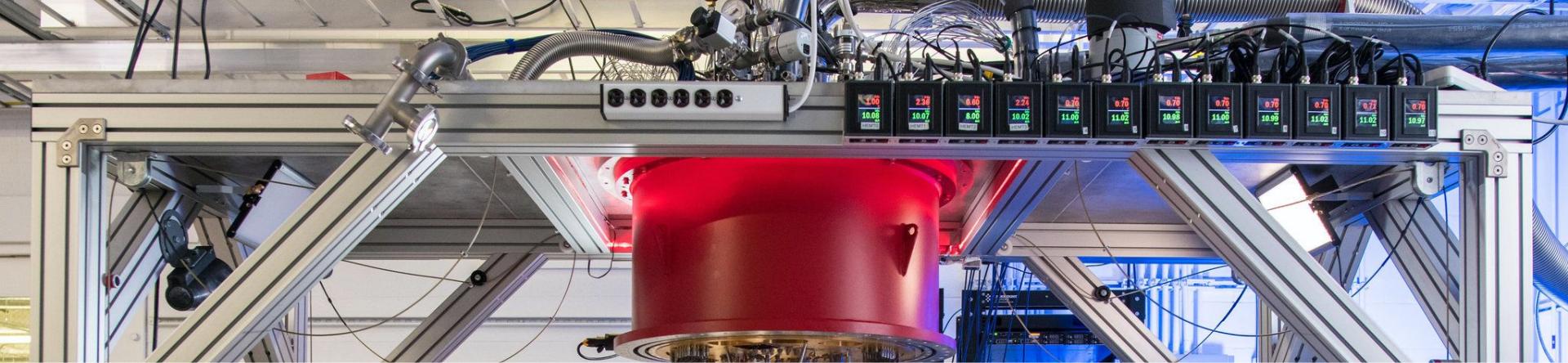


Critical Computing Education

Amy J. Ko, Ph.D.
Professor
The Information School
University of Washington, Seattle





Computing can be magical



I fell in love with this
magic early in life

As a closeted trans teen, code
was my escape

I programmed virtual worlds
where I could flee my body and
avoid my gender plight

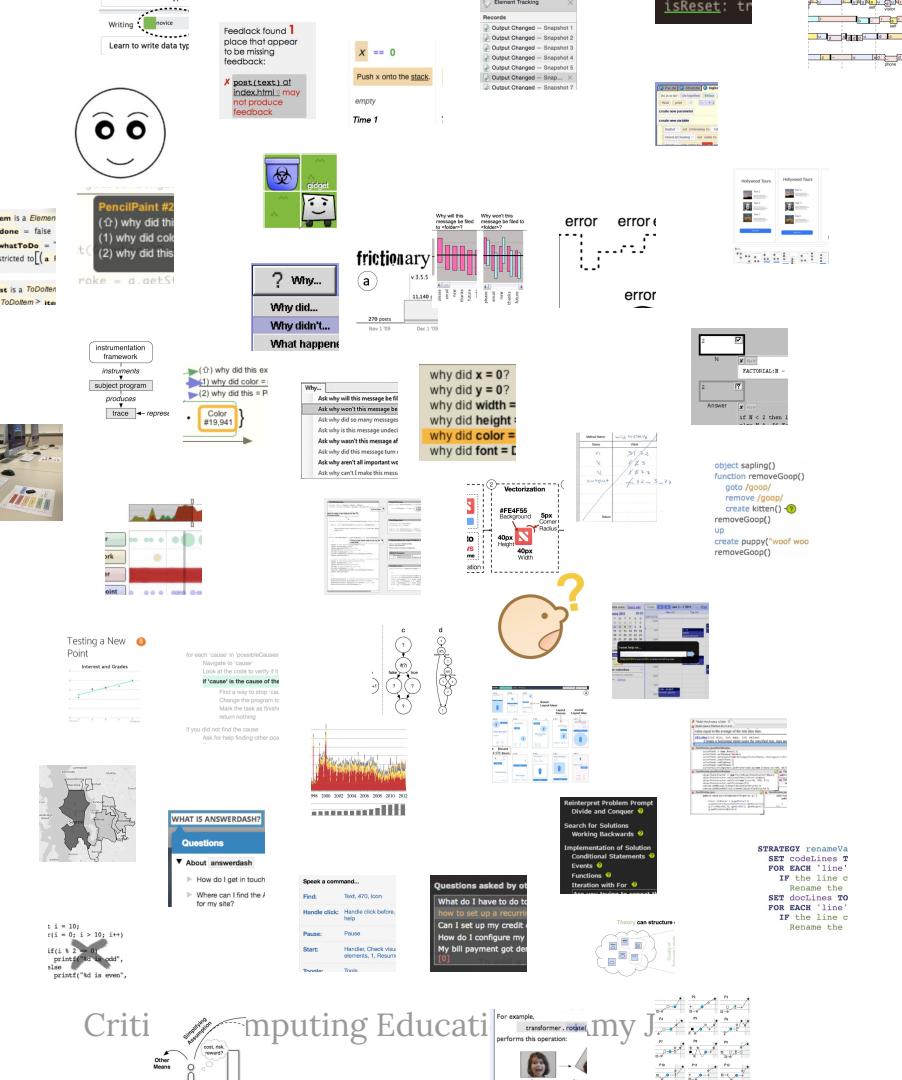
I used the internet to learn
about a world I couldn't see



Captivated, I've spent the past 20 years lowering barriers to programming.

I studied why programming is hard, and how to make it easier

I invented new ways of making, breaking, and fixing software



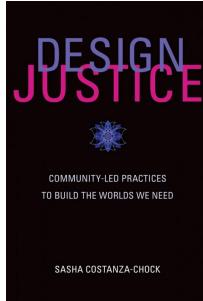
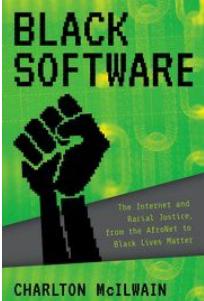
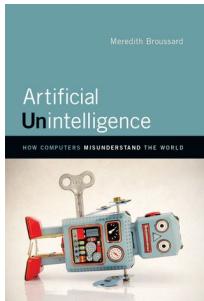
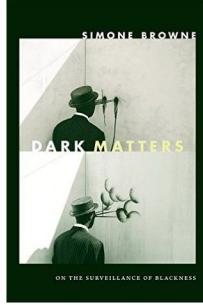
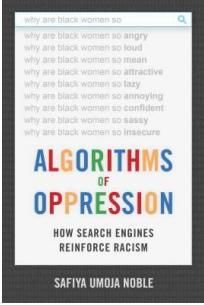
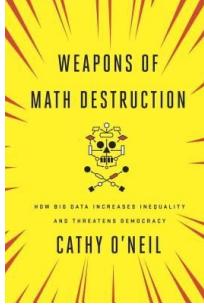
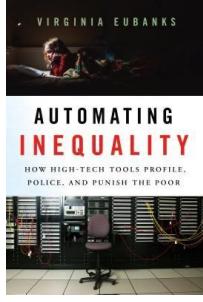
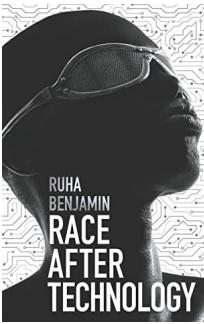
Criti

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All of this followed from
two particular notions
of justice...

1. Computing should be useful
and **usable** to everyone
2. Everyone should be
empowered to harness
computing



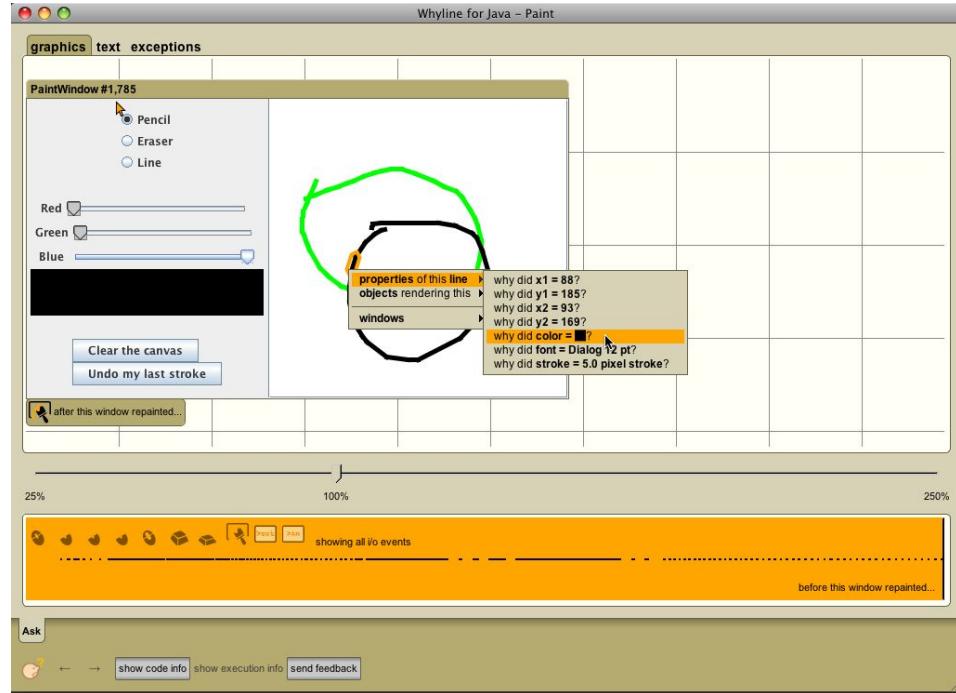
Then I started reading...

Over the past five years, I learned how software is being used to **oppress**, marginalize voices, erode discourse, dissolve safety nets, surveil communities, shrink the middle class, and encode anti-Black racism

Code, my lifelong professional and personal interest, was both a tool of **empowerment** and **injustice**

My research amplified algorithmic bias

My research on **debugging tools** made software faster and cheaper to make, helping developers write biased algorithms faster and more correctly than ever before



Faster fixes, more disruption (Ko and Myers, 2008).

My research centralized and privatized power

My inventions largely served powerful platforms owned by Amazon, Google, Facebook, Microsoft, and Apple, disempowering smaller organizations and the public



Microsoft replicated our developer tool ideas and restructured teams based on my productivity research increasing its power.



Google built upon our research on ML development, streamlining data debugging.



Apple replicated our learning technologies to attract learners to its walled garden through Swift Playgrounds.



Facebook leveraged our work on help systems to lower usability friction, keeping people on its platform.

My research replaced people with machines

Our research on help systems, and the startup that grew out of it (AnswerDash), created two dozen jobs replaced tens of thousands of customer service agents with information retrieval algorithms, while enriching investors (a little)

The screenshot shows a woman with long brown hair and glasses, wearing a blue shirt, looking at a digital screen. On the screen, there is a green rectangular graphic with white text that reads "ALL CUSTOMERS HAVE QUESTIONS" above a small icon of a person holding a question mark. To the right of the woman, there is a blue button with the text "Q&A" and the number "188". Above the woman, there is a text overlay that says "Empower your customers with instant answers right in your site or app." At the top of the page, there is a navigation bar with the AnswerDash logo, social media links (Facebook, Twitter, LinkedIn), and buttons for "Create free account" and "Log in". Below the navigation bar, there are links for "PRICING", "DEMONSTRATIONS", "CUSTOMER SUCCESS", "INTEGRATIONS", "ANALYTICS", and "BLOG".

Empower your customers with **instant answers** right in your site or app.

We eagerly found ways to replace human effort with machine effort.

Coming out, I faced oppression first-hand

- TSA body scanning leads to body searches when I travel
- ACM/IEEE digital libraries deadname me every day
- Trans-exclusive health IT has led to medical errors
- Twitter has facilitated cyberbullying at the scale of thousands
- News aggregators remind me daily of violence against trans people



Being trans is in a transphobic world is hard. Software makes it harder.

A moral quandary...

I love computing as a medium
and want other people to love
it too!

I've spent my whole career
trying to share that love

*Computing is harming me and
others, and few in CS seem to
care or do anything about it.*

*How can I continue advocating
for something that is doing such
harm?*

I had to
revise my
notions of
justice...

1. Computing should ~~be useful and usable~~ respect everyone
2. Everyone should be empowered to harness computing to dismantle systems of oppression, rather than reinforce them

I had to
reconsider
my research

1. *How can we educate the public to ensure that computing respects everyone?*
2. *How can we educate developers to ensure they make choices that dismantle systems of oppression, rather than reinforce them?*

Today, I want to share my lab's nascent efforts to explore these notions of justice in our research, teaching, and service, and entice you to join us.

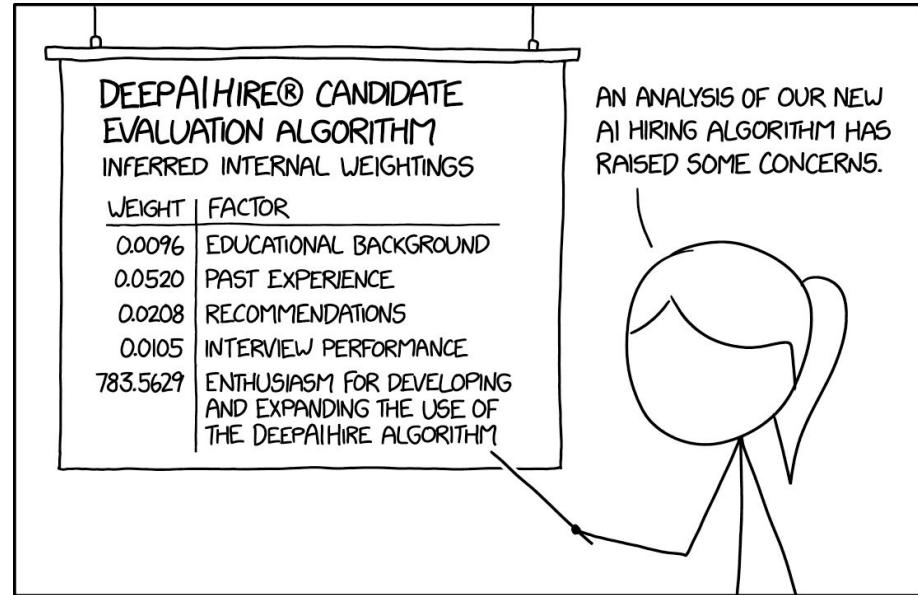
I'll discuss three ways that computing reinforces systems of oppression

For each, I'll share research by my Ph.D. students that explores how to teach these reinforcing patterns, and empower students to disrupt them

Warning

This is an unconventional talk. There will be research, but there will also be teaching, service, and politics.

Computing has limits



<https://xkcd.com/2237/>

Many of us think of computing as endlessly powerful.

The world is using it to simplify retail and transportation, but also poverty, crime, hunger, climate, health, wellness, and more.



Young, white male doctors helping young white women through the power of computing.



Computing is not neutral.

But this neophylic myth has ignored real harm.

Judges are delegating sentencing decisions to racially-biased predictions.

States are delegating food stamp eligibility judgements to inhumane algorithms.

Filter bubbles are dividing our discourse.

etc.

What everyone should know about computing

- Code is often *wrong* (O'Neil, 2016)
- Code embodies its creator's *values* and *biases* (Costanza-Chock, 2020)
- Code can't solve *every* problem; it often *causes* new ones (Toyama, 2015)

The public doesn't know these facts because **we're not teaching them**. In fact, many in CS are saying the opposite, that software is neutral, that it *is* infinitely powerful.

How can we teach these limits?

Three examples from my lab.

Greg Nelson has invented tutors that teach **limits** of programming languages

His tutor teaches the mechanics of program execution and reflects on its limits. Students learn that what little intelligence programs have is bestowed by people.



- I'm on the job market this year, and do HCI and Computing Education!

Lesson

Learning step 1 of 180

If statements

Now it's time to use what you learned about boolean values and operators!

Before this, the computer would execute all instructions created from the code.

If statements allow computers to do some set of instructions if a condition is true or not.

They look like this

```
if ( condition )
{
    code goes inside the { }'s
}
```

Let's step through one to see how it works.

Program

```
var x = 0;
if ( 10 > 0 ){
    /* the computer will execute inside here
       because the condition is true
       and that leaves true on the stack
       we put x = 100000; here
       just so you can see some code
       execute inside the if */
    x = 100000;
}

x;
var x = 0;
if ( 0 > 10 ){
    /* the computer will NOT execute inside here
       because the condition is false
       and that leaves false on the stack */
    x = 100000;
}
x;

var x = 0;
if ( 10 != 0 ){
    /* the computer will execute inside here
       because 10 is not equal to 0
       and that leaves true on the stack */
    x = 100000;
}
x;

var x = 0;
if ( 0 == 10 ){
    /* the computer will NOT execute inside here
       because 0 is equal to 10
   }
```

State

first frame()	
instruction	This is a variable declaration statement. It declares one or more names and can optionally assign them values.
stack	empty
namespace	{}

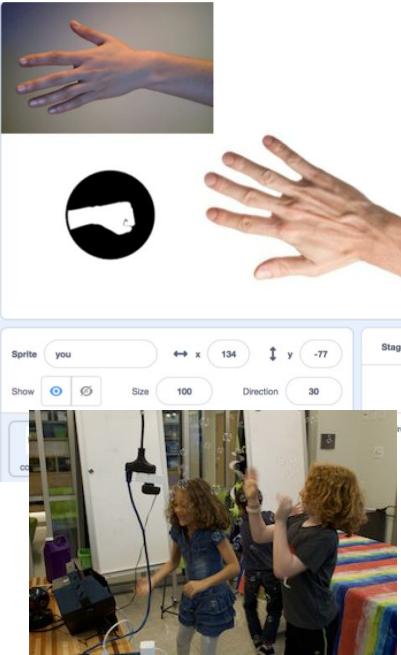
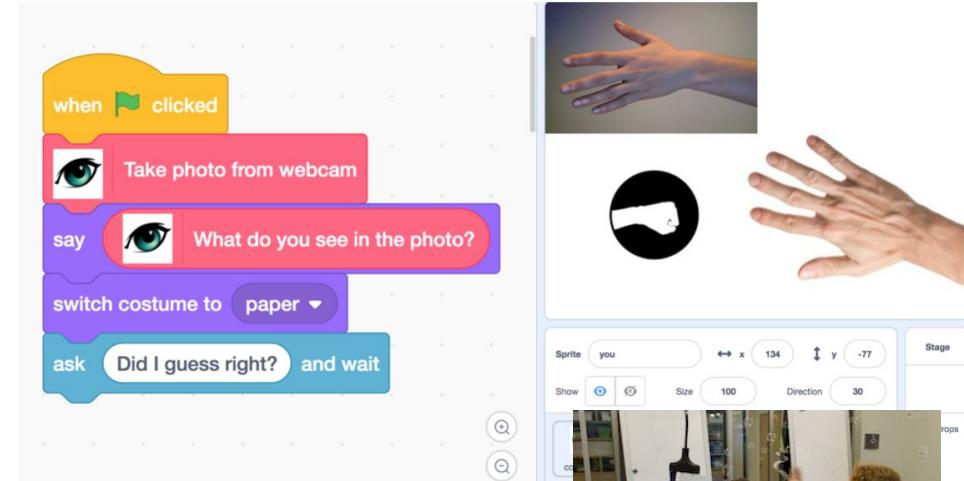
Greg Nelson, Benjamin Xie, Amy J. Ko (2017). **Comprehension First: Evaluating a Novel Pedagogy and Tutoring System for Program Tracing in CS1**. ACM International Computing Education Research Conference (ICER), 2-11.

Stefania Druga has shown youth the limits of AI.

When children begin to create with machine learning embodied in robots, they begin to debate the capabilities with peers, and come to see the power of AI skeptically.



– I study AI literacy, HCI, and Computing Education



Alannah Oleson has invented methods for uncovering designers' assumptions.

Over a period of weeks, students come to realize the narrow ways in which they understand human diversity and the complexity of designing for it.



– I study HCI and Design Education from a social justice lens.

"I feel slightly less confident in my inclusive design skills [now]... the result of **a reality check** the [method] gave me."

"... helped us understand the **assumptions that we had but didn't notice** while we were creating the design."

"... taught us to think about **all kinds of users** rather than just a generic one"

"My biggest takeaways from [class] were that **I had prejudices... that I didn't even realize**, that I actively needed to change those biases."



President Obama participates in the Hour of Code, which frames computing as creative expression without critically questioning its limits.

These are just a few questions of many, e.g.,

How can we develop views of CS that balance skepticism with optimism?

How well do shifts in beliefs about CS persist long-term?

How do new conceptions of diversity influence algorithm design choices?

Data has limits



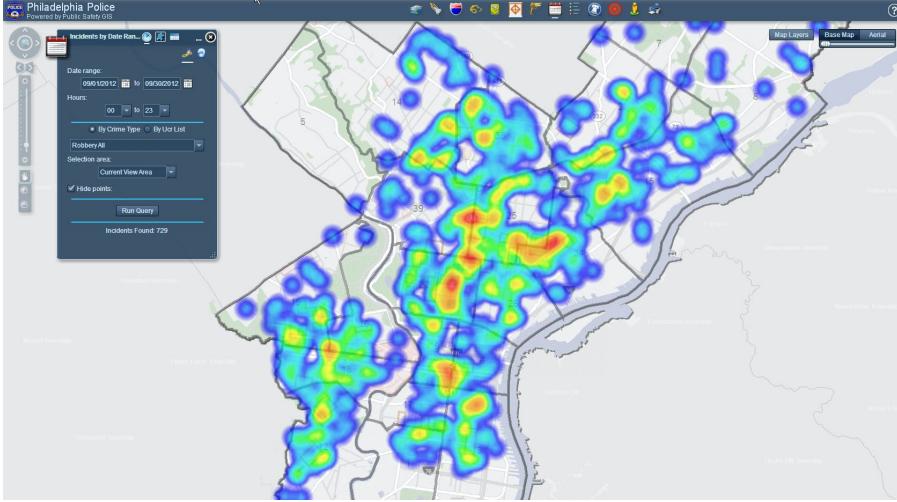
<https://xkcd.com/1838>

Many think of data as being *inert*.

Computing makes it easy to capture, easy to store, easy to process. Therefore, computing is the powerful thing, data is just input, right?

	A	B	C	D	E	F	G
1	ID	Age	Gender	District	SATV	SATM	GPA
2	54419	18 M		38	368	253	3.52
3	62516	22 M		5	670	496	1.11
4	55509	21 F		54	639	439	2.68
5	36489	19 M		49	368	465	3.11
6	36387	21 F		36	620	306	2.16
7	95507	20 F		13	512	593	2.83
8	16360	20 M		52	621	377	2.79
9	12838	18 F		44	571	544	2.13
10	73450	20 F		59	647	746	2.08
11	26869	18 F		28	337	371	2.28
12	48552	22 M		63	260	498	3.24
13	23416	19 M		51	476	294	2.31
14	42635	19 F		35	677	241	3.19
15	67448	19 F		55	335	533	1.81
16	34689	21 F		42	585	708	1.80
17	32763	22 F		20	556	787	1.18

Data is just bits, right?



Philadelphia crime data is used to predict where crimes will happen, perpetuating the oppressive past of Black surveillance in the city.

But data is a dominant force behind unjust code

It's biased crime data that has bolstered the carceral state.

It's cisnormative data on that cause gender nonconforming people be harassed by the TSA.

It's our desire for data that's driving increases in carbon output.

What everyone should know about *data*

- Data is a record of the *past*, not the future (Boyd, 2011)
- Data encodes values, assumptions, and goals (Garcia, 2018)
- Uses of data harm people in *unequal ways* (Costanza-Chock, 2020)

The public doesn't know these limits because we talk about data in **abstract, static** terms. But developers, harnessing data for computational ends, can do **concrete, dynamic** harm.

How can we teach these limits?

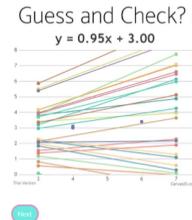
Two examples from my lab.

Yim Register is teaching the limits of data with tutors.

Their tutor teaches prediction concepts with **personal data**, which their recent study shows is superior at helping people learn a model's semantics, and frame self-advocacy arguments in terms of those semantics.



- I'm interested in creative ways to develop machine learning literacy!



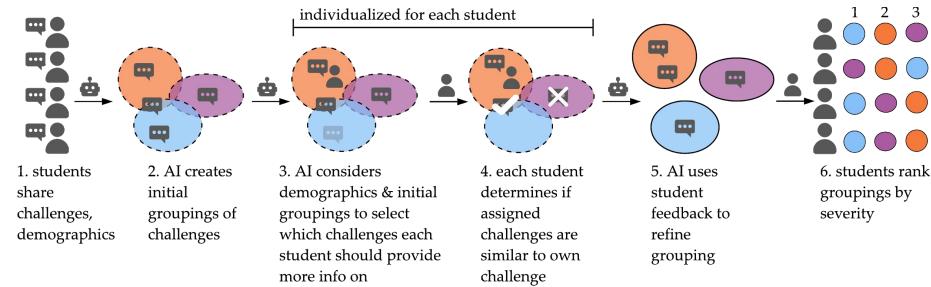
Yim Register, Amy J. Ko (2020). **Learning Machine Learning with Personal Data Helps Stakeholders Ground Advocacy Arguments in Model Mechanics**. ACM International Computing Education Research Conference (ICER), 67–78

Benji Xie is modeling inequity in learning contexts.

His latest project is investigating a new ways for teachers to gain insights about inequities in their classrooms, amplifying minoritized voices while preserving their privacy.



- I'm interested in equitable human-AI interaction in learning contexts!





Google surveils Paris without consent.

These are just a few questions of many.

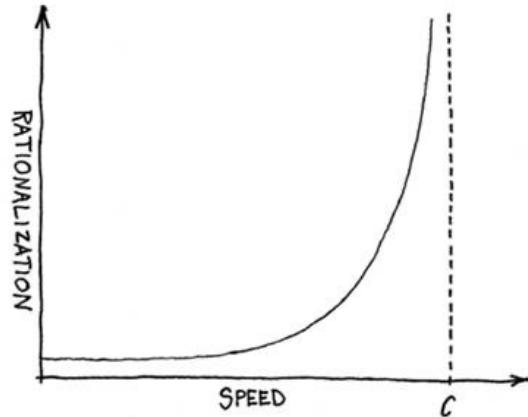
How can we develop learners' understanding of data harm?

How should we reframe algorithm design in a way that embraces the limits of data?

How should we reframe data structure education to highlight the role of structure in erasing diversity?

Computing has responsibility

MORAL RELATIVITY



RELATED TO MORAL RELATIVISM, IT STATES THAT ETHICS BECOME SUBJECTIVE ONLY WHEN YOU APPROACH THE SPEED OF LIGHT. THAT IS, IT'S OK TO BE SELF-SERVING, STEAL, AND MURDER AS LONG AS YOU'RE GOING REALLY, REALLY FAST.

(NOTE: THIS IS WHY RAP SOUNDS BETTER ON THE HIGHWAY AT 90 MPH)

<https://xkcd.com/103/>

CS values innovation, disruption, power, and speed

We celebrate students who
secure powerful roles,
companies that restructure
markets, and innovations that
reshape society.



For some companies, breaking things is the goal.



Many CS departments are structured as bootcamps for big tech—including ours at UW.

But CS often leaves the moral choices about *what* to create to investors, or worse, a myth of technological determinism

But *what* we make is not an individual, inevitable choice, but a moral, collective one. It's our responsibility to center these individual and collective value tensions and impacts in student learning.

What everyone should know about the responsibility of CS

- Software design choices are *collective choices* (Vakil, 2018)
- Developers' *values* and *politics* are infused in their *choices* (Vakil, 2018)
- Developers are *responsible* for what they make (Friedman, 1992)

Too few people—including CS faculty—understand these responsibilities. It's our job as teachers to develop awareness of these them, creating a global sense of accountability amongst people who amplify social forces with computing.

How can we teach these responsibilities?

Two examples from my lab.

Neil Ryan is understanding career choices.

Their latest project has found that most undergraduate CS majors rapidly absorb the dominant narratives about careers from their departments and shape career trajectories accordingly.



- I want to change the narrative of what's standard, acceptable practice in computing to better serve humanity!

“it really normalizes going into big tech just after undergrad. Which I think implicitly normalizes not going down other paths, and not asking questions of these big tech companies. I mean, this is what makes (CS) money, right? When they can have recruiters and big tech companies come recruit successfully, and get, like, tech workers into their capitalist agendas, then (CS) gets more money.”

- CS-P1, reflecting on the large gifts given to CS departments by tech philanthropists.

Jayne Everson is studying how to prepare justice-focused K-12 CS teachers.

She's just starting to observe how critical reflection CS and society changes the way they see computing and how they frame computing to youth, across STEM learning contexts.



- I'm interested in tools and teaching methods for supporting project-based learning about CS and social justice."

CRITICAL CS ED



An NSF-funded project investigating how to prepare justice-focused middle and high school CS teachers.

PREPARING JUSTICE-FOCUSSED CS EDUCATORS

We are researcher-practitioner partnership at the [University of Washington](#), [Shoreline School District](#), and [Highline School District](#) investigating innovative ways to integrate CS education and social justice. Our team combines diverse perspectives and expertise in secondary teacher education, CS education research, administration, and social justice perspectives on computing and society. Our goal is to prepare a new generation of secondary CS educators who center social justice in their teaching, developing students critical consciousness about their relationship to computing in the world.

For my lab, this is just
the beginning.

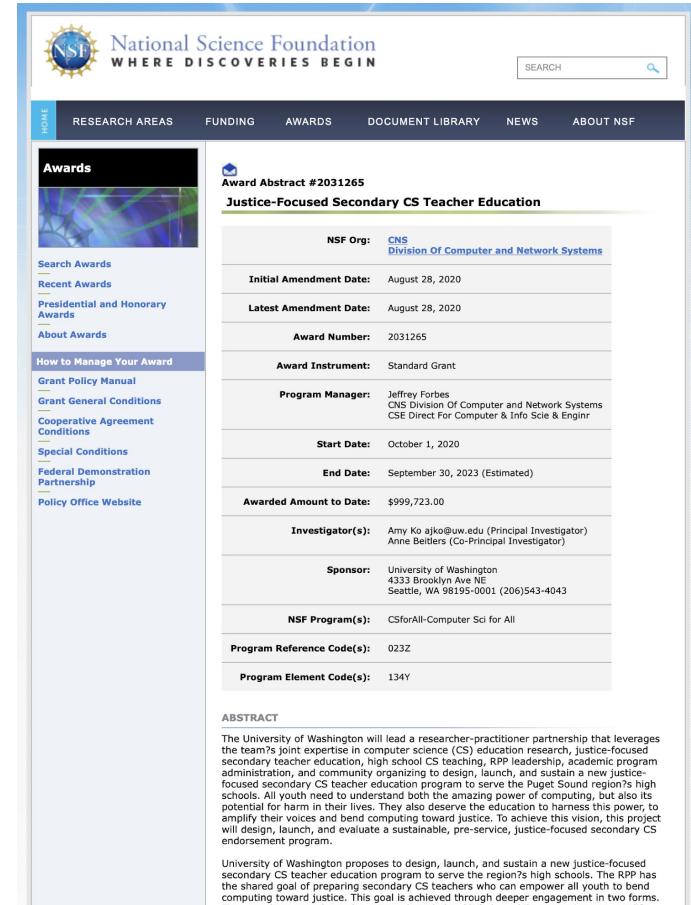
Justice-Focused Secondary CS Education

<https://criticalcsed.org>

A new NSF grant with my College of Education that will:

- Launch a unique **masters in teaching** that teaches foundations of CS in terms of justice, graduating hundreds in the next 10 years
- Produce a new book on teaching methods for critical computing education
- Investigate shifts in CS teacher identity as they engage sociopolitical issues in their **teaching**

Critical Computing Education — Amy J. Ko



The screenshot shows the NSF website with the search bar containing 'SEARCH' and a magnifying glass icon. The main navigation menu includes Home, RESEARCH AREAS, FUNDING, AWARDS, DOCUMENT LIBRARY, NEWS, and ABOUT NSF. The current page is the 'Awards' section, indicated by the blue header bar. The main content area displays the 'Award Abstract #2031265' for 'Justice-Focused Secondary CS Teacher Education'. Key details include:

- NSF Org:** CNS Division Of Computer and Network Systems
- Initial Amendment Date:** August 28, 2020
- Latest Amendment Date:** August 28, 2020
- Award Number:** 2031265
- Award Instrument:** Standard Grant
- Program Manager:** Jeffrey Forbes CNS Division Of Computer and Network Systems CSE Direct For Computer & Info Sci & Engnr
- Start Date:** October 1, 2020
- End Date:** September 30, 2023 (Estimated)
- Awarded Amount to Date:** \$999,723.00
- Investigator(s):** Amy Ko ajko@uw.edu (Principal Investigator)
Anne Beletz (Co-Principal Investigator)
- Sponsor:** University of Washington
4332 Brooklyn Ave NE
Seattle, WA 98195-0001 (206)543-4043
- NSF Program(s):** CSforAll-Computer Sci for All
- Program Reference Code(s):** 023Z
- Program Element Code(s):** 134Y

ABSTRACT

The University of Washington will lead a researcher-practitioner partnership that leverages the team's extensive experience in computer science (CS) education, justice-focused secondary teacher education, high school CS teaching, RPP leadership, academic program administration, and community organizing to design, launch, and sustain a new justice-focused secondary CS teacher education program to serve the Puget Sound region's high schools. All youth need to understand both the amazing power of computing, but also its potential for harm in their lives. They also deserve the education to harness this power, to amplify their voices and bend computing toward justice. To achieve this vision, this project will design, launch, and evaluate a sustainable, pre-service, justice-focused secondary CS endorsement program.

University of Washington proposes to design, launch, and sustain a new justice-focused secondary CS teacher education program to serve the region's high schools. The RPP has the shared goal of preparing secondary CS teachers who can empower all youth to bend computing toward justice. This goal is achieved through deeper engagement in two forms.

Can't make progress without \$.

Justice-Focused Undergraduate Teaching

<https://faculty.washington.edu/ajko/books>

This summer, I revised all of my online books to center issues of justice.

Dozens of faculty, including me, use these to teach HCI, design, and software engineering.

So far, students appreciate raising issues at the intersection of race + tech, but are hungry for more.

Critical Computing Education — Amy J. Ko



Design Methods. This book covers interaction design, design methods, and HCI fundamentals. I have my students read it in the first five weeks of class, then launch into a five week design project.



Cooperative Software Development. This book covers software engineering fundamentals, but from a human, social, collaborative, and organizational perspective, rather than from a technical perspective.

10101010
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User Interface Software and Technology. This book covers the history, theory, and innovations in user interface software and technology.

through the 1980's, it was standard practice for banks to lend to lower-income white residents, but not Black residents, even middle-income or upper-income ones. Banks in the 1980's wrote software to automate many lending decisions; would a software requirement such as this have been legal, ethical, or just?

No loan application with an applicant self-identified as a person of color should be approved.

That requirement is both precise and verifiable. In the 1980's, it was legal. But was it ethical or just? Absolutely not. Therefore, requirements, no matter how formally extracted from a design specification, no matter how consistent with law, and no matter how aligned with an organization's priorities, is free from racist ideas. Requirements are just one of many ways that such ideas are manifested, and ultimately hidden in code¹.

CS for All Washington

<https://csforallwa.org>

I lead a coalition of 300+ teachers, researchers, district leaders, industry advocates, not-for-profits.

We've passed legislation that 1) requires CS electives in all schools, 2) legally defines CS in justice terms, and 3) secures a \$3 million in annual state funding to support teacher professional development.

CS for All Washington
[Home](#)
[For all?](#)
[Parents](#)
[Current Teachers](#)
[Future Teachers](#)
[K-12 Administrators](#)
[ESDs](#)
[Higher Ed - CS](#)
[Higher Ed - Education](#)
[Policy](#)
[Communities](#)
[Volunteers](#)
[About Us](#)
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EVERY STUDENT AT EVERY K-12 LEVEL IN WASHINGTON STATE SHOULD LEARN ABOUT COMPUTING.

Across our state, **too few students learning about computing**, whether it's a lesson in a K-5 class that integrates computer science ideas, a computer science elective in a middle school or high school, or an after school or summer coding camp. Why should our state's youth learn CS?

- **Diversity.** Participation in CS by women, people of color, and people with disabilities is among the lowest of all STEM fields.
- **Skills.** Learning CS promotes 21st-century skills such as *creativity, collaboration, and communication*.
- **Citizenship.** Being a good citizen in the 21st century include literacy about how computing shapes our lives and society.
- **Community.** Our communities need people empowered to use computing to address local problems.
- **Workforce.** There is a global shortage of skilled software engineers. CS education can fill that gap.
- **School reform.** Teaching CS is a compelling, creative space where pedagogy is rich, experimental, and innovative.
- **Empowerment.** Computing provides youth with the ability to express themselves creatively and have voice.
- **Justice.** Computing can be a powerful tool for enacting justice; everyone should be able to harness it.

Washington state needs pathways for all youth from across the state to develop interest and confidence in computing skills, including understanding about how technology shapes society, learning how to data and algorithms can be used to solve problems in any domain, and learning how to use these ideas to create software for themselves, for their communities, and for their careers.

Want to learn more?

- **Parents and students.** [see our growing list of resources](#).
- **Current teachers.** [learn how to teach CS](#).
- **Future teachers.** [learn how to become a CS teacher](#).
- **Administrators.** [learn how to bring CS to your school or district](#).
- **Policymakers.** [learn about the state of state law on CS education](#).

Broadening K-12 participation in CS across Washington state.

AccessComputing

<https://www.washington.edu/accesscomputing/>

With Richard Ladner and Jacob Wobbrock, I co-PI AccessComputing, an NSF-funded Broadening Participation in Computing alliance that creates pathways for students with disabilities to learn CS, and identifies ways to integrate accessible computing into CS curricula.



The Alliance for Access to Computing Careers

[Home](#) [About](#) [Get Involved](#) [Resources](#) [Videos](#) [Knowledge Base](#) [Search](#)



AccessComputing

High school, college, and graduate students with disabilities can connect with mentors and professionals to learn about internships and other opportunities in computing fields.

For Educators and Employers

- [Join a Community](#)
- [Teach Accessible Curricula](#)
- [Join as an Industry Partner](#)
- [Make Your Current or Future Project Accessible](#)
- [Become an Institutional Partner](#)
- [Find Additional Resources for Educators and Employers](#)



For Students with Disabilities

- [Join the Team](#)
- [Find an Internship](#)
- [Consider an REU](#)
- [Consult ChooseComputing](#)
- [Find a Scholarship](#)
- [Consult Additional Resources for Students](#)

Students with disabilities are systematically excluded from CS learning throughout K-12 and higher education. Let's change that.

Research in the Code & Cognition Lab

<https://faculty.washington.edu/ajko/lab>

Many more justice-focused CS literacy projects on motivating and supporting:

- Learning at home
- Learning in school
- Learning in communities
- Learning at work
- Self-advocacy



Students of the Code & Cognition Lab, eating donuts without me.

What can you do?

Augment your research with BPC plans

NSF CISE now requires
broadening participation in
computing plans.

Use them to seriously address
not only issues of equity and
inclusion, but also justice.

See bpcnet.org for guidance.



NSF wants us to focus on broadening participation.

Interrogate your teaching

What values are you supporting?

How are your explanations, examples, and assessments reinforcing these values?

How can you be more explicit about your values?



Students are looking to us for moral guidance.

Recognize your power and the responsibility that comes with it.

You have far more than you think,
and unless you carefully reflect on
the consequences of your choices,
you won't see them.

Being *apolitical* is just another
kind of political.



Students at the University of Washington
protesting a Suzzallo library with faculty.

Learn to have *hard conversations* about CS + justice. We can't let our fear of conflict and politics let code and data further aggravate an already unjust world.

Questions?

The gist:

1. Computing has limits
2. Data has limits
3. CS has responsibility

We need research, teaching, and service that seriously engage these facts; I'm trying to figure out how to do that in CS education.



Greg Nelson he/him
greglnelson.info
HCI+CS Ed



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The many wonderful doctoral students with which I collaborate.