Community Computation

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In my doctoral and postdoctoral work in Human-Computer Interaction (HCI) at UC San Diego and Harvard University, **I have enabled community-led complex knowledge work using online platforms**. I call this phenomenon **Community Computation**. My research goal is to make Community Computation systematic for multiple communities and experts.

Current platform designs draw on presuppositions and relationships that mark offline systems for complex knowledge work. For instance, online platforms have scaled institutional experts' access to communities and data. Community Computation provides an alternate vision where communities answer personally-meaningful questions by accessing or acquiring expertise. With my research, online platforms support communities in performing complex knowledge work *for* themselves. Community Computation builds on communities' contextual knowledge, social structures, and lived experience, and contributes **computational and social computing techniques** including conceptual and procedural guidance [1] [2], collaboration roles [3], and designs for institutional impact [4] [5].

Figure 1: Global communities have used my research platforms to design, review, and run week-long experiments. By taking different roles, motivated community members can broaden and deepen science

Contributing principles to social computing, accessibility, and digital phenotyping, my research demonstrates several firsts. Volunteers generated hypotheses that microbiologists rated novel. Communities evaluated hypotheses with controlled experiments with global participants (Figure 1). A rare disorder community contributed estimates of motor impairment from home.

Community Computation is inherently multidisciplinary. 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 /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). Future research directions include three themes:

1. **Deeper knowledge contributions** with computational and learning tools,
2. **Prototyping community-expert configurations** with novel systems, and
3. **Techniques for ~~mis~~information and better discourse** on online platforms

Community Computation in science and medicine

In theory, the scientific process is accessible to anyone who can read and write. In practice, however, scientific work is synonymous with institutional research. For instance, Randomized Controlled Trials (RCTs) provide a rigorous methodology to evaluate treatments and tools in science and medicine. Despite their successes, such scientific processes suffer from two critical limitations.

[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. 4 In Preparation

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

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

[7] International Congress for Ataxia Research

1. **Reliance on trained experts** to design experiments and track outcomes
2. **Long latency** to enroll participants and evaluate interventions

Overall, **the current approach of relying solely on institutional experts to create knowledge is insufficient to meet the scale, diversity, and novelty of people's needs**. Most people are limited to participating in the scientific process as data donors even when they possess the motivation and lived experience to contribute more. This gap between experts and people has important consequences for the quality of academic knowledge, its real-world applicability, and the relation between institutional experts and the publics.

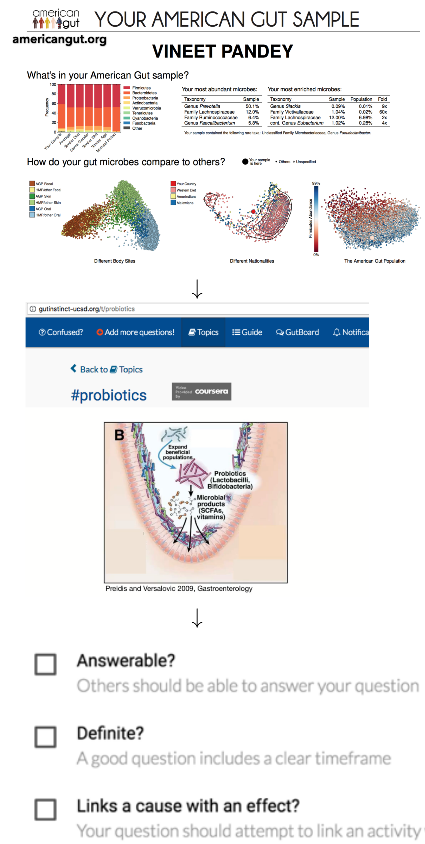

Figure 2: From donating data to generating hypotheses. DOCENT integrates conceptual and procedural learning.

Achieving Community Computation: Tools, Platforms, Institutions

> "Part of what distinguishes science from cognition more broadly is the **cultural accumulation of tools and knowledge**...
> -Schulz, L. E. (2012). Finding new facts; thinking new thoughts.

My research suggests that technological efforts for complex knowledge production succeed when they intervene at three levels: individual, community, and institutional. My collaborations with scientists, clinicians, and communities over longitudinal deployments have taught me the lesson about including existing institutions. I believe the long-term success and value of Community Computation relies on leveraging existing institutional expertise and meeting existing needs.

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: GUT INSTINCT, DOCENT, GALILEO, HEVELIUS AT HOME. Results with online 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.

Collaboratively generating hypotheses: DOCENT

DOCENT explicitly teaches people to create hypotheses by combining personal insights and online learning with task-specific scaffolding (Figure 2). Novices contribute hypotheses: short lectures provide conceptual learning, and the interface contributes procedural guidance. DOCENT's Learn-Train-Ask workflow 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 score of questions. **Participants generated 399 hypotheses; 19% were rated novel by microbiologists.**

[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

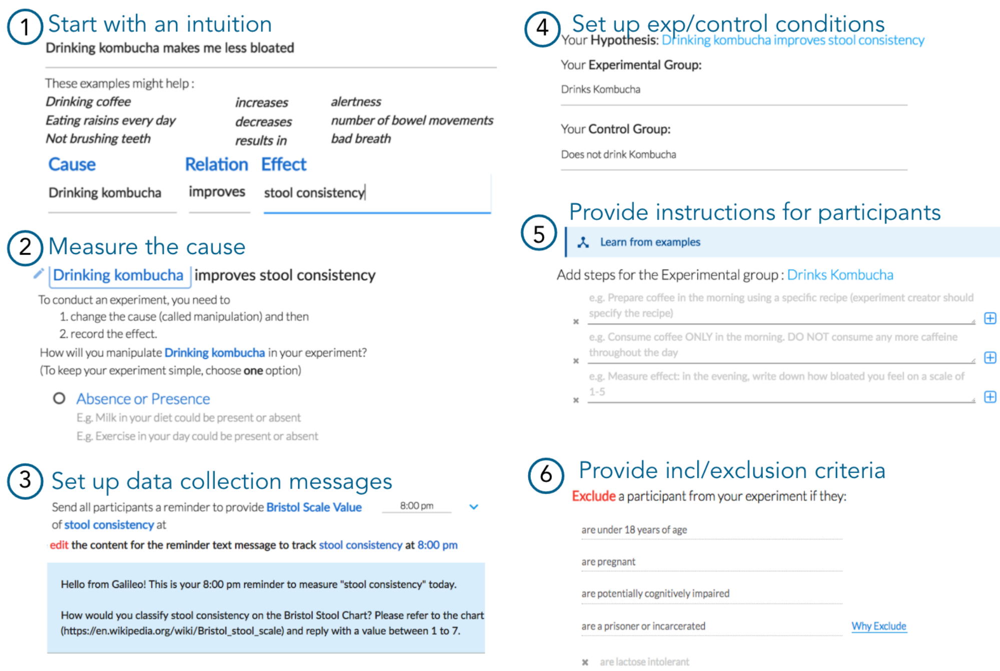

Figure 3: GALILEO's design module helps people transform intuitions into experiment designs

Designing experiments without prior expertise: GALILEO

To perform a complex activity, people need to have a good working model of both the concepts and procedures. My research systems provide a conceptual framework and introduce procedural guidance to build just-in-time expertise for difficult tasks. Procedural guidance has multiple advantages: it is minimal, leverages teachable moments, and can be ability-specific. Because learning complex activities overwhelms working memory, the Galileo design workflow for between-subjects experiments chunks related elements and embeds procedural guidance with examples, checklists, and templates (Figure 3).

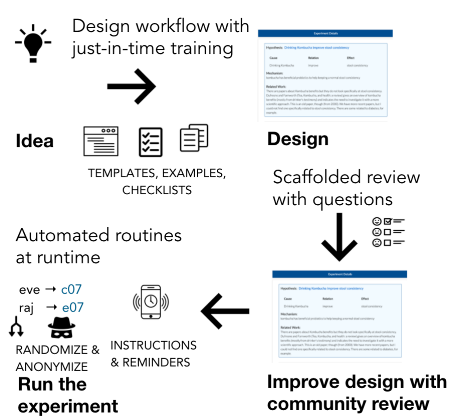

Figure 4: GUT INSTINCT supports communities in designing and running between-subjects experiments to test intuitions

Community-led experiments: GUT INSTINCT

GUT INSTINCT reifies experimentation in the software, provides multiple roles for contribution, and automatically manages inter-dependencies. The platform contributes an experimental design workflow, review with scaffolded questions, and automated routines for data collection (Figure 4. Experiment creators can invite others to review and participate in the experiment. Participants from around the world join experiments, follow instructions, and provide data in response to automated data collection reminders. A deployment across 16 countries found that people generated structurally-sound experiments on personally meaningful topics. Communities designed, piloted, and ran multiple week-long experiments.

Remotely characterizing neurological disorders: HEVELIUS

My Postdoctoral research demonstrates how web-based tools can support communities in **creating valid and reliable health assessments without using ex-**

pert time. A recent computer-based system, called HEVELIUS [9], quantifies motor impairments in the arm. Hevelius' quantifies people's motor performance with *pointing tasks*. People move the cursor to indicate a particular target; trajectories and events from the task yield features; such features are then compared across people with motor impairments and normative data from age-matched healthy controls. Such characterization efforts meet experts' objectives as well: they improve researchers' understanding of motor impairments in natural settings. Five neurological disorder communities have contributed to an empirical in-the-wild evaluation of multiple motor impairment measures from accessibility literature.

[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

Figure 5: Assessing motor performance with Finger to Nose test is challenging over video-based telemedicine solutions. My research demonstrates that few minutes use of a web-based tool provides fine-grained, valid, and reliable quantitative measures of motor impairment. Such tools can support better characterization and support of neurological disorders.

Research Directions

Current technological innovation efforts have succeeded at **automating low-level human skills**. My research provides a different vision: **augmenting higher-order thinking and problem-solving skills** among online communities. Better distribution of expertise can catalyze new knowledge creation across domains including science and medicine. Creating greater expertise in more people by combining personal motivation and social structures will require appropriate computational and social computing techniques. This section outlines future research ideas for low-threshold capacity-building tools and platforms. By designing novel collaborative systems and evaluating social and organizational theories, such research can guide the next generation of social computing, citizen science, and telemedicine platforms.

Computational and learning tools for deeper knowledge contributions

My 10-year goal is to **create a suite of online tools that augment lived expertise with deeper data acquisition and learning**. Beyond current behavioral biomarkers, I intend to build low-burden web-based data acquisition tools that track fine-granular measures of performance correlated with different mechanisms. Such *mechanistic markers* can offer lightweight ways to gain insights into important questions; for example, how does cognition affect motor performance across neurological disorders?

An intermediate goal includes quantifying parameters like rate of progression and task learning. At home monitoring creates opportunities to study such questions in more natural environments. I'll get started on these goals with **three parallel year-long projects**. First, I'll create measures for higher-order topics from features tracked by digital phenotyping tools (like dysmetria or tremors from low-level HEVELIUS features). Second, I'll characterize different disorders using their unique profiles for reliability, median performance, and correlation with ground truth. Third, I'll continuously reduce participation burden while using digital health assessment tools and share my lessons with the community.

My work seeks to place learning experiences at the right time for people to use them. This offers both theoretical and practical benefits. Many domains–beyond microbiology and neurology–provide people with inherent motivation plus unique insights from their lived experience. **Another 3-to-5 year goal would be to build appropriate conceptual and procedural guidance for different domains** (like circadian rhythms) and relevant scientific activities (observational studies).

Platforms that prototype community-expert configurations for complex work

My long-term goal is to **expand our collective understanding of the opportunities with community-expert collaboration** [10]. The rapid spread of access to technology makes such endeavors possible and pressing. Architectures that combine different expertise can help academics transform *helicopter research*[11] to co-pilot models.

Community Computation has immediate applications for clinical work. People try different behavioral innovations to manage their conditions; such expertise drawn from lived experience can complement clinical expertise. **I intend to build the first examples of double bottom line systems for clinical settings that explicitly use people and clinicians' complementary knowledge and needs to provide benefits to both groups**. This goal requires answering numerous exciting questions that make for **parallel year-long projects**. For example, how does the heterogeneity in patients' knowledge and expertise alter the design of such platforms? Such self-experimentation platforms open the way of valid single control designs (SCDs) that might support communities with rare disorders in creating personally- and clinically-relevant knowledge. Since I develop platforms that can be used by multiple experts and communities, this provides opportunities for collaboration with clinicians (including complex care teams), people with disorders, and caregivers.

My research goals are complementary to current directions in social computing research—including computational social analysis and systems research—that focus on better understanding and improving community internals like moderation, governance, resolution/redressal mechanisms, and managing mixed competencies.

[10] **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

[11] "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 underrepresented in development research**. Nature

Techniques for ~~Mis~~Information and Better Discourse on Social Platforms

One long-term goal of my research is to create a healthier relationship between science and society. Deepening collaborative scientific contributions can support more reflective, rational discourse on online platforms. One intermediate goal: creatively managing the tension between the social and the scientific. For instance, the scientific studies that are read the most online are also likely to be incorrect. Current social platforms nudge creating ephemerally popular posts. Science requires patient, process-driven investigations. For instance, does performing/participating in experiments update people's beliefs? Some preliminary work suggests that simple exposure to scientific concepts is not enough; recreating these ideas on one's own is important [12].

Such community work can be accelerated with novice-appropriate interactive visualization of physiological data. While massively multivariate data– like microbiome information– are extremely difficult to interpret, smaller data with interpretable features can help communities develop and understanding of their performance. Furthermore, the quality of knowledge from community experiments can be improved with better contextual support for catching/correcting human biases. For instance, experiment length, potential confounds and lack of double-blind processes can be tricky to implement for a novice experimenter.

Finally, my prior work demonstrates that small interfaces have big effects [13].

[12] **Pandey**, Ngoon, and Lau. Constructive activities for people to develop their creative scientific insights. 2 In Preparation

[13] 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

Evaluating online platform design for access, use, and dropouts will continue to be a focus of my research.

References

[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.

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