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Putting the Discipline in Interdisciplinary: Using Speedstorming to Teach and Initiate Creative Collaboration in Nanoscience

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The most powerful scientific advances are propelled by creative ideas that cross disciplinary boundaries. Few fields exemplify this as thoroughly as nanoscience, which promises to benefit humankind by delivering radically new technologies—if scientists from different disciplines can work together creatively. Unfortunately, initiating interdisciplinary conversations can be a costly undertaking in the context of academia, where disciplines are separated by entrenched physical and social structures. We present a new method, called 'speedstorming,' designed to improve the process of teaching and initiating creative collaboration. Early results show great promise for accelerating the rate of collaboration formation in the field of nanoscience. We found that for teaching and forming creative collaboration, speedstorming is more efficient and more effective than group brainstorming. This article explores the rationale for using such a method in nanoscience research and education and details the steps to conducting speedstorming sessions to achieve several common aims in a variety of settings. Limitations and unanswered questions regarding the method are also explored.

Keywords: Creativity, Brainstorming, Idea Generation, Interdisciplinary Collaboration, Social Interaction, Boundary-Spanning.

1. INTRODUCTION

The last 50 years have been marked by a profound acceleration of scientific progress that spans nearly every field of inquiry. In many ways, the field of nanoscience is the crown jewel of this new era. The brainchild of biology, physics, chemistry, materials science, and engineering (among other fields), nanoscience is poised to make significant contributions by leveraging the immense creative power of interdisciplinary collaboration that characterizes scientific advances today.

Like the field of nanoscience itself, innovative new ideas are born by marrying concepts from one field with those from another. Scientific progress depends upon creativity and innovation, processes that have been empirically shown to occur when experts recognize analogous qualities between ideas from distant conceptual realms and identify ways that they can be usefully connected for the first time (Burt, 2004; Hargadon, 2003; Hargadon & Sutton, 1997; Schumpeter, 1934; Sternberg & Lubart, 1995). In other words, science is advanced by developing "bridging ideas."

Bridging ideas are also notable because they are rare. To be a scientist, particularly in the 21st century, means to be a specialist, dedicating oneself to the focused mastery of one specific area of expertise. Ironically, the depth of knowledge required makes it challenging for ideas bridging multiple domains to be developed entirely by a single scientist working in isolation. This means that scientists who wish to take part in boundary-spanning work must learn not only the material of their own domain, but also how to collaborate with those outside it. Collaboration is rapidly becoming a linchpin of individual scientific achievement.

Recognizing this, universities, national laboratories, government funding agencies, and industry have created a variety of forums—such as conferences, research institutes, and informal seminar series—to encourage

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cross-disciplinary interaction (National Science Foundation, 2005, 2007). However, simply creating the institutional infrastructure is insufficient to ensure that collaboration will occur. Finding the right collaborator requires not only a match of ideas, but also of personalities. Thus, even with the benefit of supportive institutional structures, individuals must have a great deal of personal initiative and make a significant investment if they are to find collaborators and identify an idea worth pursuing jointly. Making this "last mile" less costly to traverse would offer substantial rewards in terms of realizing the true potential of existing interdisciplinary forums.

2. NANOSCIENCE: SETTING A NEW STANDARD FOR INTERDISCIPLINARY CREATIVITY

As a new field of research and education, nanoscience is uniquely positioned to become a template for future interdisciplinary pursuits. Compared to older fields, nascent fields have more malleable social structures, including norms, habits, and patterns of social interaction. While nanoscience is still young, there is a window of opportunity to leverage knowledge about effective social interactions to become one of the first fields to self-consciously shape itself from the inside out. Social self-awareness will distinguish the scientists of tomorrow from the scientists of today.

It is from this perspective that we present a new way of structuring social interaction, speedstorming, that can enable scientists from different domains to efficiently identify collaboration opportunities in a creative and engaging format. We contrast this new method with a common alternative, brainstorming, which emphasizes unstructured group idea generation. Paradoxically, we argue that by constraining and structuring creative interactions, researchers from different fields can not only produce a greater number of more original and more concrete ideas but can do so in less time and leave with a stronger sense of their overall collaborative potential with a large number of other researchers.

3. BACKGROUND

Above we referred to the importance of interdisciplinary, boundary-spanning, or bridging ideas to scientific innovation. Interdisciplinarity can be conceptualized as a continuum from *weak* to *strong*. In this section we will explore how this distinction has important implications for the types of social interactions required for scientific collaboration.

3.1. Weak Versus Strong Interdisciplinarity

All research projects begin with an idea, or a research question. Conventional, single-discipline research ideas can be generated by specialists examining their field's literature and asking questions about the domain's theory, data, and observations (e.g., Dunbar, 1989, 1993). Often, however, cross-pollination—bringing ideas from one field into another—can significantly expedite the generation and implementation of useful new ideas. This collaboration is one way, with a solution from one field imported into and customized for another. Therefore, we call this kind of interface "weak" interdisciplinarity. (The terms *strong interdisciplinarity* and *weak interdisciplinarity* are in many ways paralleled by the terms interdisciplinary and cross- or multi-disciplinary. *Interdisciplinary* connotes multiple disciplines working as equal partners, joining together their different bodies of knowledge to create new knowledge that answers a question or solves a problem important to all stakeholders, while *multi-disciplinary* connotes multiple disciplines working together side by side, but without integrating knowledge or creating new knowledge. *Cross-disciplinary* is a related but distinct term meaning the use of knowledge from one discipline to better understand another, such as the sociology of music.)

There are other cases, however, where importing ideas is not enough. In these cases, skills from several fields (for instance, mathematics, biology, and engineering) must come together in concert to break new ground. It is this form of "strong" interdisciplinary collaboration that is essential to nanoscience. While it is certainly possible for boundary-spanning individuals to tackle unanswered questions in multiple fields (e.g., scientist Herbert Simon who won the Nobel Prize in economics and made important contributions to cognitive psychology, decision-making and computer science, among others), strong interdisciplinary research is more likely to be achieved when two or more researchers from disparate fields, come together to apply their varied theories, methods and insights to a common research problem. (The authors of this piece are humble examples of this phenomenon.)

3.2. Problem: Finding Collaborators is Essential to Generating and Executing Interdisciplinary Ideas

Scientists from all fields are beginning to call for increased attention to interdisciplinary research efforts. In fact, the National Science Foundation (NSF) places a priority on supporting interdisciplinary research collaborations through grants for research, conferences, and institutes that specifically unite scholars from divergent fields. In a recent budget request to Congress, the NSF states, "multi-disciplinary research at the intersection of nanotechnology with information technology, biology, and social sciences will invigorate discoveries and innovation relevant to almost all areas of the economy," and emphasizes the importance of such programs for "laying the groundwork for an interdisciplinary culture among tomorrow's nanotechnology leaders" (*FY 2008 NSF Budget Request to Congress*).

Despite this institutional emphasis, it continues to be difficult for scientists to create new productive collaborations. There are many reasons for this problem. First, the effects of physical proximity on interaction are dramatic (Kraut et al., 1988)—even members of the same department are significantly less likely to collaborate with those just one floor away.

Second, many forums were designed with the intent of presenting ideas rather than generating them jointly, which is an important aspect of identifying potential collaborators. Conferences, for example, bring scientists from across the world together to share their work. Presenters have an opportunity to share their polished research with an audience of various interests and backgrounds, and the audience members get to learn about the state of the field and who is doing what. While one-to-many communication achieves this goal with great efficiency, there is a trade-off with individual relevance. This kind of forum by nature does not allow participants to readily identify creative intersections between each others' interests. Thus, it is difficult for presenters and audience members to assess each other's potential as collaborators.

On the other hand, because conferences offer plenty of opportunities for casual socializing in an unstructured setting, potential collaborators might still find each other. However, unstructured networking activates a variety of goals (such as status seeking, self-presentation, and socialization) that may compete with the goal of identifying viable creative collaborators. Conversation with strangers tends to be brief, polite, and surface-level, and social norms do not encourage deep, critical discussions about ideas. It is common to leave a conference with a pocket full of business cards but little sense of who might realistically be a solid future collaborator. Even more troubling is the recent finding that in unstructured social gatherings, people are likely to talk only to people they already know or people from their own status groups (Ingram & Morris, 2007; Borovoy et al., 1998). Finally, conferences are time consuming and resource intensive. While this investment can achieve many aims, it is not the most cost-effective way to form interdisciplinary collaborations.

Institutes are often formed for the express purpose of enabling interdisciplinary collaboration. They offer the opportunity for sustained interaction and often collocation. Sharing a group identity and purpose helps alleviate hesitations about discussing the possibility of collaborative work. However, institutes are not a magic bullet for maximizing potential interdisciplinary research. It is easy to sit at a desk next to someone from another field and yet never get into deep, focused conversation about how each other's different research interests and skills may complement each other. You may get to know your neighbor's general research areas, attend the same seminars, and eat lunch together, but there is still no structured method for identifying if collaborative opportunities exist.

Beyond these physical barriers, there are also social barriers that exist. First, there are social pressures based on entrenched feelings of (not always convivial) rivalry between disciplines, stemming from the traditions of single-discipline science. For instance, when scientists are educated, they usually adopt the norms and opinions of their superiors in order to show that they belong. Given that academic disciplines often become specialized due to fundamental disagreements originating in some common ancestor, part of these norms often include a distrust of other disciplines. As a shared norm of a discipline's culture, this can lead researchers to dismiss ideas from other disciplines, or to consider as "impure" researchers who seek to cross-disciplinary boundaries.

Additionally, the very process of specialization creates paradigmatic divisions that make it difficult for experts in different disciplines to speak the same language, if they want to speak at all. These disciplinary differences in terminology, methodological preferences, and theoretical assumptions can lead to cross talk and missed opportunities. One wonders how many vitriolic disagreements in the published literature could have been averted by a frank, personal conversation between two authors in which differences in assumptions and definitions were carefully discussed.

3.3. What is Needed: A Structured Social Situation Designed to Initiate Creative Collaborations

In practice, discovering opportunities for interdisciplinary research requires several steps to be completed successfully: Ideally, researchers from divergent areas should come to a place where they can meet each other face to face. But meeting face to face is not enough. Each must share their own ideas/interests/research questions, and come to understand one another well enough to be able to identify potential areas of overlap in their research interests. This must be done in a way that minimizes the social and communication difficulties of spanning disciplinary boundaries. Participants also need to get to know each other well enough to be able to gauge the potential value of collaborating together. The potential payoff of participating in the event needs to be worth the investment of time, which can be done by providing an efficient way to interact and understand how their work could complement each others'. One does not need to come away from the first meeting with a detailed plan for life-long co-authorship, but one does need to have some confidence in his or her own assessments of potential collaborators in order to be considered successful.

At present, most interdisciplinary venues do not fully address the challenges described above and so fall short of providing an optimal environment for creating new ideas. Without *improved* means of finding interdisciplinary research partners and generating interdisciplinary ideas, the interdisciplinary research movement runs the risk of becoming a trendy ideal rather than an institutional sea change.

4. BRAINSTORMING AND OTHER TRADITIONAL APPROACHES TO CREATIVITY

Aside from simply placing scientists from different disciplines in a room and hoping for the best, the simplest way to encourage the development of new ideas is to use *brainstorming*. Developed in 1953 by advertising executive Alex Osborn, brainstorming spread quickly throughout organizations and institutions of all kinds. Osborn's (1953) book *Applied Imagination* introduced the rules of group brainstorming, which were promised to turn groups into creative idea generating machines. According to these rules, groups will be most creative when criticism is forbidden, freewheeling is encouraged, the goal is to produce more (but not necessarily better) ideas, and there is an explicit goal to combine and improve upon the ideas of others (Osborn, 1953, p. 156). The assumptions behind this practice is that by removing the fear of being evaluated, stimulating one another with novel ideas (e.g., ideas that are new because they are not one's own), and removing traditional prohibitions against appropriating others' intellectual work, everybody will be able to generate more ideas, some of which will be truly creative.

Although this practice was adopted widely and with fervor (Grossman, 1984; Grossman et al., 1989; Sutton & Hargadon, 1996; Jablin, 1981; Prince, 1970; Rawlinson, 1981), empirical research on its results has been surprisingly negative. Empirical work shows that while individuals in brainstorming groups tend to *feel* more creative than individuals working alone (Paulus et al., 1995), their output is actually less creative than it would be if they were working alone. "Nominal groups"—sets of individuals generating ideas independently—have been repeatedly shown to out-perform real groups both in terms of the raw number of ideas generated (Diehl & Stroebe, 1987) and the originality of those ideas. These results are not limited to the laboratory: these rules have been adopted by high-profile design firms such as IDEO, but an in-depth case study revealed that while it does serve other purposes such as being a forum for securing social status, brainstorming is not the idea-producing panacea it is assumed to be (Sutton & Hargadon, 1996). For these reasons, some have referred to brainstorming as "the illusion of group effectivity" (e.g., Paulus et al., 1993).

For the last 20–30 years, a large body of research has been aimed at identifying the reasons for the productivity loss incurred by brainstorming groups. The main classes of explanation are *evaluation apprehension* (fearing that one's ideas will be judged negatively by others), *production blocking* (wherein procedural concerns of allocating time and task participation amongst members interferes with individuals' generation and expression of ideas), and *social loafing* (self-interested free-riding) (Diehl & Stroebe, 1987; Mullen et al., 1991). Of these, production blocking has received the most support (Mullen et al., 1991). Turn-taking between individuals in the group prevents both the sharing of new ideas as they arise (Diehl & Stroebe, 1987, 1991) and interferes with the cognitive processes involved in generating ideas (Nijstad & Stroebe, 2006). It has been posited that these phenomena may be exacerbated by group size, such that in a larger group, fewer people participate and fewer creative ideas they will generate (Bouchard & Hare, 1970), although mixed results demand further investigation (see Nemeth & Goncalo, 2005, for a review).

Some problems with brainstorming are likely to be exacerbated by the unique character of interdisciplinary groups. First, conversation in brainstorming groups tends to be unfocused and too broad to go into substantive depth. Instead, for ideas to appeal to many people with different areas of expertise, they must appeal to a (shallow) lowest common denominator. When discussions *do* go deep, the diverse expertise among group members means that more time will be spent on topics irrelevant to any given person. The longer any one participant must struggle to understand something outside of his or her interests or comprehension, the more disengaged that person will become from the process and the less likely that person will be to re-engage when the topic of conversation moves on.

The social and communication differences among disciplines will also be exacerbated by the group structure of brainstorming. For instance, while there is little direct social pressure to appear loyal to one's discipline when engaged in one-on-one conversations, the presence of other members of one's discipline during brainstorming might serve to embolden a person's belief in the correctness of his or her discipline's approach, and the faults of the others. Also, when communication difficulties arise due to differences in definitions or assumptions, it is harder to clarify those differences when (a) others in the group share the same misapprehension and (b) norms of conversation make it difficult and embarrassing to interrupt for clarification. In short, an "us" versus "them" dynamic is more salient and more powerful in a group setting.

This is not to say that brainstorming is without value, especially when done in established teams where participants work together often. In addition to generating ideas, brainstorming achieves multiple other goals, such as enabling participants to project an air of wisdom and to compete for status on the basis of technical expertise (Sutton & Hargadon, 1996). However, brainstorming is likely of little value when searching out new collaboration opportunities. The research briefly outlined above suggests that in most groups, brainstorming is unlikely to be productive (resulting in few original collaborative ideas), diagnostic (revealing little about interpersonal compatibility), or personally motivating (the process can be irrelevant to individual participants much of the time).

5. A SOLUTION: SPEED-STORMING

We are excited to share a promising new alternative to these conventional collaboration means: *speed-storming*. This concept was developed as a means to promote new, creative collaborations within the NSF Center of Integrated Nanomechanical Systems at UC Berkeley. Speedstorming builds on the rapidly growing phenomenon of speed-dating as a means for singles to find potential dating partners. Traditional speed-dating works by lining up equal numbers of (typically) men and women and gives them several minutes to meet each other in pairs before moving on to the next person. This process is repeated until all of the men have met all of the women (and vice versa). Analogously, speedstorming iteratively pairs those from different disciplines (rather than genders) in hopes of helping participants efficiently find those with whom they share research interests (rather than romantic interests). Researchers are given a short time for a focused conversation about themselves and their research before working on a shared goal of an interdisciplinary research proposal title. Speedstorming improves upon brainstorming and unstructured interactions via three primary features: *structure*, *time limit*, and *one-to-one interactions*.

5.1. Structure

Speedstorming is a structured social interaction. Structure is provided in a goal and purpose for the interaction: finding potential collaborators. This shared goal has substantial advantages over, for example, a conference interaction, where researchers may have widely different purposes for being there. The conversation stays focused and relevant to both parties.

In contrast to the often shallow exchanges possible at conferences or in brainstorming, enforced structure regarding the information to share, the mixing of people with different expertise, and the depth into which each participant can go in a one-on-one interaction results in the ability to "go deep" into their research areas in a short space of time. That the explicit purpose of the event was to generate ideas with potential future collaborators relieves participants from social obligations of small talk. Instead, they can use their limited time to dive into a candid and focused discussion immediately.

Additionally, speedstorming makes sure that each participant from one group talks to each participant from the other group. Compared to unstructured conversation, this means that each person will have the maximal opportunity to interact with people from other disciplines. It also means that the set of ideas each person will be exposed to will, on average, be larger. This is because while mingling might lead to being trapped in a conversation for too long, and brainstorming might result in one topic being over-explored while others remain in one person's mind, speedstorming ensures that each person will hear as many different ideas as there are pairings in the session. Even if no collaboration opportunity is identified, each participant will have been exposed to more "food for thought" to take home.

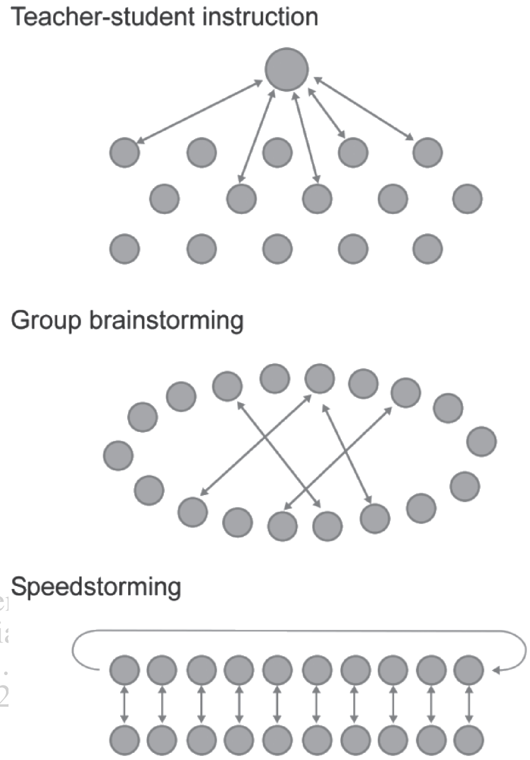

Fig. 1. Structural differences between three types of social interaction.

Figure 1 illustrates how different forms of social interaction—classroom, group brainstorming, and speedstorming—differ in structure and interactivity. Each structure lends itself to different types of social interactions, which lead to different cognitive and interpersonal processes and different outcomes.

Speedstorming greatly benefits from a strictly enforced short time limit. Interactions of five minutes or so minimize the risk of engaging with another researcher—if your research interests or personalities are not a good match, then the interaction will be kept to a minimum and time freed to spend searching for other collaborators.

Like a shared goal, a short time limit also helps focus the conversation—a five minute conversation leaves little time for pleasantries, encouraging both participants to "get to the point," both in evaluating the other as a person and in sharing one's own research.

Short interactions also leverage our abilities to assess a situation. When we sense danger, read a stranger, or react to a new idea, we tap our "adaptive unconscious" to instantly evaluate a complex situation. Gladwell (2005) refers to this as "thin-slicing." Research on speed-dating has shown, for example, that women typically make up their mind as to whether their current partner is a good fit within the first 30 seconds (men, it seems, take a little longer, about two minutes) (Wiseman, 2005). Much of what makes speed-storming effective is that collaboration compatibility can be assessed as powerfully in the first several minutes of an encounter as it can over a much longer period of time. With speed-storming, one can more efficiently "cut to the chase."

5.2. One-to-One Encounters

Speedstorming is designed to create one-to-one encounters. This dyadic interaction helps create what Goffman (1963) calls *focused interaction*, wherein all attention is held between the two participants. As each participant is always either talking or listening, the content of the interaction stays more relevant to them than it would be in a group setting, keeping them fully engaged at all times.

Compared to larger group encounters, one-to-one interactions also have several other advantages. Whereas large group brainstorming can easily become "status auctions" (Sutton & Hargadon, 1996), the lack of observers in one-to-one encounters helps to reduce the influence of status as a factor. In the same way, speedstorming reduces evaluation apprehension, thereby encouraging participants to be more open and to share more speculative, but also potentially more rewarding, ideas.

One-to-one encounters also help minimize production blocking, the key factor in productivity loss in brainstorming groups. On average each participant will be able to speak 50% of the time as compared to only 10% in a 10-person brainstorming group. With more time to speak the potential flow of ideas in a room can be significantly greater.

One-to-one encounters also have the additional benefit of eliminating the "lowest common denominator" effect, wherein a person is required to speak to the person with the least understanding in a group. Instead, conversation is quickly tailored to the level of understanding and interest of the other participant, allowing discussion and questions to go deeper into complex research.

Finally, one-on-one encounters are less likely to suffer from the unique challenges of interdisciplinary research. First, one-to-one exposure to members of another discipline helps to personalize them, helping to remove any prejudices that might have been held about the out-group (or at least allowing the out-group members you met to be a "special case" of "good" members of that discipline). Second, with no audience there is diminished pressure to defend one's discipline or denigrate the other. Third, when there are confusions due to terms or assumptions, it is possible to gain clarification privately and immediately, rather than waiting for a break in the conversation.

In short, speedstorming provides many benefits over conventional ways of identifying collaboration opportunities, providing an environment that stimulates creativity without being too chaotic. The structured social interaction helps address the lack of depth in brainstorming and conferences, minimizing distractions and dilution from attending to many goals simultaneously. The short time limit and one-to-one encounters ensure that the conversation stays relevant to each participant, maintaining engagement and yielding greater potential payoff in terms of quality and creativity of interdisciplinary ideas and finding suitable research collaborators.

5.3. Early Results from Speedstorming Research

To date we have conducted five pilot speedstorming workshops in multiple settings: with members of established interdisciplinary research groups, at a conference social event, and as part of an organized event to encourage collaboration among biologists and engineers. The events ranged from 12 to 35 participants and from one to two hours long. In all but the conference event, some information was known about the background of each participant and we manipulated the interactions to ensure that individuals with different backgrounds had the opportunity to meet each other.

At each event we required each pairing to produce a concrete output of their short interaction in the form of a joint research proposal title. To facilitate this process each station was supplied with pens and a short stack of blank forms with prompts such as: "Write your creative interdisciplinary research proposal idea." In one session we also asked for possible applications of the idea (which it turned out, proved too difficult and distracting for the short interaction). While many submitted proposal titles were the result of a simple melding of each others' research areas, preliminary analyses by domain experts have shown a high number of exciting and creative topics.

Responses to the speedstorming sessions were positive with participants enthusiastic to take part in a similar event in the future. In general participants found the sessions "fun" and "good for getting to know potential collaborators" and reported feeling confident, creative, and interested throughout most of the sessions. As facilitators it was a telling observation to watch the interactions before the events where participants mingled almost exclusively with people they previously knew, compared with the energy level observed during the sessions.

Responses from participants to the sessions have been positive and encouraging. Reactions have included: "Fun and amazing to hear about various projects and look for intersections;" "Low cost method of meeting as many potential collaborators as possible;" "Even within the lab we rarely discuss research with others (because everyone is busy);" "Great to be forced to talk about research;" "You get to make many connections in a short period of time;" "*Great* way to find out about new research and learn about people around you;" and, "It's a good, quick way to get a taste of multiple research perspectives."

Several unintended benefits also arose during the sessions, primarily around the different perspective that is gained on one's own research as you practice explaining it to different people: "It helps you think of your own project in completely new perspectives by explaining to people of other disciplines—really extends boundaries of imagination;" "My elevator pitch got better, but also varied since I ended up adjusting and tailoring it to the audience depending on their background;" and "I noticed that I was getting better at describing my own project to others, and that the description itself took on a wider and more interdisciplinary feel."

Even though participants were given time and encouraged to continue discussion at the end of the event, there were mixed feelings on the enforced short interactions with some participants feeling the "time pressure helped" as "it keeps you focused" and others who felt it was "too fast."

Anecdotal evidence aside, a quantitative comparison of speedstorming and brainstorming (Joyce et al., 2007) revealed that even though speedstorming was slightly more stressful than brainstorming, people were able to generate more ideas that contained more specialized knowledge than in brainstorming. Furthermore, they tended to form more decisive opinions about each other as potential collaborators.

6. APPLICATIONS OF SPEEDSTORMING IN EDUCATION AND BEYOND

Speedstorming has great potential in K–12 educational settings. It is now known that creativity is a skill and a mindset that can be taught (Scott et al., 2004). With this in mind, teachers may wish to include idea-generation exercises in their curricula. While brainstorming can be done individually, brainstorming with a group helps stimulate new ideas and expose students to different ways of understanding the same problem. For this reason, collaborating with peer groups is already a common component of creativity training.

As reviewed above, group brainstorming also has its drawbacks. Especially in a school-age setting, the success or failure of a brainstorming group can easily hinge upon one person's behavior or even their perceived behavior. A very talkative participant can dominate the conversation, thus blocking contributions from the rest. Shy students are less likely to share ideas in front of a group audience, especially given the sensitivity to social dynamics that school-age children commonly experience. The threat of embarrassment or judgment can steal the focus of the group, and social pressures to associate only with higher-status peers can make creative collaboration a challenge.

Speedstorming finds a happy medium. It combines the social stimulation of group brainstorming with the safety and focused engagement of individual idea generation. Furthermore, removing the audience of one's peers diminishes the social stakes of one-to-one interaction. With the social justification of "the teacher made us do it," talking with ones' peer, regardless of status, on substantive topics is more easily stomached.

Speedstorming can also be used to reinforce material presented in the classroom. Unlike the one-way, one-to-many communication of the teacher–classroom setting, in speedstorming both participants must be active participants. Both partners are fully engaged for the entire time they are participating, while still benefiting from the thought-stimulating variety brought by rotating partners. Much like *Peer Instruction* wherein short lectures are alternated with peer-to-peer discussions and quiz reviews to significantly increase understanding (Crouch & Mazur, 2001), speedstorming is an active process of reviewing and building from material with peers.

Speedstorming however, is not simply about peer interaction. The specific design of the interactions sets limits on the range of conversation topics available, so that participants must search more deeply and thoroughly for ideas that will appeal to both partners. Such "creativity within constraints" has long been thought to support problem solving and design (Moreau & Dahl, 2005; Stokes, 2006; Stokes & Fisher, 2005) but has only recently been given psychological consideration (Joyce, 2007).

While counterintuitive when considering existing theories on freedom and creativity (Amabile, 1979, 1983), constraints could make a creative task more motivating by narrowing the "search space," thus allowing greater focus on the range of options available (see Chua & Iyengar, in press). This can increase the attention given to novel ideas, which are often otherwise dismissed because of their riskiness and unfamiliarity. Teaching students to make the most out of the material available to them, in this case the ideas of one other person, can help them to be more ingenious and nimble problem solvers when future challenges arise.

Speedstorming is also a practice in crafting and presenting audience-focused messages, a key to effective communication. Knowing how to quickly assess a specific target's interests and then tailor one's ideas to appeal to those interests is critical for success in nearly all fields. Yet academic programs usually can only offer opportunities for one-to-many presentations. Speedstorming, on the other hand, is ideal for honing this skill, providing multiple successive chances to practice communicating their ideas and get immediate feedback on one's ability to do so.

Outside of the classroom, we envision many potential successful venues for speedstorming, including the following: at conferences; between business and academia; facilitating inter- and intradepartmental collaboration; assisting new graduate students and at faculty mixers; within committees and task forces; composing improved brainstorming groups; for students to share ideas in classes; and as a means to get on the same page with existing collaborators.

7. LIMITATIONS AND FUTURE RESEARCH

In this paper we have argued that speedstorming may be more effective at reaching the specific goal of initiating creative collaboration than other types of social interactions, including group brainstorming and conferences. Our overarching message is that, given all that is known from social science research, social interactions can and should be consciously structured to suit the instrumental goals of the situation. One type of social interaction does not do the same things as another, and traditional means can indeed be improved upon and changed when such innovations are possible.

Thus it is important to remember that, depending on one's goals, speedstorming has certain features that may make it less useful than conferences, group brainstorming sessions, or even individual work. For example, speedstorming requires more active coordination and explanation of the process than the loosely structured group brainstorm. To address this, we have developed an easy to use software tool which automates much of the design of a speedstorming session and also keeps time depending on a variety of configurations and supporting materials to make it easy to run and simple to understand as a first-time participant. Still, even though the event itself is more efficient for participants, it can take more time on the front end to plan and prepare than brainstorms.

So how does one pick which method of social interaction to use for which goal? One must consider whether

Table I. Selecting the best type of social interaction by considering structural features.

Interaction (social unit)	Communication direction	Relevance to individual participants	Best for...
Speedstorming–round-robin diads (2*x*)	Two-way, one-to-one	Each participant drives more of the conversation, greater specialization of knowledge and depth of understanding possible.	Idea generation and collaboration initiation amongst specialists of different areas of expertise. Best choice when: —all participants do not yet know if they share common goals and interests —time is limited —there is resistance to sharing ideas in a group setting —ideas are specialized and require personal explanation.
Group brainstorming small groups (6–10)	Two-way unstructured	Moderate conversation driven by group dynamics, stays at level of group understanding.	Idea development and consensus building focused on specific issue shared by all group members. Best choice when: —there is already some consensus about solving a certain problem —group members' work is interdependent and will build on outcome of brainstorming session.
Classrooms medium to large group audience (15–350)	One-way, one-to-many	Low to high depending on match of students' learning needs and interests to content.	Disseminating information to relative novices in one subject area. Best choice when —teachers are experts in subject matter and have knowledge to share —active participation not needed to engage students.
Conferences very large, multiple distinct subgroups (virtually unlimited)	One way, one-to-many and two-way unstructured	Moderately high degree of choice about which events to attend, but little control over material once there.	Disseminating information to a variety of specialists within one broader subject area, socializing novices in a field, and establishing a forum for reputation-building. Best choice when: —there is much new information to share in a short amount of time with a distinct segment of people who self-identify with the field —participants know the domain well enough to select the best events for their own interests —stakes are low (see below).
Unstructured networking diads to very large groups (face to face conversation limited to small groups)	Two-way unstructured	Low- to high-moderate degree of choice about which people to talk with, but information about the likely content of conversation is usually superficial.	Renewing and reinforcing existing relationships between people. Best choice when: —stakes are low: low risks associated with strangers not interacting with each other in a meaningful way —no concerns about social skills, status, and similarity determining who talks to whom.

the cognitive processes are best achieved alone or with others, in focused interaction in diads or in larger groups, and whether communication should be mostly one way or two way. Table I compares the features and ideal situations for using four types of social interactions: speedstorming, group brainstorming, classrooms, conferences, and unstructured networking.

While speedstorming is already an effective technique, it remains at an early stage and we have many more questions to answer for it to reach its full potential. Our research program is currently investigating the following questions:

• Is speedstorming more effective using a specific problem-focused prompt or through a more freeform session? What is the optimum engagement time between participants and the optimum number of encounters? What techniques are most effective to balance the mix of participant experience and background?
• What are the longer term effects of speedstorming sessions? Do collaborators who meet in speedstorming stay together longer? What is the success rate of speedstorming for connecting researchers?

Other questions, that we hope other researchers will begin to address include whether speedstorming acts as a more stable stimulant to creativity. In other words, is the creative atmosphere of speedstorming long-lasting, resulting in creative research ideas after speedstorming sessions?

Also, it is worth asking what the optimum incentives for effective speedstorming sessions are. Does speedstorming require competitive incentives and protections (secrecy, legality, informal norms of authorship) to be dismantled to a certain degree? Are there conflicts over ownership of ideas? Can cultural norms be used to counteract the secrecy effect of incentives typical of academia?

8. SUMMARY

In this paper we discussed the problem of enhancing interdisciplinary collaboration in the nanoscience field. In particular, we noted how traditional methods such as conferences and brainstorming groups suffer from important disadvantages for encouraging interdisciplinary collaboration. As a potential solution we presented a new method called speedstorming that builds off the growing phenomenon of speed-dating. Speedstorming provides structure, a time limit and one-on-one encounters that together help create an atmosphere where ideas can be discussed and generated in depth and potential collaborators can be quickly assessed. Initial responses to five speedstorming sessions have been highly positive. As we continue to develop the technique we see exciting applications across education, business, and academia for stimulating interdisciplinary collaboration.

APPENDIX: HOW TO RUN YOUR OWN SPEEDSTORMING SESSION

Things to Consider

• *Goals*: What are the goals of this session? Coming up with ideas? Answers to specific questions? Helping collaborators find each other? Explicitly emphasizing the reason for participating before the group begins speedstorming helps ensure everyone is focused and feels free to pursue those goals (without concern about breaking social norms).
• *Participants' Prior Experience Together*: There are pros and cons to speedstorming with people that already know each other. If participants have never met, give them a few minutes to exchange names and chat casually before speedstorming—getting people comfortable and familiar with each other's faces, even just for a few minutes at the beginning of the event, will allow speedstormers to spend their minutes speedstorming productively generating ideas together.
• *Incentive Alignment for Collaboration*: Speedstorming is probably unable to overcome significant structural barriers to collaboration, such as if reward structures do not consider collaborative work or if funding is unavailable to follow up with projects. In cases where collaboration opportunities are possible afterwards, speedstorming is a good fit.
• *Disciplinary and Status Mix*: An event to encourage interdisciplinary collaboration with a room full of physicists is unlikely to payoff. Consider the mix of participants you have at the event and arrange for different disciplines and functions to meet each other during the session.

Materials

(For sample materials, templates, and a web-based timer tool, please contact the authors.)

• a timer
• a bell to signal time above the talking of participants
• a firm attitude to keep people moving—participants will want more time for every encounter!
• proposal sheets for each encounter (half a sheet of letter-size paper works well; include boxes for names, ideas, and any other information, such as how the idea could be applied)
• plenty of pencils and erasers
• scratch paper

Length

Length should ultimately be determined by the purpose of the event, which should always be made explicit from the beginning of the event. It is likely that no matter how many minutes are given per round, participants will want more time.

We have found that ideal sessions run between 15 and 30 participants, depending on the mix of disciplines. This allows enough five minute pairings to stimulate and interest without wearing people out. Four-minute pairings can be effective if participants already know each other. For example, pairing 30 people, 15 each from engineering and biology, as we have done, means 15 research dates in the other field ($15 \times (5$ min $+ 1$ min for changeover$) = 1$ h 30 min).

If the purpose of your event is to form new collaborative relationships, the length should be long enough for each pair to identify whether they have an idea that they could pursue together in the future and to get a basic sense of whether or not they would want to talk to each other again. It will not be enough time to create a thorough proposal.

If, on the other hand, the purpose of the event is to finish with more fully developed idea proposals, offer more time per round with fewer rounds per event. Keep the total time between 45 min and an hour and a half—beyond that, fatigue can hurt participant motivation, satisfaction, and the quality of the interactions and ideas.

The Process

(1) Set up seats in pairs at least a few feet apart enough for all your participants—it can be helpful to number the stations. Provide enough proposal sheets to cover all pairings at each station with a few left over.
(2) Introduce the exercise and explain the procedure. Always make the purpose of your event explicit. We find it useful to stress the importance of moving on at the final bell—one slow pair affects the changeover of everyone.
(3) Announce the start of each encounter with the bell. Provide a one or two minute warning and a final bell when it is time to change over.
(4) Have one set of participants stay still and the other half move around to their next encounter.
(5) Repeat.

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