Scientific Foundations: A Case for Technology-Mediated Social-Participation Theory

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Technology-mediated social-participation systems, such as Wikipedia and TopCoder, allow a vast user base to collaborate to solve difficult problems. TMSP could be applied to many current social issues, but doing so requires new theory and infrastructure for social design.

New forms of technology-mediated social-participation (TMSM) provide unprecedented opportunities to solve important social problems while increasing the collective intelligence of our nation and the world. By supporting closer coordination among larger groups of people, new computing and communication technologies make it possible to address an amazing range of problems in new ways. Consider, for example, how vast groups of people have created massive intellectual products such as Wikipedia and Linux, successfully predicted election outcomes using the Iowa Electronic Markets, provided data to track bird migrations using eBird, and detected earthquakes using Twitter.

We have an opportunity to explore, exploit, enrich, and repurpose these novel technologies to support many national priorities, including healthcare, education, energy and environmental sustainability, and emergency response. Achieving this aim will require a deep scientific understanding of current and emerging systems and the human behavior around these systems. Such understanding will provide a foundation for the design and engineering of powerful new architectures for social participation that achieve desired results in sustainable ways.

An analogy to mapping the human genome suggests one way to proceed toward this goal. Although there are no explicitly represented “genes” in TMSP systems, recurring patterns in their design elements certainly exist. Many of these systems, for instance, include various types of group decision-making patterns, such as voting or prediction markets, as well as other patterns such as contests or collections.¹
Just as the biology research community developed a map of the human genome, an interdisciplinary research community could collaboratively develop a comprehensive map of TMSP design patterns. Researchers are starting to develop such a map, including examples of each pattern, the conditions under which each pattern is useful, and the theories that apply to using each pattern effectively. Unlike the human genome map, a map of the TMSP “genomes” would never be finished, because new design patterns and new combinations of old patterns could always be invented. But the goal of mapping the scientific foundations for the most important collaborative systems could help coalesce and inspire the nascent TMSP research community.

Bringing the TMSP research community together to work toward making theoretical advances and developing the underlying technologies present several challenges. These include meeting the general need for theoretical integration across levels of analysis (for example, from individual psychology and behavioral economics through social processes and organizational dynamics), within levels (such as communication, relationship formation, and trust building), and across theoretical frameworks and representations (for example, dynamic systems, random graph theory, and computational cognition).

**THE ROLE OF THEORY**

TMSP systems are typically valuable when a large and diverse user base provides information and insight and tackles problems that are too large for individuals or small groups. Successful examples of TMSP and the goals they have achieved include

- Wikipedia—the social construction of knowledge;
- Google Image Labeller—the social construction of image labels;
- eBird—social participation in tracking bird migration;
- TopCoder—social participation in developing computer programs; and
- NASA Clickworkers—social participation in identifying craters in scientific images.

These systems were developed without a theory of TMSP and have emerged from intuitive and insightful uses of the Internet and social technology. These successful uses of technology have motivated hundreds of thousands of people to participate in activities outside their professional or normal daily activities.

Although these particular systems have been successful, many others have failed—Wikipedia’s success is the exception and not the rule. For example, of the more than 6,000 wikis using the MediaWiki platform, fewer than half have even eight contributors. Developing relevant theories that help determine how to achieve positive outcomes is essential for advancing our understanding of current and future TMSP systems. Without relevant theories to describe or predict these phenomena, we’ll continue to be surprised at how this emerging technology makes radical changes in the fabric of our society, and we’ll lack the potential to guide the technology toward effective and positive applications. Success will continue to be hit or miss.

**MULTIDISCIPLINARY INTEGRATION**

Human social behavior is affected by multiple layers of organized systems rooted in physics and biology at one end of the spectrum and large-scale social and cultural phenomena at the other end. This hierarchical organization produces layers of phenomena—neural, psychological, economic, and so on—dominated by different mechanisms and factors. This space is large, spanning 10 orders of magnitude of time scale (from milliseconds to years) and 10 orders of magnitude of organization (from individuals to nation-sized collections). Natural pressures in the sciences create a division of labor in which causal processes are isolated and under-
stood, often from different explanatory frameworks, in each system layer.

Understanding and architecting TMSP systems requires elaboration and integration of theory between levels and new metrics. To accomplish this agenda, we need the following.

We need a deepened understanding of the sociocomputational processes themselves. The science must provide the foundations for new systems that build upon diverse sociocomputational processes such as collective intelligence, collective action, game-theoretic interactions and tradeoffs, and so on.

Dealing with the complexities of interacting processes at each level calls for within-level theoretical integration. For instance, participation and contribution rates in an online community don’t result from a single isolated social process, but from the complex interaction of cognitive, economic, and social processes.

We must identify key metrics that gauge the viability and evolution of TMSP systems and support ongoing organization, management, and decision processes.

Integration across theoretical levels is also necessary. Microscale factors at the individual user level can percolate upward to affect emergent macroscale phenomena (for example, small changes in the effort an individual must make to contribute to a community has large effects on the value that the community can provide its members). Similarly, embedding a person in the macroscale social fabric can affect that individual’s behavior and outcomes. We now have an opportunity to advance science by synthesizing psychological, organizational, economic, and social factors and testing this synthesized theory against the empirical behavior of online communities. We can also use this theory to guide the complex tradeoffs needed to design socio-technical systems that improve individual and community performance.

We must identify key metrics that gauge the viability and evolution of TMSP systems and support ongoing organization, management, and decision processes. More generally, we need models to form the basis for measurement and to identify key metrics such as member satisfaction, type and degree of cooperation, network structure and dynamics, and community efficacy.

Understanding and designing for TMSP will depend on integrating various (sometimes competing) theories in the cognitive and social sciences that partially explain contribution behavior and how group membership changes it.

Relevant disciplines and the theories they can contribute include

- individual psychology, for theories about human motivation;
- social psychology, for theories about group formation, member socialization, leadership, group decision making (for example, information cascades and risky shift);
- organizational design, for theories about the tradeoffs involved in ways of grouping and linking activities in organizations;
- economics, for theories about how to design incentives to influence choice (mechanism design) and theories about how human decision making often differs from the theoretical optimum (behavioral economics);
- political science, for theories of democracy, voting and governance;
- sociology, for theories about many noneconomic factors that facilitate and inhibit community formation and the social factors shaping collective action; and
- law, for theories about effective ways of balancing individual and group rights (for example, managing intellectual property rights).

We highlight just a few of the relevant theories or studies that provide a starting point for a theory of TMSP. Each of these areas is already witnessing new development because of the interdisciplinary work among computer and social-behavioral scientists. However, we still have a long way to go before we have robust theories for TMSP.

Behavioral economics

Researchers have explored behavioral economics in the development of incentive mechanisms for enhancing participation. Network scientists have explored incentive mechanisms for optimal structuring of effective social networks. Theories of social evolution build upon iterative game theory to predict evolutionary stable strategies for social ecologies. These approaches hold promise because of their generality, but researchers have not yet applied them to large-scale complex online communities.

Relation of offline to online

Social systems and networks aren’t new, but technologies change the conditions and constraints in which social processes operate. People can now network—communicate, collaborate, and interact—with anyone, anywhere, anytime. Our social and cultural worlds have evolved offline, and these worlds remain primary. However, the virtual environment is essentially a new niche for social and cognitive adaptation and evolution. To understand the evolution of new forms of social interaction in the online world, we must
understand their historical and continuing relations to the offline world. Echoes of ongoing activity in the offline world are reflected in the activity of the online, and vice versa. Research has begun to show both how the online and offline social worlds are related and how they differ.13,14

Social capital
Social participation and social connectedness can create advantages for individuals and groups. This is the notion of social capital. Social capital includes the accrual of benefits associated with increased common ground (including shared tacit knowledge, language, trust, and norms) that improve society’s efficiency, productivity, and civility. Social capital also includes the effects that accrue with diversity (improvements in innovation, decision making, problem solving, and visions of otherwise unseen opportunities). New ways of measuring the impact of social structure and dynamics on social capital are emerging from the computational and network sciences.15,16

Sociocognitive mechanisms and dynamics
Just as the Internet is an abstraction implemented in the mechanics of different layers (application, transport, and TCP/IP) that are ultimately realized in computers, routers, cables, and wireless technology, so too are social networks and processes a theoretical abstraction that is realized by people’s social-cognitive mechanisms. Numerous network science studies illustrate phenomena such as idea contagion,16,17 the spread of obesity, smoking, and happiness,6,8 effects of social brokerage on innovation; and effects of network structure on reputation. However, the mechanics underlying these phenomena at the level of individual psychology and interpersonal interaction are largely a mystery. For instance, it’s unclear how the disposition for smoking or obesity transfers from one person to another, or how individuals process digital representations of others to judge their behavior.18

Motivation and incentive structures
Theories of motivation are beginning to explain the technologies and organizing principles that motivate people to participate in TMSP. Motivation theories come from various perspectives, ranging from Darwin’s evolutionary theory, which offers a biological basis for human motivation, to Maslow’s hierarchy of needs—ranging from the purely physiological to self-actualization, to more economically oriented theory—which focus on external incentives. Thomas Malone and his colleagues analyzed mechanisms that induce participation in computer-enabled collective intelligence systems.1 Other work has explored the interaction of psychological, technical, and social factors that shape online participation and contribution.19 Although these approaches to understanding motivation provide an underlying basis for a theory of motivation in TMSP, they lack theoretical rigor.

THE RELATIONSHIP BETWEEN THEORY AND PRACTICE
An oversimplified model of science holds that scientists develop theory based on observations of the natural world, conduct controlled experiments to test these theories, and then, when the theories are sufficiently refined, use them to guide the design of real-world systems. More recent studies of the history of science, however, demonstrate that practice leads to theory as often as it follows from it.20 Because the problems facing humanity, to which systems for social participation can be applied, are so pressing, we can’t wait to fully develop theories of technology-mediated social participation before using these systems for problem solving. A decentralized, multcentered, multidisciplinary

A TMSP collaboratory could help researchers in different locations to advance the use of social participation to solve problems of global importance.

collaboratory, which itself is an example of TMSP, can provide a venue where researchers can match advances in theory with successes in practice, communicate, and share tools.

Collaboratories are collections of researchers, not collocated, who work together to address a set of common problems, coordinating their research through supporting technologies and social practices. A TMSP collaboratory could help researchers in different locations, using a range of methods and theories, to advance the use of social participation to solve problems of global importance.

This collaboratory could consist of smaller, more focused centers. At the core, however, would be a distributed coordination center, made up of a coordinating and cooperative superset of researchers and providing a place to share ideas, tools, and findings. The distributed coordination center would provide infrastructure for smaller centers, much like the Biomedical Informatics Research Center does for its associated collaboratories. It would be the coordinating node for more focused centers aimed at fostering design research and research in domains such as healthcare and education. The TMSP collaboratory would include research infrastructure (access to server farms, data sources, subject pools, and so on) and technology-based tools (such as wikis, discussion forums, and digital libraries), which can be customized to fit the researchers’ needs. It would also
include a recommended set of policies and best practices used in previous successful collaborations.

A TMSP collaboratory would also require data depository centers to house large datasets made available to researchers (for example, from Google or Yahoo), and living laboratories of participants engaged in TMSP projects.

Theoretical work on TMSP will likely involve multidisciplinary work at all levels, with theories about

- the individual (for example, theories of motivation for participation),
- the dyad (for example, theories of reciprocity, trust, conversation, and common ground),
- small groups (for example, theories of coordination, leadership, and diversity),
- organizations (for example, macro theories of coordination and governance),
- communities (for example, theories of membership growth and diffusion of innovation), and
- society (for example, theories of the tipping point and viral marketing).

Advances in multidisciplinary integration and deepened understanding will depend partly on the emergence of computational social science and the translation of TMSP science into practice. Several other centers can help foster this movement.

A simulation center will provide extensible simulation capabilities that researchers can use to model and reason about the underlying behavioral mechanisms of communities and test design ideas (for example, about incentive structures). The simulation center would provide shared tools for testing design decisions before implementing them.

Translational centers will bridge scientific research and practice, much like translational medicine centers bridge research results and clinical practice. These translation centers would provide technology-based tools for social-participation efforts, infrastructure for empirical research, and support for developing new design and engineering approaches such as design pattern languages.

Mapping foundational science and theory onto a design approach is central to TMSP. Pattern languages provide a useful way to generalize what works and offer useful guidelines for designing real systems. A pattern is the named description, at a general level, for a recurring problem and solutions. A pattern language is a lattice of patterns pertaining to and covering a particular domain. Patterns typically exist at various levels. For example, physical architecture involves patterns about overall city design as well as patterns dealing with much lower-level details about specific buildings, such as a floor plan. A pattern language thus allows something positive to be done at many control levels. Often, designers won’t have the power or resources to build complete complex systems, but can nonetheless make important changes or additions within their sphere of influence. Thus, pattern languages are particularly useful in a domain such as social participation, where designers have direct control over some parts of a system (for example, incentives for contribution), but not others (for example, the number of participants). Pattern languages can serve as a lingua franca among professionals and nonprofessionals from assorted backgrounds. They’re therefore suitable both because many relevant formal disciplines must be brought to bear on social participation and because most real-world design settings involve a wide variety of stakeholders.

We suggest that enough knowledge exists to construct the beginnings of a pattern language for social participation. For example, researchers have compiled patterns, which they call “design claims,” to map theories in social psychology and economics to design alternatives for successful systems for social participation. The proposed collaboratory would include tools to help scientists and practitioners jointly construct, link, edit, visualize, search, and discuss design claims and pattern languages.

Patterns will be useful for design, and evaluations of their success in practice will provide feedback to inform TMSP theories. Although pattern languages can help guide design, they don’t specify a design. Typically, investigators must develop prototypes to test designs through observation and experimentation, and, as theory building becomes more formal, test designs using simulations. In some cases, researchers can apply their observations and simulations to the same design and use the results to refine the simulations and their observation methods. In addition to refinements to general theory, which simulation and observation provide, the observations and simulations would improve the specific design and often lead to refinements to the more general patterns.

Of course, observations can also serve to refine theory or simulation techniques; they don’t always need to be associated immediately with a real-world design. Modeling and simulations can also be useful in determining which observations will likely prove useful and how many are needed. Similarly, the attempt to design a system to solve a real-world problem can shed significant light on issues not currently addressed by theory.

The construction of a common pattern language could be associated with common datasets, simulation tools, and
observation tools, making the design of particular systems more efficient and effective and furthering the development of theory. Many research participants will be remote from each other, and even physically colocated participants will find the associated tools useful. To provide a testbed for the development of a theory of effective social participation, we plan to instrument and initially design this tooling using the processes described here. In this way, the scientists’ collaboration efforts will themselves be an important source of data.

In a prescient article about the foundations for a science of human-computer interaction that was published 25 years ago, Allen Newell and Stuart Card declared that “nothing drives science better than a good applied problem.” Technology-mediated social-participation systems present not just scientific problems, but truly Grand Challenges that—if solved—could help address problems of national and even global importance, including healthcare, education, climate change, security, and commercial innovation.

The challenge is multidisciplinary and complex. Consequently, we’ll need advances in computational thinking, modeling, and methodology to support scientific understanding of the social, economic, and behavioral phenomena surrounding TMSP systems. We’ll also need new theories of design and engineering to move from ad hoc approaches to predictable and sustainable sociotechnical systems.

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References


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