

Searching for Justice in Programming Language Design

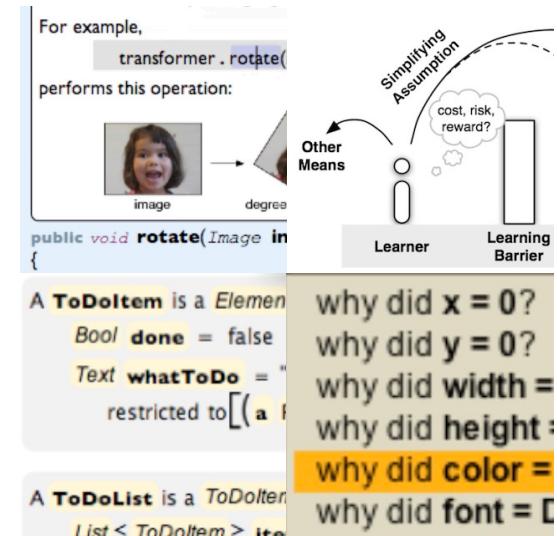
Amy J. Ko, Ph.D.

The Information School
University of Washington, Seattle



A bit about my scholarly start...

I started my career on **human-centered programming tools**, trying to make creating with code a less frustrating and more productive experience. Building things was fun, and there were millions of developers who I tried to help have better experiences in engineering software.



But I set this work aside for good reasons...

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.

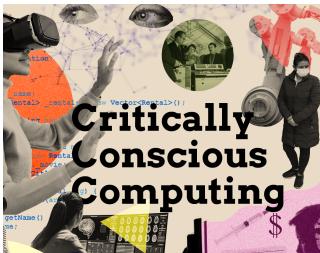
We've worked toward justice on many fronts



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



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



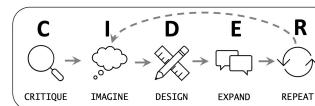
Books that prepare students and teachers to see computing through the lens of justice, and discover their own “limiting situations”

“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.

```
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.



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.

A photograph showing the backs of several children's heads. They are all wearing dark-colored shirts. In the background, a person with long, light-colored hair is visible, though they are mostly out of focus. The lighting is soft, suggesting an indoor environment.

(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.



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.



Textual programming for the classroom

Try it

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 humbly 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 **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 language scripts in Unicode.
- I explicitly deferred **evaluation**, and so view the work as generating new questions, not answers.

My aesthetic goals



Global — Celebrate the world's languages without centering English



Accessible — Center ability diversity and neurodiversity, and their tensions



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



Simple — Ruthlessly avoid complexity



Wordplay

Learn to code by animating words, emojis, and symbols from the world's languages, whatever your abilities.

Wordplay is an innovative programming language with block and text editing , playful inputs like time , sound , webpages , and physics , instant time-travel debugging , and comprehensive documentation . All in a growing list of the world's languages , following the latest web accessibility standards . Share with friends, private groups, or the world . Free forever from the **University of Washington Information School** .

Learn



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**.

```
1 var bookshelf = require('../lib/db-connection');
2 var _ = require('underscore');
3 _.str = require('underscore.string');
4 _.mixin(_.str.exports());
5 _.str.include('Underscore.string', 'string');
6
7 module.exports = bookshelf.Model.extend({
8
9   constructor: function() {
10     Model.apply(this, arguments);
11
12     this.initializeamps;
13     this.unloadamps;
14
15   }
16
17 })
```



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.

()	[]	{ }	「 」	< >	(())	,	/	\	_
<i>f</i>	?	∅	⊤	⊥	“ “	↖ ↗	← →	↑ ↓	
^	#	•		&	.	:	△	...	՞ ՞

all other symbols are names

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

+ - × ÷ √

⚡ ↪ 🔁 ☈ ✖

* ▶ ○ ↩ ↴

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

حصيلة

אבד

😊😊😊

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**

start

- 

```
`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' : · T · 'Dr.Ko' : · T · 'yo' : · L · }

• **Kitty**(**name** · '' · **breed** · '') (

 f · **hello**() · "Hi, my name is \name\ and I'm a \breed "

)

a functional grammar

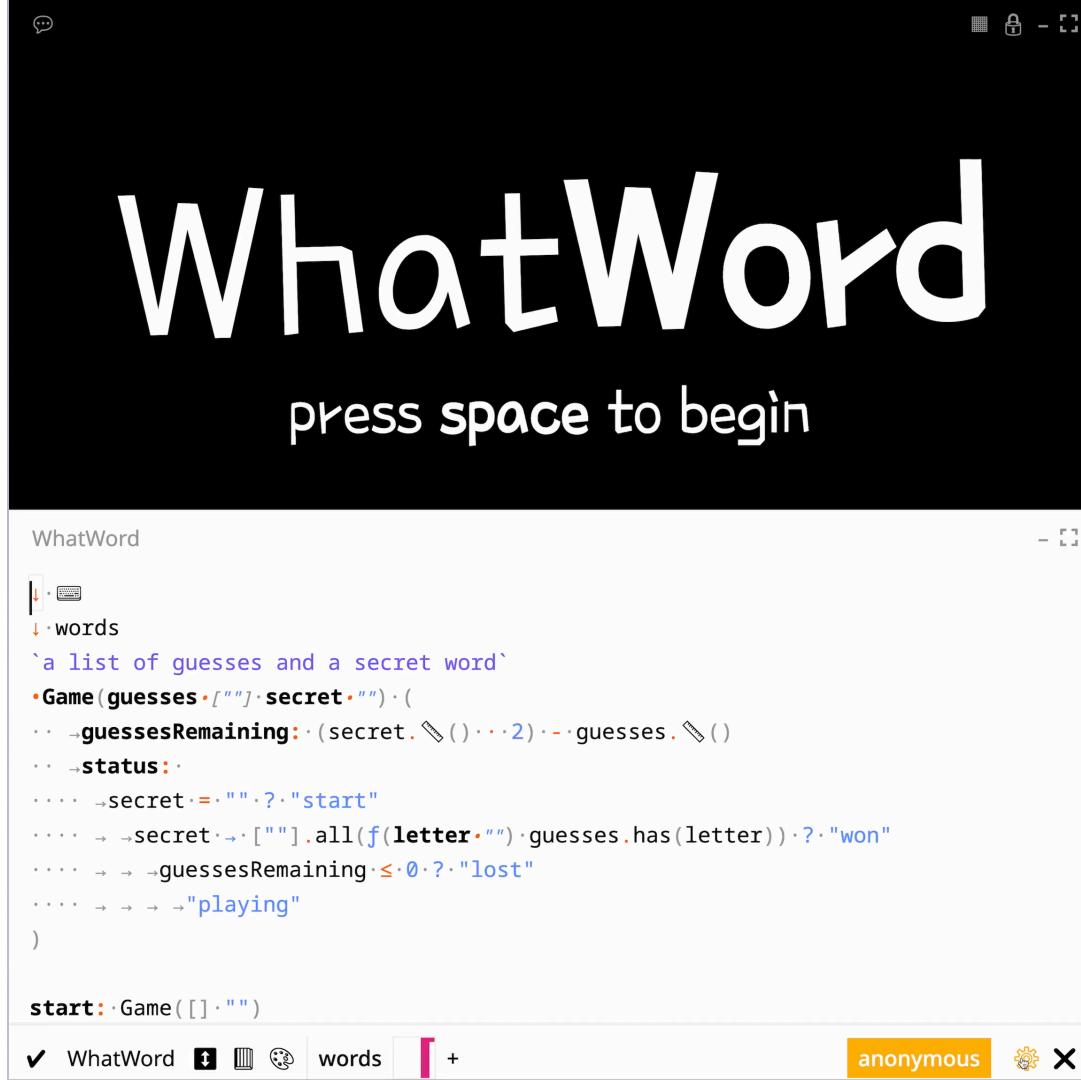
Wordplay blends Smalltalk's love of **objects**, Lisp's love of **parentheses**, APL's love of **symbols**, and functional programming's love of **expressions**, while avoiding natural language mimicry to avoid privileging a grammar.

$f \cdot ! (n \cdot \#) \cdot$
 $n \cdot = 1 \cdot ?$
 1
 $n \cdot \cdot \cdot ! (n \cdot - \cdot 1)$
 $! (5)$

number

120

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



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?

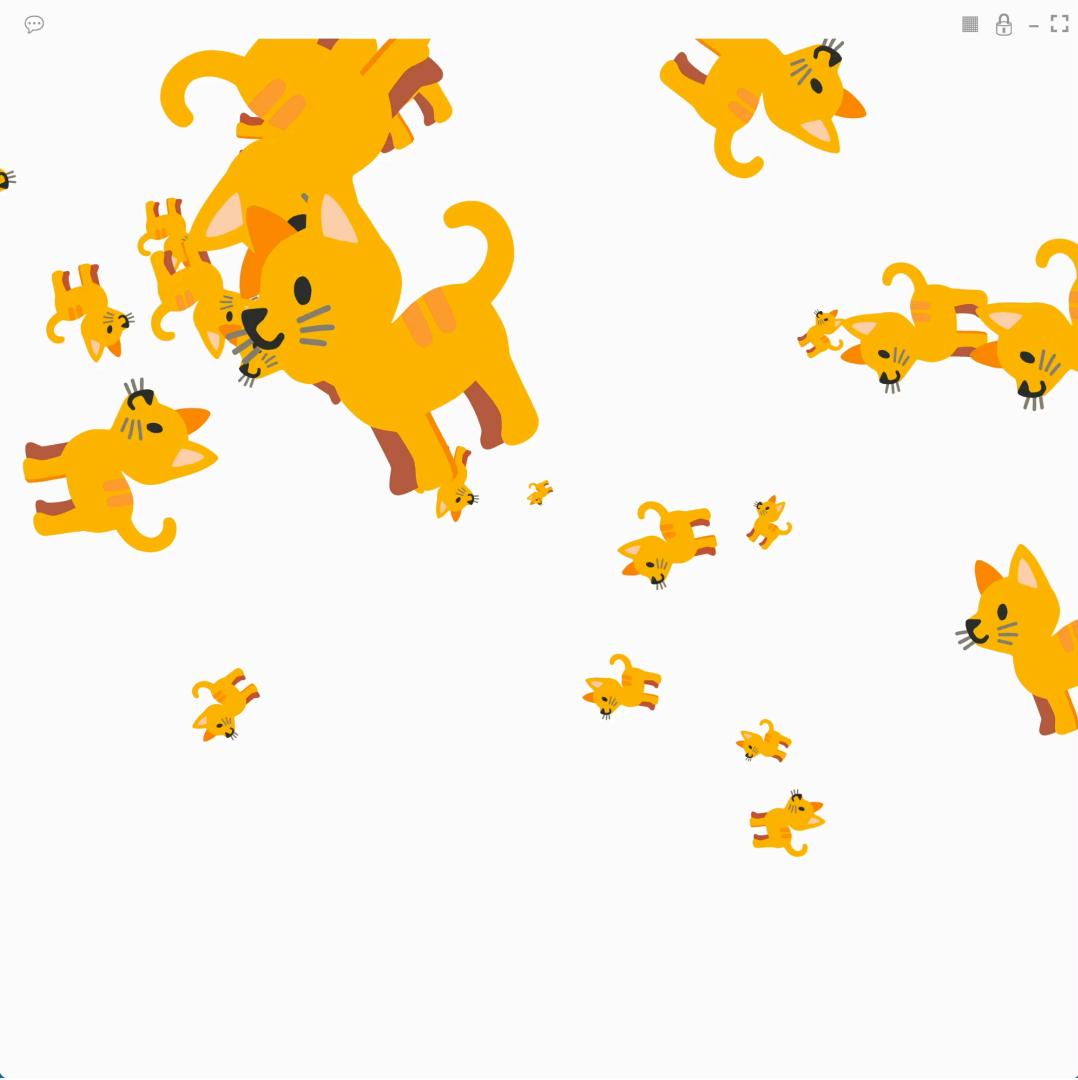
Is this justice?

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.

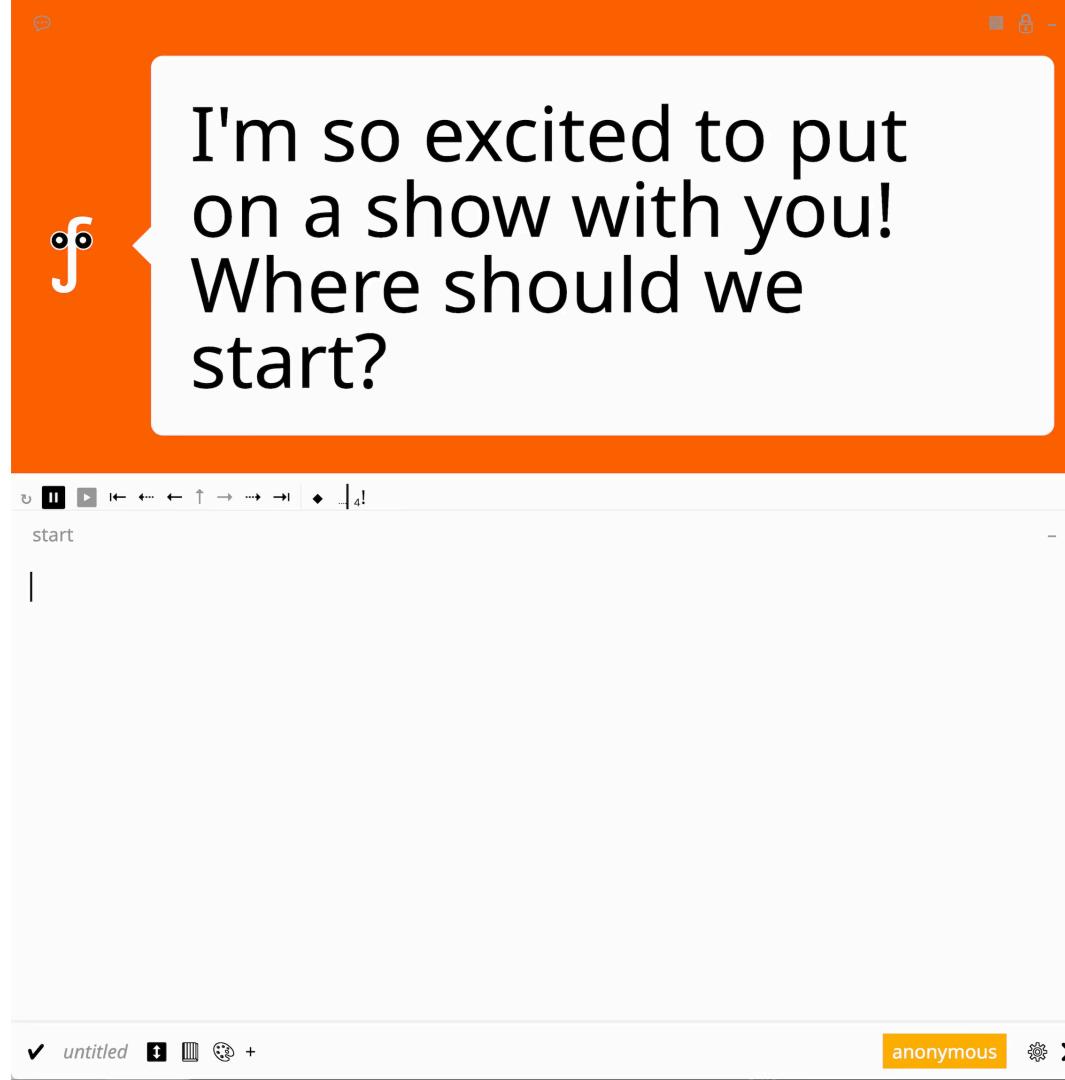
Wordplay operationalizes this by anthropomorphizing computing concepts through **lore**, offering building a world in which computing concepts interact, have conflict, and collaborate.

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.

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

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



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.

The screenshot shows a digital diary application interface. At the top, there are navigation icons (undo, redo, search, etc.) and a page number '21'. Below the toolbar, a note is displayed with a yellow border:

conditional

condition • ? ?
yes no

?

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

start

food: · 10 bananas

hungry: · food · < · 15 bananas

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.

n

Oops, I don't k
how to >

start

```
`True if n is between min and max, exclusive`  
f·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

X 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.

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**.

The screenshot displays the Wordplay interface with two main sections. The top section shows a hybrid text editor where the word "Injustice" is written in pink. The bottom section shows a block-based editor where the same text is displayed. Below these sections is a code editor window titled "main" containing the following Python-like pseudocode:

```
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'
```

At the bottom of the interface, there are several status indicators: a checked checkbox labeled "Justice", a user icon, a document icon, a circular icon with a plus sign, an "anonymous" button, and a close button.

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.

RainingLetters

```
..... f(letter·Letter)
..... letter.y > 0m ? (letter.y · letter.y - 0.5m), angle: · letter.angle + letter.y · letter.size + 2m).visible: · ⚡(0·amps) > 50
.....)

`Convert the letters into phrases`
(
.... [
.... ⚡(" " · size: · 3m · place: · ♪ (-8m · 12m))
.... ⚡(" " · size: · 5m · place: · ♪ (8m · 11m))
.... ⚡(" " · size: · 1m · place: · ♪ (letter.x · letter.y)
.... · rotation: · letter.angle · · 1°
.... · rest: · ⚡(
.... · · opacity: · letter.visible · ? · 1 · 0 ·
.... · · color: · ⚡(100% · 0 · 0 °)
.... · · )
.... · )
.... ]
.... .+
.... letters.translate(
.... f(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)

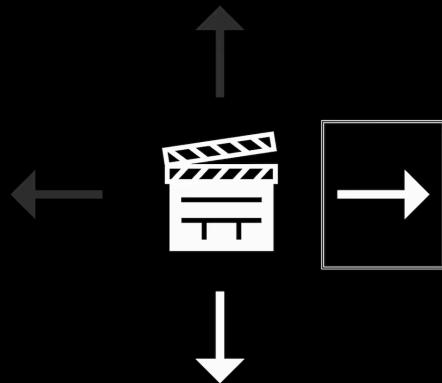


Output is a scene of **phrases** that enter, change, and exit stage.

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

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

`x → , 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.

A screenshot of a game interface. At the top right are window control icons. Below them is a small speech bubble icon. In the center is a white rectangular area with a yellow border. Inside this area, a black mouse head with ears and whiskers is positioned near the bottom right. A small cursor arrow is visible just above the mouse. At the very bottom of the slide is a thin yellow bar containing several icons: a circular arrow, a double square, a play button, and various navigation arrows. To the right of these are two clock icons and a progress bar with the number 9566 at the end. At the very bottom of the screen, there is a dark footer bar with several buttons: a checkmark and 'Catch', a double arrow and 'Catch +', an anonymous status indicator, and settings and close buttons.

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?)

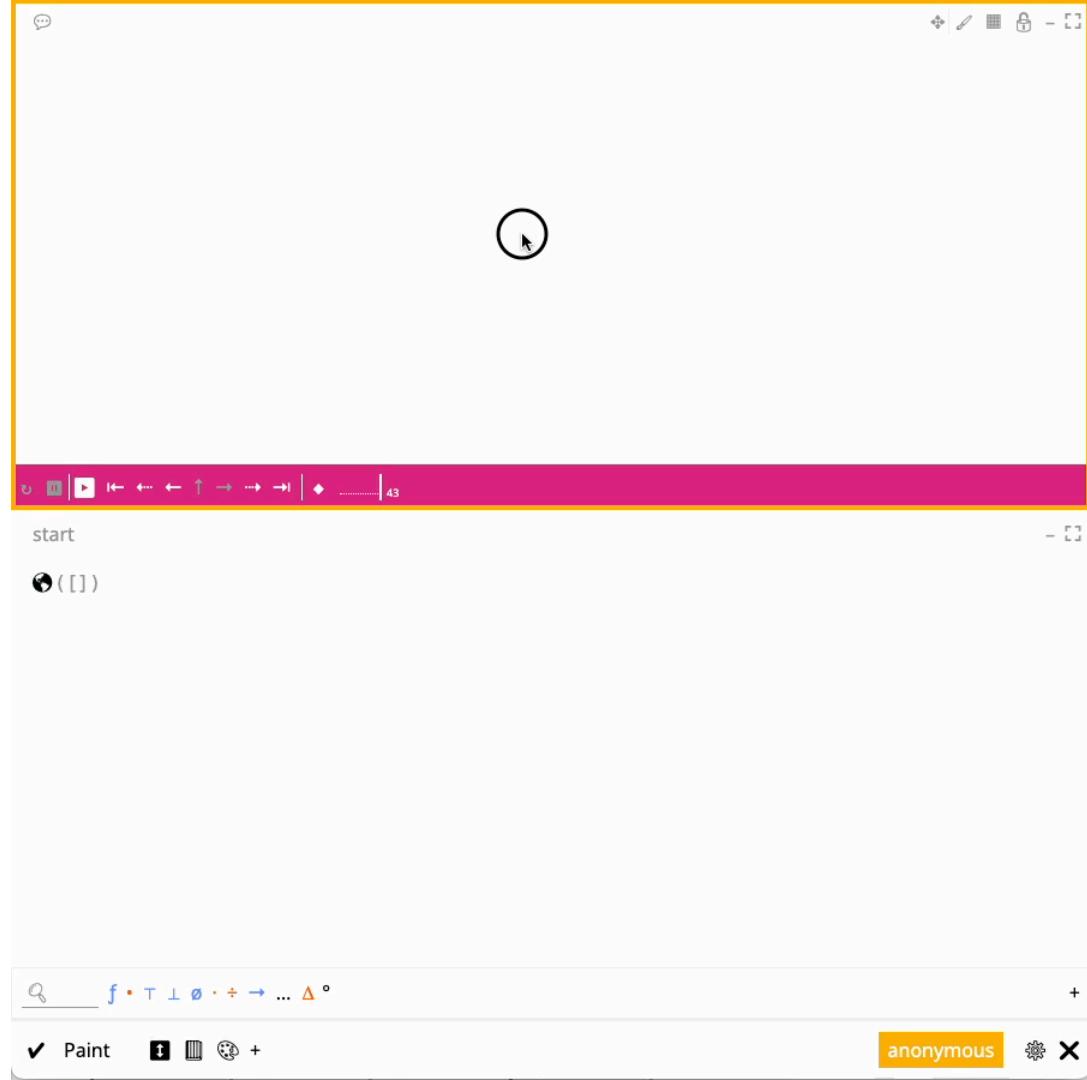
Is this justice?

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.

The slide shows a presentation interface with a toolbar at the top and a code editor below. The code in the editor is:

```
(dotimes [i 2]
  (print "d a ")
  (Thread/sleep 1000)
  (print "value, but I "))

Timer
```

The code uses a `dotimes` loop to print "d a " twice, with a one-second delay between prints. It then prints "value, but I ". A yellow box highlights the word "Timer" in the code.

At the bottom of the slide, there are navigation icons and user information: "anonymous" and a gear icon.

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.

start

f greeting()

f evaluating program for the first time

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

🔍 f • T ⊥ Ø • ÷ → ... △ °

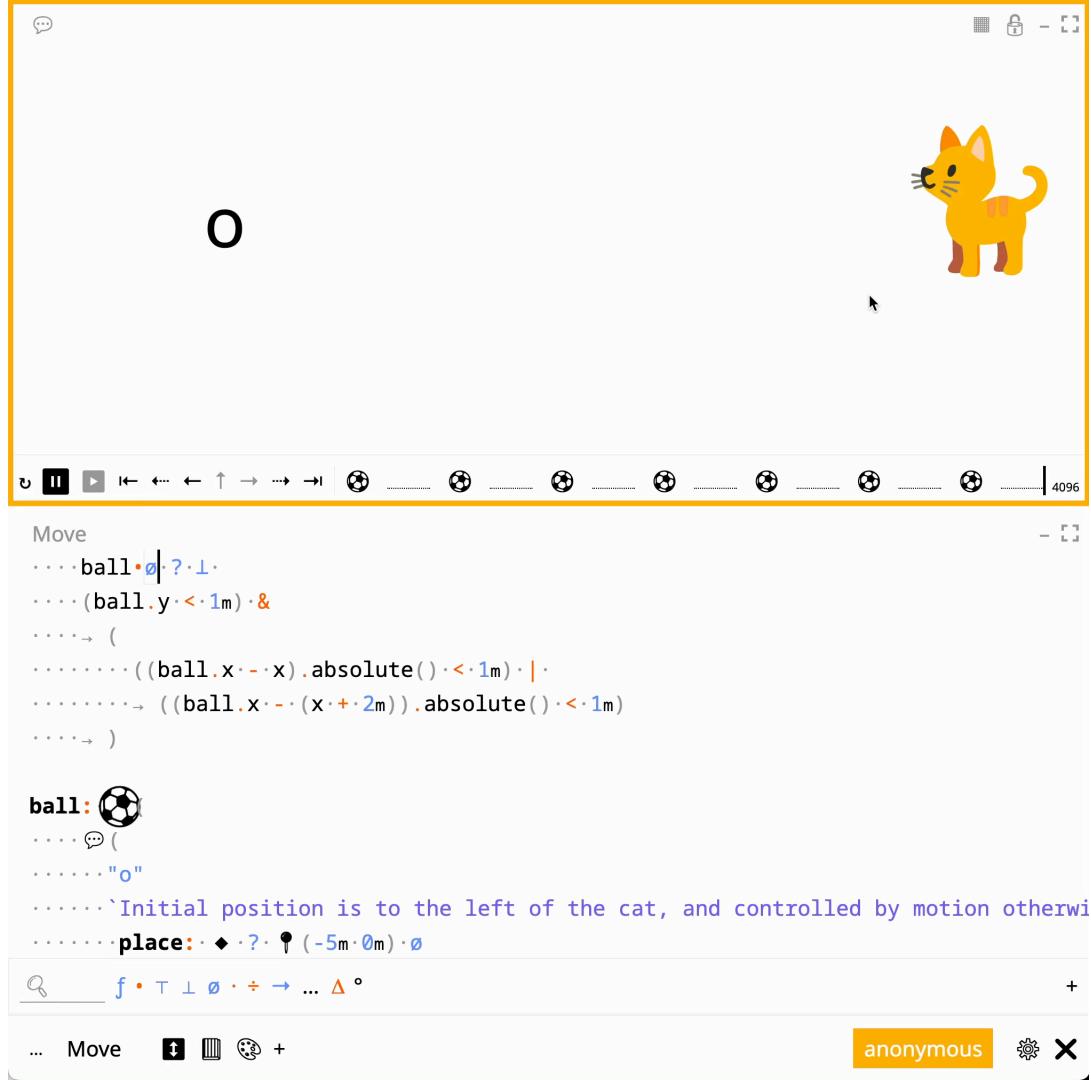
✓ Stepping ⏪ 📄 💬 🎨 +

anonymous



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 in time, by **scrubbing**, stepping to prior **inputs**, and stepping to prior expression **evaluation**.



The screenshot shows a code editor interface with a yellow border. In the top right corner, there is a small orange cat icon. The code editor displays a snippet of pseudocode:

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

Below the code, there is a variable definition:

ball:  (

....."o"

.....`Initial position is to the left of the cat, and controlled by motion otherwise

.....place: ◆ ·?· ♪ (-5m·0m) ·ø

At the bottom of the editor, there is a toolbar with icons for search, move, and other functions, and a status bar indicating the user is anonymous.

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.

The screenshot shows a browser window with a yellow border. Inside, the word "Wowie" is displayed in a large, orange, tilted font. Above the word is a small speech bubble icon. Below the word, the word "Color" is written in a smaller font. Underneath "Color", there is a code snippet:

```
color: △ ⚡ (?) ? ⚡ (0% · 0 · 0°) ... ⚡ (50% · ⚡ (?) · · 200 · ⚡ (?) · · 360°)
```

Below this, another code block starts with a speech bubble icon and contains:

```
(  
  .... "wowie"  
  .... name: "kitty"  
  .... size: 6m  
  .... rest: ⚡ (color: color · tilt: · ( ⚡ (?) · · 0.5) · · 30°)  
  .... ⚡ : · .1s  
)
```

At the bottom of the browser window, there are several icons: a checkmark, "1. Zzzz", a refresh button, a document icon, a gear icon, a plus sign, and an "anonymous" button. On the far right, there is a close button.

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.

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)

But that would not be justice either

Justice is more than just a better tool, and some missing resources.

It is also **agency** and **power** over the future of computing. Because I created this alone, on behalf of others, it offers neither of those things. It is simply my worldview, projected onto others' needs.

Perhaps justice mean **sharing** power,
being community led.

I've just begun to attempt to do this,
starting an open source community of
more than 120+ undergraduates,
many with disabilities, many
multilingual English learners, many
allies, and have begun to explore how
to structure power over Wordplay's
design around the needs, values, and
dreams of youth in Puget Sound.



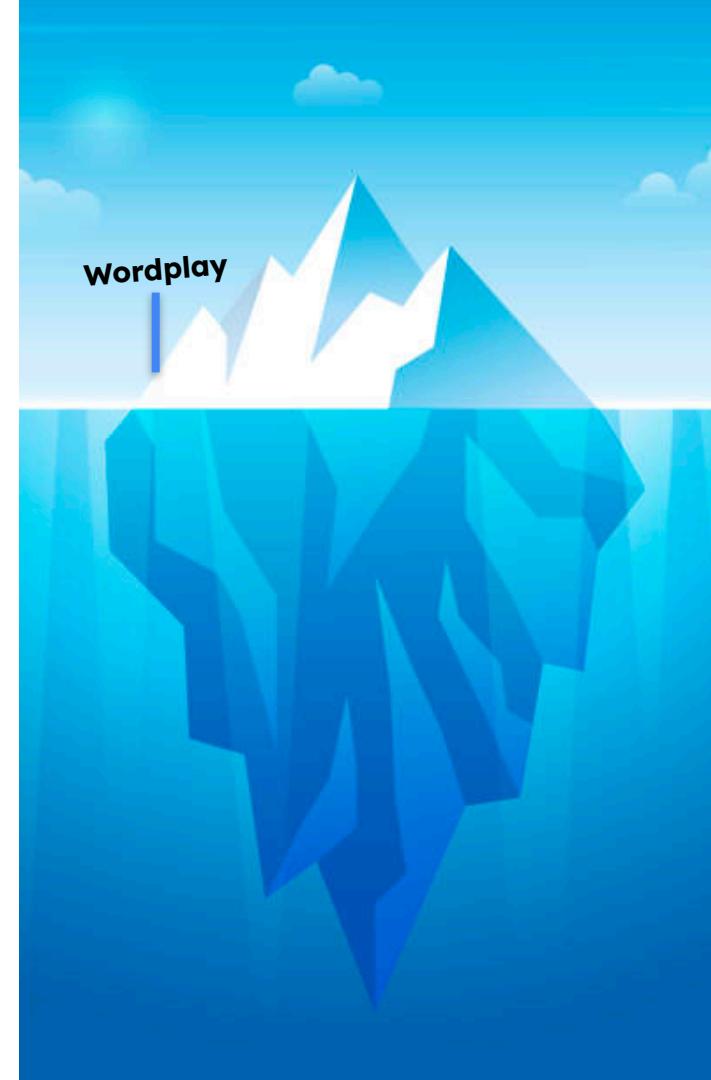
(stock photo)

What I've learned so far from students

- Many youth fear the responsibility of power and devalue the expertise of their lived experience
- Many youth cannot imagine a world that was designed around them, instead of one they have to adapt to
- Some youth, in contrast to the above, are inspired by radical futurism, and are far more engaged in making a new world than succumbing to the one we have.

This, of course, is just the beginning.

“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!

Try wordplay beta at
wordplay.dev. Contribute if you
like it, and help us built a more
just future of programming.

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.



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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.