Community Computation

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November 27, 2021

Figure 1: Global communities generate hypotheses and run experiments. My research platforms–that integrate learning and collaboration– augment communities' strengths.

In my doctoral and postdoctoral work in Human-Computer Interaction (HCI) at UC San Diego and Harvard University, **I've developed ways for communities to collaboratively perform scientific work like generating and evaluating theories**.

COVID-19 vaccine trials have triggered massive public interest in how science is performed. Meanwhile, misinformation about vaccines and health ravages social media. Why? Social platforms amplify ideas and claims at a global scale. However, unless experts lead, they rarely provide systematic ways to evaluate such claims. To **support knowledge creation with social software**, my research rethinks the design assumptions and computational support embedded in social computing platforms.

Current platform designs draw on presuppositions and relationships that mark offline systems for producing knowledge. For instance, online platforms have scaled trained institutional scientists' access to communities and data. My research investigates the inverse question: **how might online platforms augment communities' access to scientific expertise and high-quality data**?

My research offers a new model– **Community Computation**–where communities perform complex knowledge work *for* themselves. Contributing to social computing, accessibility, and digital phenotyping, my research demonstrates several firsts. Volunteers generated hypotheses that microbiologists rated novel [1] [2]. Communities evaluated hypotheses with controlled experiments with global participants [3]. A rare disorder community contributed reliable, valid estimates of motor impairment from home [4] [5].

Supporting Community Computation with Roles and Learning

The key insight across my research is **embedding task-specific learning in structured roles** for complex knowledge work. My research platforms provide an alternate vision for social platforms that **builds on communities' contextual knowledge, social structures, and lived experience**. In turn, they contribute computational techniques including conceptual and procedural guidance, lightweight support for contextual insights, and designs for institutional impact.

I will continue building systems at scale that:

1. Structure novice-appropriate, real-world data collection
2. Design interactions among communities, experts, and algorithms, and
3. Devise Techniques for ~~mis~~information and better social discourse

Community Computation intrigues experts too

Apart from publishing first-author publications at HCI venues including CHI, I have been invited to present my research at American Society of Microbiology (ASM), Precision Medicine Initiative; Innovation Lab at MIT, and NPR

[1] **Pandey**, Amir, Debelius, Hyde, Kosciolek, Knight, and Klemmer. Gut Instinct: Creating scientific theories with online learners. In *Proceedings of the 2017 CHI conference on human factors in computing systems*, pages 6825–6836, 2017

[2] **Pandey**, Debelius, Hyde, Kosciolek, Knight, and Klemmer. Docent: Transforming personal intuitions to scientific hypotheses through content learning and process training. In *Proceedings of the Fifth Annual ACM Conference on Learning at Scale*, pages 1–10, 2018

[3] **Pandey**, Koul, Yang, McDonald, Ball, Tzovaras, Knight, and Klemmer. Galileo: Citizen-led experimentation using a social computing system. In *Proceedings of the 2021 CHI Conference on Human Factors in Computing Systems*, pages 1–14, 2021

[4] **Pandey**, Khan, Gajos, and Gupta. At-home use of a computer-based pointing task accurately and reliably estimates motor impairments. In Preparation

[5] Khan, **Pandey**, Gajos, and Gupta. Free-living motor activity monitoring in ataxia-telangiectasia. *The Cerebellum*, pages 1–12, 2021

/KPBS. My doctoral research was awarded the **School of Engineering Exemplary Ethical Engineering Award**. My collaborators have presented our work at domain-specific scientific venues [6] [7]. Classes in social computing, computing for good, and interactive systems design have including my research in their curriculum. My work has been funded by sponsors across **government** (NSF, NIH), **technology design** (SAP, Google), and **biotechnology** (Biogen).

[6] 2021 International Symposium on Ataxia and MND/ALS

[7] International Congress for Ataxia Research

Achieving Community Computation: Tools, Platforms, and Institutional Support

Technological efforts for complex knowledge production succeed when they intervene at three levels: individual, community, and institutional.

1. **Deepen individual contributions** with tools that formalize novice work
2. **Support community structures**, motivation, and participation levels
3. **Produce outcomes that support institutional processes**

To evaluate the feasibility of Community Computation in science and medicine, I have contributed the design, deployment, and evaluation of four novel systems. I have evaluated my ideas with **longitudinal field deployments with 1200 participants from citizen science, neurological disorder, fermenters and open science communities**. Results with communities suggest that there's a massive opportunity to accelerate knowledge creation using tools that formalize novice contributions and platforms that provide multiple contribution mechanisms.

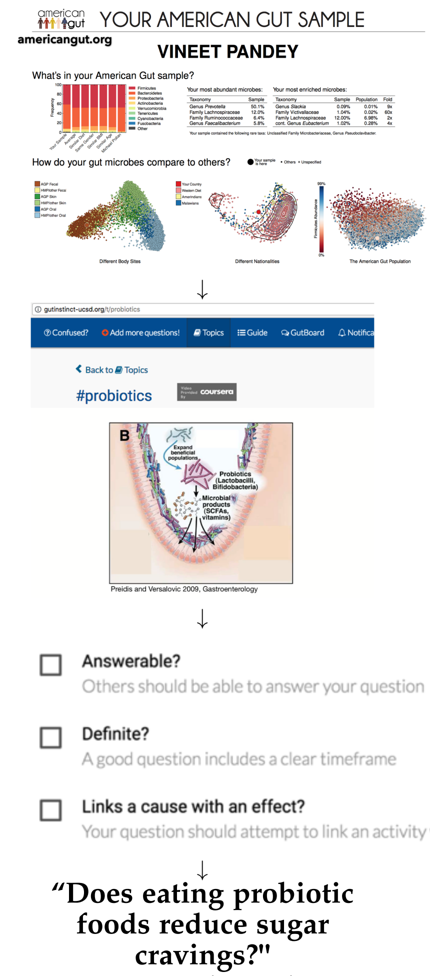

Figure 2: Most people contribute to citizen science with data, not designs. My research improves this by support different learning needs, like content learning and process guidance.

People generate hypotheses with content and procedural support

Useful insights are lost in long, rambling posts in online discussions that keep going on and on like this while failing to identify a central key point. DOCENT explicitly teaches people to create hypotheses by combining personal insights with task-specific scaffolding (Figure 6): short lectures provide conceptual domain-specific learning (like the science behind probiotics), and the interface provides heuristics for asking clear and potentially useful questions. I designed this **Learn-Train-Ask workflow**; it substantially improved quality of hypotheses in a 2x2 between-subjects experiment with 344 online volunteers including American Gut [8] participants. Prompting participants to explicitly connect personal observations with existing knowledge increased the overall quality and novelty of questions. **Participants generated 399 hypotheses; 75 were rated novel by microbiologists.** Experts also preferred skimming through the hypotheses structured as questions and answers over rambling accounts on online fora.

[8] McDonald, Hyde, Debelius, Morton, Gonzalez, Ackermann, Aksenov, Behsaz, Brennan, Chen, and American Gut Consortium (including **Pandey**). American gut: an open platform for citizen science microbiome research. *Msystems*, 3 (3):e00031–18, 2018

Communities evaluate hypotheses by designing, reviewing, and running experiments

People need to have a good working model of both the concepts underpinning an experiment and the procedures to perform them. However, learning resources are seldom co-located with social platforms. After googling "design

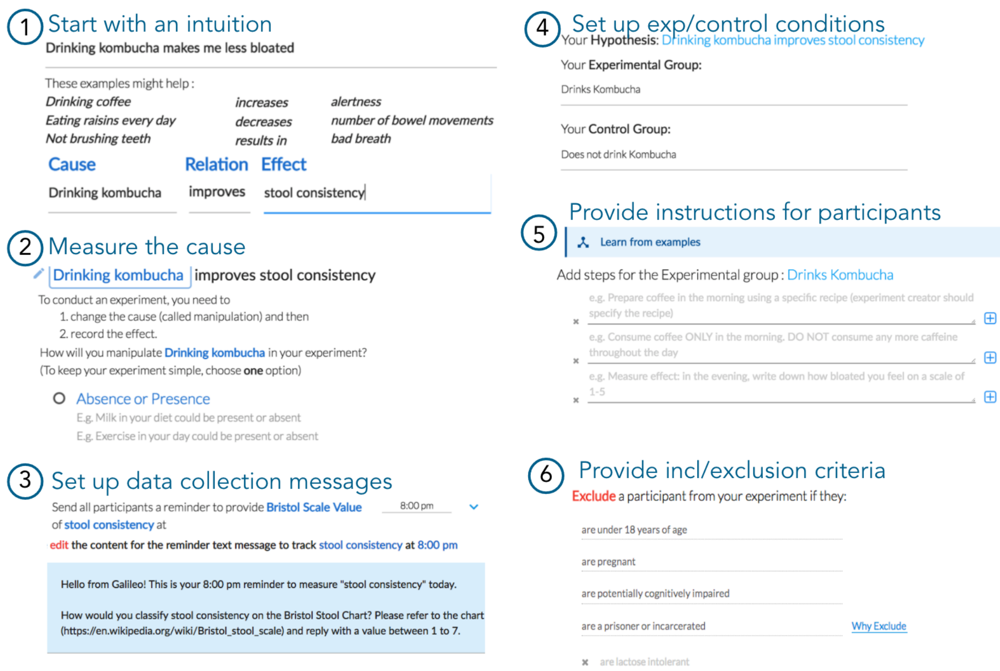

Figure 3: People transform intuitions into experiment designs with a workflow that embeds experimentation elements and learning support

an experiment", it took me 4 false starts, 17 clicks, and overall 10 minutes to find and consume a video that was somewhat helpful.

GALILEO reifies the structure of the experiment in a workflow and introduces procedural guidance to build just-in-time expertise for its different components (Figure 3). Reviews with scaffolded questions and automated routines for data collection complete the **Design-Review-Run pattern. Leaders design experiments, community reviews with contextual insights, and anyone on the internet can join**. A longitudinal evaluation found that people from 16 countries generated structurally-sound experiments on personally meaningful topics. Communities designed, piloted, and ran multiple week-long experiments.

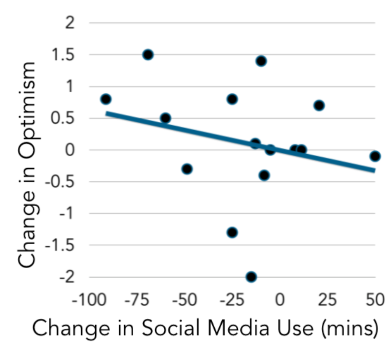

Figure 4: A community concerned about social media use designed and ran an experiment with participants from 7 countries

Collecting data that requires expertise

Some expert activities –like health assessments–are quick and draw on years of expertise that can be difficult to teach. For instance, neurological assessments of motor impairment require an expert evaluation on tasks like Finger to Nose test. My Postdoctoral research demonstrates how web-based tools can support communities in **creating valid and reliable health assessments** without using expert time. The tool is simple to use: people move the cursor on the screen to indicate a particular target; trajectories and events from the task yield interpretable movement features. When compared to normative data collected online from thousands of age-matched healthy controls, such measures yield good assessments of motor impairment across lab [9] and natural settings [10]. With a rare disorder community, my research demonstrates how neurological disorders could be better characterized in the wild.

[9] Gajos, Reinecke, Donovan, Stephen, Hung, Schmahmann, and Gupta. Computer mouse use captures ataxia and parkinsonism, enabling accurate measurement and detection. *Movement Disorders*, 35(2):354–358, 2020

[10] Khan, **Pandey**, Gajos, and Gupta. Free-living motor activity monitoring in ataxia-telangiectasia. *The Cerebellum*, pages 1–12, 2021

Research Directions

My research goal is to make Community Computation systematic for multiple communities and experts across domains in science and medicine.

How might communities collect, understand, and use data in the wild?

Similar to Mechanical Turk, current citizen science platforms provide ways for crowds to collect and annotate data to support institutional requests. I want to build software-defined processes that help communities collect and interpret appropriate data for their own purposes.

How might communities perform deeper science in more domains?

One clinical trial for a rare disorder collected 39 participants in 10 years. Meanwhile, online communities for many rare disorders run into hundreds. I will **design tools that provide reliable, robust estimates of health impairments that can be accessed by anyone** with a working web browser (Figure 5). Such data collection efforts can better characterize many poorly understood disorders. I am currently collaborating with five neurological disorder communities towards characterizing their real world performance using web-based tools [11].

I intend to complement such deeper behavioral biomarkers with **tools for better planning and cognitive support** as well. Deepening community contributions –with mechanistic and contextual insights–can expand scientific understanding. For instance, fermenters using my research system found that kombucha helps the gut; follow-up questions include *why? when?*

Many scientific domains–beyond microbiology and neurology–provide people with inherent motivation plus unique insights from their lived experience. Which **learning abstractions can help with community-led scientific work in circadian rhythms or accessibility studies**?

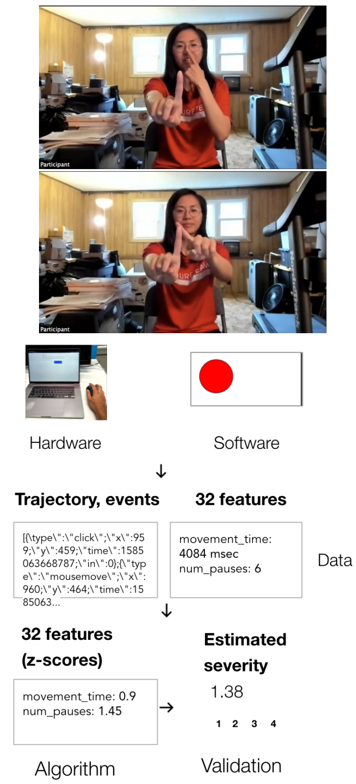

Figure 5: Assessing motor performance with Finger to Nose test is challenging over video-based telemedicine interactions. Can we build tools that capture clinically useful representations of people's performance from mouse and smartphone trajectories?

[11] Studd, Gajos, Gupta, **Pandey**, and Jacobs. Understanding clinician perspectives to identify opportunities for telemedicine beyond covid-19. In Preparation

How might ideas from scientific collaboration improve crowdsourcing?

A long-standing goal of crowdsourcing is to collect and synthesize novice contributions that go deeper than raw data, labels, or Likert scale ratings. Various methods in science provide ways to find predictably close estimates to the ground truth. Designing **environments for greater scientific collaboration among people will also improving domain-specific, expert-level crowdsourcing**.

I am interested in evaluating real-time science with environments for synchronous collaboration. As communities engage with the broader scientific ecosystem (e.g. interpreting and presenting data for publication), they will need novel ways to synthesize information. I am keen on **exploring techniques from visualization and multi-modal interactions** to develop low-ceiling, low-threshold data analysis tools for novices.

How might we measure learning gains in real-world tasks?

Knowledge workers are increasingly expected to possess abstract skills that require learning, reflection, and creativity. However, measuring these skills in real-world, open-ended activities is challenging. I will continue collaborating with learning science researchers to **rethink existing assessments for informal learning and doing** [12]. Such work has natural applications for learning both

[12] **Pandey**. *Citizen-led Work using Social Computing and Procedural Guidance*. University of California, San Diego, 2019. **School of Engineering Exemplary Ethical Engineering Award**

inside and outside classrooms.

How can researchers both study and support communities?

My long-term goal is to expand **what communities achieve and illuminate how they do it**. Social computing research (design and analysis) has expanded our understanding of *community internals* like composition, members' motivation, and structure.

I will design and analyze a different class of systems building on *community externals* which are socio-technical factors that influence the scale and depth of communities' achievements. Some such factors include **experts, other communities, and algorithms**.

How might we prototype community-expert configurations?

I want to shift measures of social computing from *time spent* to *goals achieved*. While working on complex needs, when do communities make steady progress and when do they stall? How might experts help [13]? Sometimes, a dash of technical input from experts can unblock people; at other times, experts might need to be more hands-on and provide a clear outline. Prototyping platforms that combine communities and experts' complementary strengths will be useful in developing a playbook.

Such empirical research will also inform the design of novel tools that eventually reduce the need for expertise. Such community-expert architectures have immediate applications: *helicopter research*[14] can become co-pilot models.

[13] **Pandey**, Gajos, and Gupta. From novices to co-pilots: Fixing the limits on scientific knowledge production by accessing or building expertise. In *Proceedings of the 7th International Conference on ICT for Sustainability*, pages 294–304, 2020

[14] "Most studies on economic development are led by researchers based in the global north, even when they focus on a country or region in the global south.". **Researchers from global south under-represented in development research**. Nature

How might communities collaborate with other communities?

People can use the same tool in radically different ways by bringing their prior knowledge, lived experience, and goals to the task at hand. My research found early evidence that this is true for communities as well. How do we design interactions among communities with multiple competencies and goals? For instance, learners on Coursera, data analysis hobbyists on reddit, and health enthusiasts on twitter can perform independent activities in the same scientific project while refining their skills with real-world feedback.

How might we create more ~~mis~~information and better discourse on social platforms?

I want to create a research culture of proactively thinking about how social platforms reshape institutions, especially how ubiquitous data and technology interacts with existing human skills and deficits across diverse situations.

Deepening support for collaborative scientific work can likely support more reflective, rational discourse. Performing science *can* help people update their beliefs. But *does* it? My preliminary research suggests that simple exposure to scientific concepts is not enough to update people's beliefs; recreating these ideas on one's own is important [15]. I want to continue evaluating my techniques with multiple objectives that support immediate community and institutional objectives but also take a long-term view of people's knowledge needs.

There are other challenges with online community-led science. My research platforms were primarily used by participants in developed countries. My

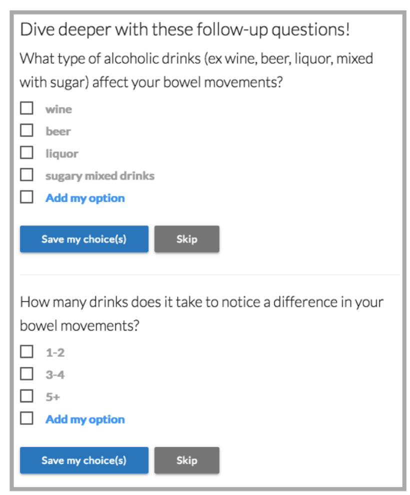

Figure 6: Structured sharing interface supports quickly creating, browsing, and responding to hypotheses. Otherwise, people ramble online.

[15] **Pandey**, Ngoon, and Lau. Constructive activities for people to develop their creative scientific insights. In Preparation

research has demonstrated that small interfaces have big effects [16]. Evaluating platform design for access, use, and participation will continue to be a focus of my work.

[16] Hicks, **Pandey**, Fraser, and Klemmer. Framing feedback: Choosing review environment features that support high quality peer assessment. In *Proceedings of the 2016 CHI Conference on Human Factors in Computing Systems*, pages 458–469, 2016

Figure 7: Technology supports motivated and organized communities. An experiment designer in Brazil created a poster to publicize a kombucha experiment among her social network.

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