

## Research Statement

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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 hypotheses, designing experiments, and running them with global participants. My research creates new possibilities for what social platforms can achieve.

### Community Computation

COVID-19 vaccine trials have triggered massive public interest in how science is performed. Meanwhile, misinformation about vaccines and health infections spreads on 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.

To support complex activities like producing knowledge, current platform designs build on offline systems' presuppositions and relationships. For instance, online platforms have scaled 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—in which communities perform complex knowledge work for themselves. To support motivated communities, social platforms build on communities' contextual knowledge, social structures, and lived experience; they supply techniques for just-in-time expertise. Contributing to social computing, digital phenotyping, and accessibility, my research demonstrates several firsts. Volunteers generated hypotheses that microbiologists rated novel<sup>1,2</sup>. Communities evaluated hypotheses with controlled experiments with global participants<sup>3</sup>. A rare disorder community contributed reliable, valid estimates of motor impairment<sup>4</sup>.

### Community Computation influences institutional work

Apart from publishing first-author publications at CHI and other HCI venues, I have been invited to present my research at American Society of Microbiology (ASM); All of us Research Program; Innovation Lab at MIT; and at NPR / 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<sup>5,6,7</sup>. My work has been funded by sponsors across government (NSF, NIH), technology design (SAP, Google), and biotechnology (Biogen). Classes in social computing, interactive systems design, and computing for good have included my research in their curricula.

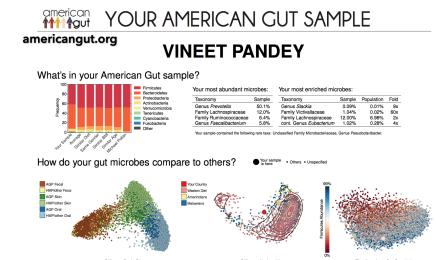


Figure 1: Most people contribute to citizen science with data, not designs. Scaling scientific enquiry beyond institutions can benefit humanity.

<sup>1</sup> 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

<sup>2</sup> 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

<sup>3</sup> 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

<sup>4</sup> Pandey, Khan, Gajos, and Gupta. At-home use of a computer-based pointing task accurately and reliably estimates motor impairments. In Preparation

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

<sup>6</sup> 2021 International Symposium on Ataxia and MND/ALS

<sup>7</sup> International Congress for Ataxia Research

## Achieving Community Computation: Tools, Platforms, and Institutional Support

The key insight across my research is to **embed task-specific learning in structured roles** for complex knowledge work. My research reinforces that 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 with **longitudinal field deployments with 1200 participants from citizen science, neurological disorder, fermenters and open science communities**. Results suggest a novel opportunity to accelerate knowledge creation using tools that formalize novice contributions and platforms that provide multiple contribution mechanisms.

### *Individuals need assistance with the structure of scientific work*

To harness people's motivation and lived experience towards potentially useful work, systems need to support appropriate representations. For instance, potentially useful insights are lost in long online posts. My social computing system **DOCENT** explicitly teaches people to create hypotheses by combining personal insights with task-specific support. Conceptual domain-specific learning come in short lectures and heuristics for asking clear and potentially useful questions are embedded in the interface. I designed an effective **Learn-Train-Ask workflow** which improved quality of hypotheses in a 2x2 between-subjects experiment with 344 online volunteers. **Participants generated 399 hypotheses; 75 were rated novel by microbiologists.** Experts also preferred skimming crowd-curated questions and responses over rambling online accounts. **Prompting participants to explicitly connect personal observations with existing knowledge increased the overall quality and novelty of questions.**

### *Multi-party scientific work calls for roles and automation*

After googling "design an experiment", it took me 4 false starts, 17 clicks, and overall 10 minutes to find and consume a video that was somewhat helpful. Such inefficiency in integrating learning resources in their workflow makes complex work impossible for internet users. My research argues for integrating learning resources at the point of action. My social computing system **GALILEO** successfully supports community-led experimentation with the **Design-Review-Run pattern**. People take roles. Leaders design experiments, community reviews with contextual insights, and anyone on the internet can join with automated data collection. And the system automatically provides relevant concepts about experiment design with just-in-time procedures to perform them.



Figure 2: My research platforms—that integrate learning and collaboration—augment communities' strengths and complement novel data tracking tools. Global communities generate hypotheses and run experiments.

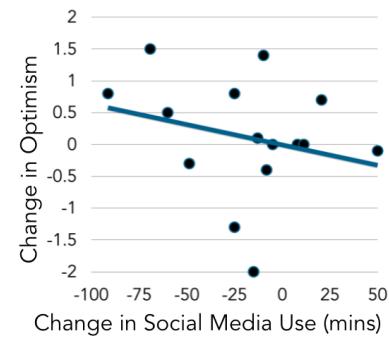


Figure 3: Communities can investigate topics that affect them. A community concerned about social media's effect on well-being designed and ran an experiment with participants from 7 countries.

## *Novel data acquisition tools scale health assessments that otherwise require experts*

Some expert activities—like health assessments—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 assessments of motor impairment** from home without requiring experts' 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<sup>8</sup> and natural settings<sup>9</sup>. With a rare disorder community, my research demonstrates how neurological disorders could be better characterized in the wild.

## *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. 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 have hundreds of participants. I will **design tools that provide reliable, robust estimates of health impairments that can be accessed by anyone with a working web browser** (Figure 4). 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<sup>10</sup>.

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 the opportunities to capture unique insights from their lived experience. Maybe **learning abstractions** can help with **community-led scientific work in circadian rhythms or accessibility studies**.

### **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



Figure 4: Health assessments over telemedicine visits can be a challenge. Asynchronous tools that create clinically useful representations of motor performance from mouse and smartphone trajectories will help.

<sup>8</sup> 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

<sup>9</sup> Khan, Pandey, Gajos, and Gupta. Free-living motor activity monitoring in ataxia-telangiectasia. *The Cerebellum*, pages 1–12, 2021

<sup>10</sup> Studd, Gajos, Gupta, Pandey, and Jacobs. Understanding clinician perspectives to identify opportunities for telemedicine beyond covid-19. In Preparation

methods in science provide ways to find predictably close estimates to the ground truth. Similarly, designing environments for greater scientific collaboration can improve domain-specific, expert-level crowdsourcing.

I am interested in evaluating environments for synchronous collaboration. As communities engage with the broader scientific ecosystem (e.g. interpreting and presenting data for publication), they will also need novel ways to synthesize information. I am keen on exploring techniques from visualization and multi-modal interactions to develop low-threshold, low-ceiling 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<sup>11</sup>. Such work has natural applications for learning both inside and outside classrooms.

### How can researchers both study and support communities?

My long-term goal is to expand what communities can 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<sup>12</sup>? 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 likely be fundamental for success. Empirical research can inform the design of novel tools that eventually reduce the need for expertise. Community-expert architectures have immediate applications: *helicopter research*<sup>13</sup> can become co-pilot models.

### 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.

<sup>11</sup> Pandey. *Citizen-led Work using Social Computing and Procedural Guidance*. University of California, San Diego, 2019.  
School of Engineering Exemplary Ethical Engineering Award

<sup>12</sup> 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

<sup>13</sup> "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 we create more misinformation and better discourse on social platforms?*

Deepening support for collaborative scientific work promises to support more reflective, rational discourse. Performing science *can* help people update their beliefs. But how does it operate? 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 crucial<sup>14</sup>. In the future I will continue to develop and evaluate techniques to support individual, community, and institutional objectives.

I plan 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 populations and situations.

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<sup>14</sup> **Pandey**, Ngoon, and Lau. Constructive activities for people to develop their creative scientific insights. In Preparation

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