CSCW Doctoral Consortium: Creating Scientific Theories with Online Communities using Gut Instinct

Vineet Pandey
UC San Diego Design Lab
La Jolla, CA 92093, USA
vipandey@eng.ucsd.edu

Abstract

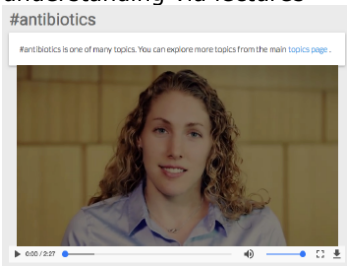
People's lived experiences provide intuitions about their health. Can they transform these personal intuitions into scientific theories that inform both science and their lives? My research introduces social computing architectures and system principles for people to brainstorm and test causal scientific theories. These ideas are instantiated in the *Gut Instinct* system (gutinstinct.ucsd.edu). 344 voluntary online participants from 27 countries created 399 personally-relevant questions about the human microbiome, 75 (19%) of which microbiome experts found potentially scientifically novel. To test their theories, end users design structurally-sound experiments, improve them via community reviews, and run them with other participants. Controlled experiments show that participants create better hypotheses and experimental designs when they have access to procedural training. My research illustrates a novel way to tackle complex, creative tasks online by building expertise in online volunteer communities.

Author Keywords

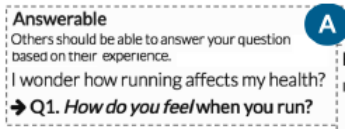
Social computing systems; citizen science; crowdsourcing; online learning.

The *Learn-Train-Ask* workflow integrates conceptual learning and procedural training to create hypotheses

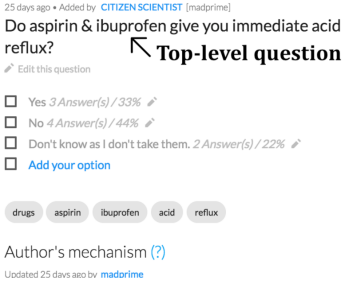
Learn: Conceptual understanding via lectures



Train: Frame useful questions using checklists, templates, and examples



Ask personally-meaningful questions



ACM Classification Keywords

K.3.1. [Computer Uses in Education]: Distance learning, Collaborative learning.

The Promise of End Users Performing Scientific Work

End users collaborate online to build software (github.com), create novel hardware & reference designs (openaps.org), and share personal data (quantifiedself.com, openhumans.org). In a few exceptional cases, lead users [3] have even authored scientific papers, e.g., Open Artificial Pancreas creator Dana Lewis discussed the benefits and challenges of first-generation automated insulin delivery at the 2016 American Diabetes Conference [5].

However, community-driven approaches to understand personal health and well-being largely reside outside the realm of institutional science and medicine. While some fads and beliefs are questionable at best, on occasion these communities break new ground that may provide widespread value, such as fecal transplants to alleviate Clostridium difficile infection symptoms. When are such personal experiences worth paying attention to? For every intuition proven right, many more may be closer to snake oil — e.g., the widespread belief in the utility of probiotics despite limited evidence [2]. The global internet increases the proliferation of both powerful and questionable ideas: sharing speculation is fast while evaluation remains slow. Moreover, people develop intuitions of cause and effect that may or may not be correct. How might we crystallize intuitions to create personally meaningful scientific knowledge?

Microbiome research: a petri dish for making scientists

The human microbiome is the collection of all microbes and their genetic components in and on our bodies. It is highly personal: each of us hosts a different collection of microbes, and this collection is influenced by our environment, diet, health, lifestyle, and genetics. Surveys by the American Gut Project has revealed lifestyle-microbiome correlations of dog ownership and beer or vegetable consumption, among others. Currently, the survey questions are handpicked by a small group of scientists. Can opening up the question-asking and experimentation process to the world yield additional insights? How can people's situated knowledge supplement institutional science?

From Knowing to Doing, at Scale

My research towards building social computing systems is informed by the following research questions:

1. How can people perform complex, creative work, such as hypotheses generation and experimentation, in the absence of expert guidance?

2. How might people's situated knowledge supplement ivory-tower science via online collaboration?

3. How can computational systems scale expertise?

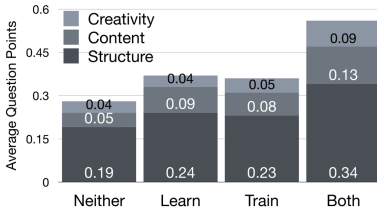
My dissertation work operationalizes one central insight: *integrating conceptual learning with task-specific scaffolding enables personally meaningful & useful scientific work*.

Integrating conceptual learning and procedural training to generate hypotheses

Gut Instinct embodies three main principles for hypothesis generation [4]. First, **two-way integration of learning and asking questions** improves conceptual understanding of the microbiome by

Current Results

Learning and Training improve quality of questions

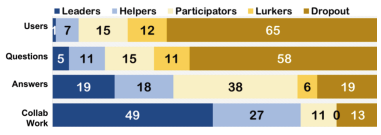


Examples of questions created by people

Quality	Sample Question
High	Have you ever eaten raw pumpkin seeds to eliminate parasites? (Structure: 2, Content: 1, Creativity: 1)
Medium	Do you get constipated when stressed? (Structure: 2, Content: 0.5, Creativity: 0.5)
Low	Does day of the week influence good vs. bad microb ota? (Structure: 1, Content: 0, Creativity: 0)

People take different roles online

Role	Actions
Leader	Add questions, answer & edit others' question add follow-ups, discuss
Helper	Add & answer questions, add follow-ups
Participator	Answer questions
Lurker	Add questions but no collaborative work
Dropout	Add a question; never return



providing online lectures and feedback on the people's questions. For instance, for a question about the effects of probiotics on mood among people suffering from gastrointestinal diseases, Gut Instinct would provide feedback using lectures about probiotics, gastrointestinal diseases, and the gut-brain axis. Second, **training seeks to focus on two attributes of questions**: a) that others can answer them, and b) that each addresses a single topic. For instance, simply asking people to discuss their use of probiotics might lead to open-ended responses. Instead, a question linking probiotics use to specific effects might begin by asking how frequently people consume probiotics and in which form, following up by asking about bowel movements and quality of sleep. Third, Gut Instinct converts **question-asking and answering into an engaging social interaction** by enabling people to participate in multiple ways, such as by asking questions, adding follow-ups, editing questions to improve clarity, or responding to questions.

Current Results

344 voluntary participants from 27 countries created 399 questions, 75 (19%) of which microbiome experts found potentially scientifically novel. A between-subjects study compared participants' question quality across four randomly assigned conditions: LearnOnly, TrainOnly, Neither and Both. Dependent variables were structure, content, and creativity of questions. American Gut researchers with multiple years of post-PhD expertise independently rated all 399 questions. Training improved overall question quality (M= 0.31, vs. M= 0.47); a permutation test with 10,000 replications found that the observed difference in question points are different than the expected differences as they fell outside the 95% CI [-19.5, 19.5], $p < .05$. Learning also improved question content (M= 0.06, vs. M= 0.11). Different roles emerged, from leaders who perform all the activities to lurkers who may watch but not actively engage in the question-asking activity.

Design-Review-Run: From Hypotheses to Investigations

Designing an experiment is a creative open-ended task without one correct answer. As people often have many hypotheses—most of which are poorly-framed—providing feedback on experimental designs in the absence of experts is near-impossible. Gut Instinct tackles this challenge by providing templates and examples that help people structure experimental designs. Gut Instinct walks users through a clear structured workflow: People design an experiment by a) converting a vague intuition to a specific hypothesis; b) providing ways to manipulate cause and measure the effect; c) providing experimental steps for control and experimental conditions; and d) providing inclusion and exclusion criteria for participants.

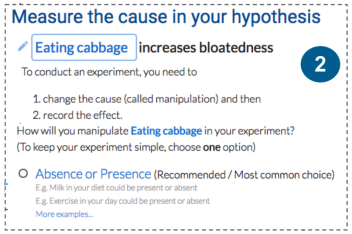
Experimental designs need to be reviewed by at least two people before they can be run. These reviewers might be friends, peers, or anyone else who can provide useful feedback. Reviewers provide both binary rubric assessments and written feedback on specific questions for each. Once underway, Gut Instinct sends condition-specific text messages to all participants: a beginning and end of experiment message, a daily reminder, and daily data collection messages.

Work in Progress

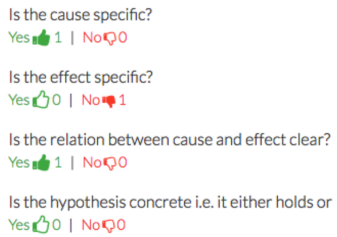
Gut Instinct is currently being deployed with patient and health enthusiast communities for them to design

The Design-Review-Run workflow to test hypotheses

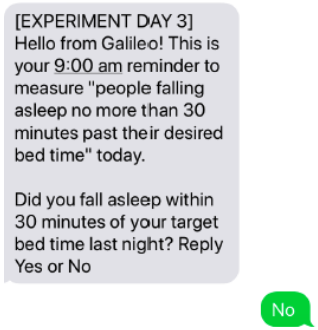
Design experiments using scaffolded procedural learning



Review: Community members improve the design



Run the experiment:



and run experiments to test their intuitions. For instance, some institutionally overlooked communities, such as people with Lyme Disease, have explored political activism, and data collection. Apart from Lyme patients, extreme users of Kombucha or Kefir are interested to test whether consuming these fermented foods affects their health outcomes. We hope to draw useful insights from these diverse communities' usage of the Gut instinct platform.

Expected Contributions

People spend massive amounts of time online driven by curiosity (e.g., reading Wikipedia articles) or social comparison (e.g. taking quizzes [6]). My research attempts to use this "cognitive surplus" towards identifying and answering important scientific questions via the following contributions:

1. Social computing architectures that integrate learning, procedural training, and role-taking to perform scientific work for both online communities and for experts

2. Tools to build expertise and enable people to tackle personally-meaningful questions. At scale, such distributed expertise can meaningfully tackle important challenges

3. Improving scientific understanding among people

Attending the Doctoral Consortium

My research building collaborative online systems for scientific work has been motivated and informed by the work done in the CSCW community including both seminal (e.g. Distance Matters) as well as more recent work about crowd workflow and organizations (e.g. Soylent [1]). I haven't yet published my research at ACM CSCW and this would be a fantastic opportunity for me to learn from the panelists and other participants. My goal is to understand the broader applicability of the techniques used in Gut Instinct, to identify the blind spots in my work, and to identify communities where lead-user innovation is prominent.

Acknowledgements

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