming domination of computing ideals in society.

I said I was seeking questions, not answers, but I do have some emerging insights.

localization + accessibility = ❤️

- Requiring descriptions of everything and requiring translations of everything are very similar requirements
- I frequently found that designing something to be **accessible** made it easier to **localize**, since description infrastructure came for free
- But localization also enables multiple alternate descriptions as well, e.g., to support **plain language**

accessibility + functional languages = ❤️

- Functional code can often be a **description** of what it computes, which means it easier to provide high level descriptions of code for screen readers
- Functional programs also tend to be **shorter**, reducing the amount of interface to navigate and describe
- Because output, animation, interactivity, and documentation are declaratively expressed as code, these benefits carry over

accessibility + standards = 😭

W3C® Web Accessibility Initiative WAI

- For conventional interfaces, standards are essential
- But for unconventional interfaces (e.g., many of Wordplay’s interfaces), standards force shoehorning into old conventions, preventing clarity.
- Access technologies such as screen readers need much richer **customizability** to enable higher forms of access and usability

deep integration = ☯️

- Most of the features I showed today **deeply integrate** the compiler, runtime, and user interface
- This is a contrast to most programming language implementations, which prioritize **modularity** and interchangeability of components
- I’m not sure it’s possible to have both, and raises questions about the feasibility of these features for general purpose languages

language implementation = 😱

- Wordplay is **100,000+ lines** of TypeScript, HTML, and CSS, spanning a lexer, parser, type system, program analysis engine, runtime, code editor, output engine, documentation system, input streams
- One **locale** is 1,000+ string templates and growing
- Where will I find **contributors** who are comfortable with PL language architectures, can read/write the world’s languages, who want to contribute to Wordplay (instead of Rust, for example), and who have time? How do I compensate them?

functional programming can be 🤪

I’ve personally found popular purely functional programming languages to be complicated and … boring.

But writing Wordplay programs is surprisingly **joyous**. Every little bit of progress feels immediate, and it can feel like I’m doing it with a community of weird little characters, each with their own quirks.

Is all of this enough support the teacher and students I mentioned earlier?

No. A platform is key, but we also need teacher education, curriculum, community, and more.

(stock photo)

Is this really **justice**?

No. That would require reimagining far more than programming languages, including CS culture, classrooms, curricula, and the broader systems in which CS are embedded.

But we can’t let that stop us…

“We must learn that passively to accept an unjust system is to cooperate with that system, and thereby to become a participant in its evil.” — MLK

Thank you!

I hope to release **in Fall 2023**.
Let me know if you’d like to help!
There’s much to do…

Wordplay is a purely functional reactive programming language for bringing words to life in accessible, global ways.

It is one small part of making computing work for everyone, but wholly inadequate for true justice.

This work was supported by the University of Washington, National Science Foundation, unrestricted gifts from Google, Microsoft, and Adobe. Thanks also to the Svelte community for making an outstanding modern platform for richly interactive web applications.