Creating and Sustaining Collaborative Efforts for Scientific Idea Exchange Through Autonomy, Competence, and Relatedness

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Abstract
Collaborative engagements among scientists and researchers are increasingly becoming dependent on information and communication technologies (ICTs), but there is little focus on developing next-generation technology-based collaboration schemes geared specifically to support and sustain scientific idea exchanges among researchers, because we lack the necessary conceptual frameworks and deeper understanding of the social and group dynamics involved. Building upon initial research leads from disciplines such as psychology, sociology, and management information systems, a novel scientific idea exchange (SIE) collaboration scheme is proposed that is instantiated in a research prototype. Given the need to understand the motivational challenges among researchers collaborating virtually, the SIE scheme takes a participant-driven approach and draws on Social Capital Theory and also Cognitive Evaluation Theory (CET) within the Self-Determination Theory (SDT) framework to address three innate psychological needs (autonomy, competence, and relatedness) to increase the intrinsic motivation of participants to engage in idea exchange. Research propositions based on these theoretical foundations are developed, along with a roadmap for the research program.

1. Introduction
Collaboration among researchers of diverse interests, disciplinary backgrounds, and methodological expertise are essential to new scientific knowledge creation and innovation. Anyone who has been a researcher for any amount of time recognizes some of the inefficiencies of current knowledge creation processes in the sciences. For example, we all have experienced sitting at a conference wanting to convey an idea or provide feedback to a presenter but the serial and synchronous nature of face-to-face communication is constrained by the limited time of the session. Additionally, we all can recall times when we would have benefited from insights and feedback from colleagues regarding our research earlier in the research process. Surprisingly, while collaboration and information and communication technologies (ICTs) have evolved over the last several decades, the inefficiencies of these scientific processes remain to plague creation and innovation in the sciences.

Collaborative engagements among scientists and researchers are increasingly becoming dependent on ICTs, but there is little focus on developing next-generation technology-based collaboration schemes geared specifically toward supporting and sustaining scientific idea exchanges among researchers, partly because we lack the necessary conceptual frameworks and deeper understanding of the social and group dynamics involved. Nascent scientific knowledge exchanges occurring between individual researchers are of immense value and are conventionally supported through face-to-face research meetings and conferences. Additional support for idea exchange and early feedback from peers and experts in the field at any given stage in the lifecycle of a research project from conception to publication can foster innovation and research agendas that lead to rigorous and relevant research. Various cross-disciplinary areas of research including scientific collaboration [1,2,3], communities of practice [4,5,6] as well as disciplines such as psychology, and sociology have provided some initial leads into this research topic. Building upon these and other fields, we propose and have developed a prototype of a novel scientific idea exchange (SIE) collaboration scheme. We have developed a set of propositions based on theoretical foundations and design principles. We plan to extend this work by conducting research studies using the scientific idea exchange prototype.

2. Literature review
Scientific idea exchange is the process of scientific collaboration where scientists exchange creative research ideas and other relevant artifacts associated with research projects integrating a diverse set of considerations including, but not limited to, relevance,
rigor, theoretical foundations, appropriateness of methodologies, data gathering, analysis, and generalizability of results. The ultimate goal is to harness the expertise and wisdom of individual scientists to advance knowledge within and across disciplines.

This work builds upon the body of knowledge in the following areas: (1) large group collaboration, (2) individual motivation considerations, and (3) communities of practice and social capital considerations.

2.1. Large-group collaboration

Social networking and Web 2.0 tools such as Wikipedia, Flickr, Del.icio.us, Facebook, and Twitter do a good job at facilitating collaboration among the masses (termed as “wikinomics” [7,8], or “crowdsourcing” [9,10]) on specific tasks such as collaborative editing, sharing and commenting on pictures or bookmarks, and (re-)connecting socially with friends and colleagues. Meservy et al. [11] have classified this kind of collaboration as artifact-based collaboration, where collaboration centers around a certain artifact like a topic (such as in blogs or discussion threads), or product (such as in product reviews), pictures or videos (such as comments). While the aforementioned artifact-based collaboration has its own merits, there is a dearth of socio-technical systems that engage large groups in scientific knowledge creation efforts. Questions remain as to how to engage large number of participants collaboratively at various stages of the scientific research lifecycle, ranging from innovative project idea generation to addressing research issues that confront individual scientists during project execution, and how to sustain these collaborative efforts. Helquist et al. [12] have reported on the challenges and benefits associated with collaboration among large groups of individuals. After reviewing different means of accommodating large groups, we introduced the idea of participant-driven group support systems as a mechanism to accommodate large, distributed groups [13]. In a similar vein, Helquist et al. [14] propose a dynamic collaboration process management scheme that (a) provides autonomy to participants for engaging in different aspects or phases of the overall process, (b) provides opportunities in terms of wide array of relevant issues for participants to engage in and channel their competencies, and (c) provides them a sense of social presence and relatedness with others among the community. Based on our research experience in this area, it is clear that scientific collaboration could benefit from many of these principles.

2.2. Individual motivation considerations

Self-determination Theory (SDT) [15,16] provides a theoretical basis for framing our investigations to further understand how social and cultural factors contribute to scientists’ individual volition and initiative and the quality of performance/participation in a group’s activities. SDT posits that individual motivations are composed of both extrinsic and intrinsic factors [17] and that there is a continuum and interplay between these factors. Extrinsic or external factors such as reward systems, evaluations conducted by others, or opinions (in certain situations) can provide enough motivational force to move a person to action and attain contingent outcomes. However, intrinsic factors, such as personal interests, intrigue, close-held values, or other motivations from within can be arguably influential motivating factors in distributed collaboration among scientists. Cognitive Evaluation Theory (CET) [18], a mini theory within the SDT framework, suggests that the psychological needs of competence and autonomy are integrally related to intrinsic motivation. Delving deeper into the psychological processes, it suggests that intrinsic motivation will be enhanced when certain stimuli trigger a change toward a more internally perceived locus, and vice-versa. Similarly, the theory argues that intrinsic motivation will be enhanced when certain stimuli trigger increased perceived competence, and vice-versa. Last, but not least, the psychological needs of relatedness (i.e., feeling connected or related to other scientists sharing similar perspectives) will likely play a more salient role in distributed collaboration among scientists, along with autonomy and competence. Together, these theoretical premises present a unique opportunity to foster scientific knowledge creation and sharing by providing the appropriate stimuli (through next-generation technology tools) to increase intrinsic motivation to participate and innovate.

2.3. Communities of Practice and Social Capital Considerations

Online communities of practice have become a common form of collaboration technology for discussion-oriented interactions among individuals with shared topics of interest. Researchers have studied factors that contribute to the success and sustainability of such online communities. A recent study by Chang and Chuang [19] found structural (social interaction),
relational (trust, identification, reciprocity), and cognitive (shared language) social capital factors to have a significant positive effect on either the quality or quantity of knowledge sharing behavior. In another study, Bateman et al. [6] studied the relationship between different types of commitments with participant behaviors. Need-based (continuance) commitment was shown to predict knowledge gathering, emotion-based (affective) commitment was shown to predict knowledge contribution and moderating behaviors, and obligation-based (normative) commitment was shown to predict moderation behaviors. Based on these and other studies in this domain [20,21,22], we assert that in the context of scientific idea exchange, the more individual scientists perceive that their efforts are valued and feel that their voices are heard, the more engaged they will be in participating in such activities. A collaborative system that supports these motivational and social factors can arguably affect participant commitment behaviors positively, and ultimately increase the quality and quantity of scientific knowledge creation.

3. Scientific idea exchange collaboration scheme

Scientific idea exchanges may be instantiated in several different ways with varying technologies. Central to scientific idea exchanges is the sharing ideas or research artifacts with a diverse group and receiving feedback on those same ideas [23]. Ideas and feedback can occur at any phase of the research lifecycle: inception (e.g., identification of phenomenon of interest, selection of methodology), design and refinement of study, data collection/investigation, analysis, integration of findings, or the validation of the contribution [24]. In this project, the prototype we developed builds on and leverages work that we have already done in the area of large group collaboration by instantiating a web-based (accessible through mobile devices) scientific idea exchange.

Figure 1 shows how ideas are submitted. Compared to some other large group systems that are extremely lean, here we provide enough facilities to more fully convey ideas and also optionally link the idea to areas of interest or topics. The overall design of the system would allow customization (e.g., number of fields, different combination of field types) for the submission of ideas at different stages/ phases of research. Additionally, different disciplines (e.g., information systems, chemistry, computational linguistics) could have customizations that match their needs.

Figure 1. Mockup of the submission of ideas
Figure 2 captures how ideas are evaluated. Ideas that may be of interest to a user (based on topic/area) but that have not been previously evaluated by that user are shown in a randomized order. The idea is to be able to provide quick feedback but also provide helpful information to the originator. This evaluation process also allows the evaluator to express interest by following the idea or by indicating interest in collaborating. Additional resources such as articles, theories, researchers, or more generic URLs can be shared with the original submitter and others interested in the idea. Again, the evaluations can be customized by research phase/discipline.

Figure 3. Composite view of ideas that a researcher has submitted and who they are following as well as ways to get inspired.
Figure 3 illustrates a composite view of other core functionalities of the scientific research exchange. ‘My ideas’ allows a user to review previously submitted ideas as well as track the ideas they are following. ‘My Contribution’ (not shown due to space limitations) shows a history of the contribution of an individual including links to all previously evaluated ideas and a measure of overall contribution and impact. The ‘Get Inspired’ tab allows browsing of ideas by topic, researcher, research phase, and overall hot ideas.

Such a scientific idea exchange has the potential to shorten the time to receive feedback in every phase of research and does so by tapping into a diverse pool of expertise where evaluations can occur in parallel rather than in serial like you might see at a conference. The features of the system have been designed to incorporate motivational and social capital factors previously discussed including social interaction, shared language, reciprocity, trust, and an appropriate level of identification.

4. Research propositions

As we embark in this research program we have developed four primary research questions to guide our efforts. Within each research question we derive propositions that are supported by the underlying theoretical foundations mentioned previously.

**Research Question 1:** How does the proposed scientific idea exchange scheme impact motivational factors, and social capital factors? More specifically we expect:

P1. In relation to the current modes of exchanging scientific ideas (status quo), higher levels of perceived autonomy, competence, and relatedness will be reported following the use of a SIE.

P2. In relation to the status quo, higher levels of perceived social capital factors, (i.e., structural (social interaction), relational (trust, identification, reciprocity), and cognitive (shared language)) will be reported following the use of a SIE.

**Research Question 2:** When using the proposed SIE, how do motivational factors and social capital factors impact scientist commitment? More specifically we expect:

P1. Higher levels of intrinsic motivational factors (e.g., autonomy) lead to higher scientist commitment (e.g., affective commitment).

P2. Higher levels of social factors (e.g., social interaction) lead to higher scientist commitment (e.g., affective commitment).

**Research Question 3:** When using the proposed scientific idea exchange scheme, how does scientist commitment (e.g., affective) impact scientific knowledge sharing, gathering, and utilization behavior? Do levels of scientist involvement affect this relationship? More specifically we expect:

P1. Higher levels of scientific involvement moderate the relationship between affective commitment and levels of scientific knowledge contribution behavior.

P2. Higher level of scientific involvement moderate the relationship between scientist continuance commitment and levels of scientific knowledge gathering behavior.

**Research Question 4:** How does the proposed scientific idea exchange scheme impact collaboration success factors? We expect that:

P1. Levels of perceived efficiency, effectiveness, productivity, and satisfaction with will be higher using an SIE compared to current processes of exchanging scientific ideas (status quo).

5. Research program roadmap

While we have made substantive progress in the research program (theory development, propositions, prototype), we are in the early stages of the research program roadmap. This research program has three main research objectives:

1. To design, develop and instantiate a scientific idea exchange scheme that challenges the status quo of scientific idea development and evaluation across diverse fields of scientific research.

We have applied principles of systems analysis and user-centered design in further developing a fully functional collaborative scientific idea exchange prototype. As we engage in our research studies, we will continue to refine the system. The knowledge of motivational factors and social capital factors will be instrumental in the iterative design decisions of the collaborative system. In that regard, a detailed mapping of factors to specific aspects of the idea exchange scheme will be developed. The system will be critiqued and additional user requirements for system design will be iteratively gathered through questionnaires and focus groups. Successful translation of behavioral
study findings into design of next-generation system will be a significant contribution.

2. To examine and assess individual participation patterns related to the submission, refinement, and evaluation of scientific ideas throughout various research phases.

Participation patterns analyzed over time can inform the nature of scientific idea exchange in a variety of ways. For example, it can help address questions such as – What role are the stimuli (instantiated in the form of distinct functional features in the collaborative system) playing in participation and commitment? How many of the existing ideas are pushing the envelope of accepted knowledge in a field? What collaboration patterns and roles emerge during collaboration over time? Do the participation patterns indicate roles that have a correspondence with conventional roles such as senior and junior scientists? What can be said about patterns of multi-institution collaborations and involvement of personnel from industry or professional practice in informing the scientific discourse? How diverse are the participant backgrounds and ideas exchanged? Measures for assessing the nature of scientific idea exchange are not readily available because the majority of such exchanges occur are non-codified face-to-face interactions (status quo) and the emerging virtual exchanges through discussion forums and communities of practice do not provide the much needed deeper insights into the scientific knowledge creation process and how collaborative efforts evolve and are sustained over time. We intend to use objective metrics for participation and activity derived from the collaboration system analytically to address interesting research questions, but also prescriptively to derive best practices and design of new features in enhancing the collaborative system. Data gathered in the system will also help in providing a map of how a field is evolving and allow positioning of scientific ideas, articles, people, and resources to provide a large-scale assessment of the broader creative impact on the evolution scientific knowledge.

3. To employ measures derived from the use of a scientific idea exchange and in conjunction with additional empirical data to investigate in an exploratory manner several substantive questions related to the impact of SIEs and motivational factors on collaboration success factors including scientific knowledge productivity as well as satisfaction with the collaborative, disruptive process.

Objective metrics gathered from the scientific idea exchange, along with measures derived from interviews and questionnaires, will allow us to address fundamental questions related to participation, sustainability, and outcomes of scientific knowledge creation in context of the use of a SIE scheme as outlined in the previous propositions.

5.1. Research studies

Research studies will initially be conducted within three scientific communities: students enrolled in PhD seminars, a HICSS minitrack, and a special interest group.

The first study will be initiated with students who are enrolled in research seminar classes in several Information Systems PhD programs. As is typical of seminar classes, students will submit research ideas and proposals and other students and faculty mentors will provide feedback through the system. This study focuses on providing earlier feedback for nascent research ideas. We expect that initially this community will be constrained by characteristics of the coursework (e.g. semester deadlines).

The second study will occur within a HICSS minitrack or HICSS symposium. Papers for the particular track will be loaded into the system and authors will be able to engage, asynchronously, with the conference attendees to more fully examine and refine their research. In this way, the system allows presenters to gather feedback in a parallel nature to improve the research ideas and continues the conversation beyond the geographical and temporal constraints of the conference.

Finally a study will be conducted within the Special Interest Group on Decision Support and Analytics (SIGDSA) within the Association for Information Systems (AIS). This group is comprised of 200+ members, focusing on developing tools, techniques, and methodologies to support decision-makers and improving decision processes in businesses and organizations. The group consists of scientists from diverse topic areas including operations research, knowledge management, and organizational science, among others. This study focuses on an environment that is less structured with defined events (e.g., conferences, classes) but is centered around a community where ideas are continuously submitted and evaluated.

5.1.1. Measurement and analysis

Across these three studies, we will have two main phases. In the first phase, after participants have used the system extensively, we will conduct a case study interviewing members to get deep insights of the motivational factors, social capital factors, and user feedback on the system. An interview protocol will be developed for conducting interviews and qualitative
data gathered will be analyzed using established coding and pattern matching techniques [25]. In the second phase, we will conduct a survey to capture participant perceptions and feedback in a quantitative form. We will gather objective, quantitative metrics regarding individual participation within the system. These metrics include systems-based measures like the number of contributors, the number of different active sessions per user, and the number of ideas contributed and the quality of those ideas. This will provide objective indicators for individual scientist productivity as well as participation patterns to understand the cycles of activity across the research process lifecycle. This data will be also analyzed based on such characteristics like academic rank, demographics, affiliation, topic interests, and so forth.

The survey instrument will assess motivational factors adapting measures from the Intrinsic Motivation Inventory [18,26] and collaboration success metrics as a means to evaluate efficiency, effectiveness, productivity, and satisfaction (adapting from Duivenvoorde et al., 2009). Quality of scientific collaboration outcomes will focus on measuring creativity and the innovation of scientific ideas exchanged [27,28]. Creativity performance of scientists will be measured through a creativity scoring technique based on ratings on novelty and value aspects of participants’ contributions [27]. Analysis of the survey data will provide insight into the motivating factors and subjective measures of success. This analysis will all be conducted at the individual level to better understand the impact of scientific idea exchange scheme in this scientific research process context.

6. Contribution and conclusion

Idea exchanges among scientists are a vital component of the scientific collaboration process, in that these exchanges are the foundation for generation of creative scientific ideas, refinement of ideas, reception of feedback and suggestions from peers, and overall enhancement of scientific research leading to innovative and rigorous knowledge creation. However, current modes of scientific idea exchanges are still rooted primarily in decades-old mechanism of face-to-face conferences and research meetings, which are limited due to resource constraints and the serial nature of communication. As virtual collaborations among scientific scholars are increasing with the proliferation of social networks, developing better mechanisms for successful collaboration are needed. Moreover, as large groups of scientists collaborate, challenges arise with respect to motivating and engaging participants and paying adequate attention to the scientific knowledge creation process. This project proposes a transformative way of supporting idea exchanges grounded in motivational and social capital theoretical foundations. The outcomes and findings of this research promise to significantly and positively alter the way scientists exchange ideas throughout the scientific research process and across disciplinary and organizational boundaries. The study will advance theory and inform science and science innovation policy by revealing new findings related to the impact of the proposed collaborative scientific idea exchange scheme on levels of motivation, participant engagement, and collaborative and creative outcomes. Science policy and practices can benefit from this research through promoting mechanisms that help support and sustain such collaborative exchanges among researchers.

Fostering scientific collaboration and innovation is a priority for scientists and policymakers. Collaboration mechanisms supporting scientific idea exchanges from the ground up are arguably vital to address this priority. The findings of this project will disrupt the current scientific process and broadly impact the society as a whole. This research seeks to facilitate and promote the ability of distributed scientists to organize and collaborate. This project will enhance their collaborative work and help as a mechanism to harness the intellect and wisdom of the crowds in numerous contexts. The benefit of this approach is broadly applicable to scientists from differing backgrounds, including academia and private industry. The public will benefit from this research as the research ideas are shaped and reviewed by a more diverse group of scientists, enabling more discussion, knowledge creativity and innovation.

This research will also enable a broader range of participation in the scientific process. In many fields, scientists develop research projects and present the project and its findings at typically discipline-based conferences or project-based workshops. While the scientists at the conference are able to contribute feedback to help guide and improve the research, this feedback is limited to those that are in attendance. This project enables more scientists with diverse perspectives to actively contribute to the discussion even if they are not physically at the face-to-face venues. Further, this distributed collaborative approach may spur involvement from other related disciplines. Additionally, graduate and undergraduate students involved in the project will benefit as they are mentored in the development of the SIE and research related to it. They will also benefit from participation in the SIE.
7. References


