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Creativity in scientific teams: Unpacking novelty and impact☆

You-Na Lee[a], John P. Walsh[b,*], Jian Wang[c]

[a] Georgia Institute of Technology, USA
[b] Georgia Institute of Technology, USA, National Graduate Institute for Policy Studies (GRIPS), Japan
[c] University of Leuven, Belgium, Institute for Research Information and Quality Assurance (iFQ), Germany

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ABSTRACT

The increasing dominance of team science highlights the importance of understanding the effects of team composition on the creativity of research results. In this paper, we analyze the effect of team size, and field and task variety on creativity. Furthermore, we unpack two facets of creativity in science: novelty and impact. We find that increasing team size has an inverted-U shaped relation with novelty. We also find that the size–novelty relationship is largely due to the relation between size and team field or task variety, consistent with the information processing perspective. On the other hand, team size has a continually increasing relation with the likelihood of a high-impact paper. Furthermore, variety does not have a direct effect on impact, net of novelty. This study develops our understanding of team science and highlights the need for a governance approach to scientific work. We also advance the creativity literature by providing an ex ante objective bibliometric measure that distinguishes novelty from impact, and illustrate the distinct team-level drivers of each. We conclude with a discussion of the policy implications of our findings.

1. Introduction

While traditionally science is seen as an individual endeavor, increasingly scientific projects are group activities (Hicks and Katz, 1996; Katz and Martin, 1997; Shrum et al., 2007), and the groups are growing larger (Adams et al., 2005; Wuchty et al., 2007). While high-energy experimental physics is the extreme example, even in other fields we can find research labs with dozens of members and research papers with 10 or more authors. For example, Wuchty et al. (2007) showed the rise in the number of authors per paper over the last 40 years, with mean group size in science and engineering nearly doubling over this period. Similarly, Adams et al. (2005) found an increase in co-authored papers, in the number of authors per paper, in papers spanning institutions, and in international collaborations. This increase in collaboration is driven by a variety of factors, including the importance of interdisciplinary research questions, growing specialization and the consequent gains from trade and division of labor, the diffusion of the Internet, and the need to develop and access large shared equipment and large databases (de Solla Price, 1986; Katz and Martin, 1997; Stephan, 2012). Jones (2009) argued that the burden of knowledge accumulation pushes scientists to specialize, increasing the need to work in teams that incorporate a variety of specialists to collectively solve a problem that spans narrow specializations.

The result of these changes is that increasingly scientific work takes place in a setting that more closely resembles a small factory, rather than an individual's lab bench (Etzkowitz, 1983; Hemlin et al., 2013; Latour and Woolgar, 1979; Shrum et al., 2007; Swatez, 1966). While scientific work has long taken place inside formal organizations such as universities, government labs and industrial R&D labs (Pelz and Andrews, 1976), the change we are focusing on here is the growth of the project team, which is taking on organization-like characteristics. This transformation of scientific

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* Corresponding author at: School of Public Policy, Georgia Institute of Technology, 685 Cherry St, Atlanta, GA 30332, USA. Tel.: +1 404 385 0400.
E-mail address: jpwalsh@gatech.edu (J.P. Walsh).

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work suggests a need to bring organization and organizational behavior theories to the study of science (Antonelli et al., 2011; Barley and Bechky, 1994; Carayol and Matt, 2004; Cummings et al., 2013; Fiore, 2008; Shrum et al., 2007).

Organizing science into research teams implies a variety of changes in the structure of the work and the work group that might affect creativity. In particular, increasing size may be associated with increasing diversity (Fiore, 2008; Harrison and Klein, 2007). Diversity can be conceptualized along a variety of dimensions, including demographic characteristics, background, and specializations (Fiore, 2008; Harrison and Klein, 2007; Page, 2007; Pieterse et al., 2013; Taylor and Greve, 2006; Williams and O'Reilly III, 1998). Furthermore, the concept of "diverse" has a variety of meanings, including separation in attitudes or viewpoints; variety of positions, categories or backgrounds; and disparity in values on some resource or asset (Harrison and Klein, 2007). In this paper, we focus on the variety of scientific fields (interdisciplinarity) and the variety of tasks in the research team (division of labor). By "variety", we mean the number of different categories represented in the team and the distribution of team members across those categories. We argue that larger teams are associated with greater field and task variety, and that teams containing greater variety in fields or tasks should have access to broader knowledge and therefore should produce more creative outputs (Hong and Page, 2004; Page, 2007; Pieterse et al., 2013; Taylor and Greve, 2006). However, larger and more varied groups may suffer from declining marginal benefits as well as a variety of process losses that decrease creativity (Andrews, 1976; Hollingsworth, 2004; Kiesler, 1969; Nooteboom, 2008). These offsetting effects of growing team size suggest that the overall impact of larger teams on creativity is not clear. Furthermore, it suggests the possibility for managerial or policy interventions that would encourage the development of some aspects of scientific teams while attempting to limit the presence of less desirable characteristics (Falk-Krzesinski et al., 2010; Fiore, 2008; Stokols et al., 2008).

Thus, the growth of team science leads to calls for application of organization and management theories of creativity to scientific work (Cummings et al., 2013; Fiore, 2008; Hackett, 1990; Vogel et al., 2013), in order to answer a key research question: how does the increasingly organized nature of scientific work affect the creativity of the research results? Since a key goal of investment in science is to produce creative outcomes, it is critical to study how the organization of scientific teams affects creativity. Much prior work on creativity has focused on individual characteristics, but in an era of team science, it is critical to study the drivers of team creativity (Harvey, 2014). In addition, we distinguish novelty from impact, which have often been conflated as proxies for creativity in the existing literature. The process of generating novel outcome and the process of those outcomes generating impact may be driven by different mechanisms, and we will analyze these processes separately in order to distinguish these components of creativity.

This paper is organized as follows. First, we discuss the two components of scientific creativity: novelty and impact. Second, we develop our theories of how novelty and impact are affected differently by team size and variety. To test these effects of team size and variety on creativity, we make use of a large-scale survey of scientific projects that collected data on team size and field and task variety. We combine these data with a new bibliometric measure of novelty based on the rarity of the reference combinations cited in the focal paper (Uzzi et al., 2013). Finally, we show how team characteristics affect novelty and how these, in turn, affect scientific impact (becoming a top-cited paper). We find that increasing team size has an inverted-U shaped relation with novelty. We also find that the size–novelty relationship is due to the relation between size and variety. On the other hand, team size has a continually increasing relation with the likelihood of a high-impact paper. In addition, while variety has a significant impact on novelty, it does not have a direct effect on impact, net of novelty. We discuss the implications of these findings in the conclusion.

2. Creativity in science

Following the definition of creativity proposed by Amabile (1983), we emphasize two aspects of a creation: its novelty and its usefulness. Correspondingly, we can discuss research teams as producing research outputs that are novel and/or useful. Psychologists have proposed diverse definitions of creativity in terms of the creative process, creative person, and creative product, but here we focus on the product definition, with novelty and appropriateness/value as the criteria for defining creative products (Amabile, 1983; Ford, 1996; Woodman et al., 1993). As Amabile (1982) pointed out, a major obstacle to creativity studies is translating the conceptual definition of creativity into an operational one in order to allow empirical assessment of creativity. Prior work has suggested a variety of indicators to categorize the creativity of artistic or scientific output: Nobel laureates as an indicator of eminent scientist (Zuckerman, 1967), prestigious prizes to identify pathbreaking discoveries in biomedical research (Hollingsworth, 2004), surveying experts to nominate highly creative accomplishments (Heinze et al., 2009), financial success and critics' reviews for Broadway musicals (Guimera et al., 2005; Uzzi and Spiro, 2005), resale value of comic books (Taylor and Greve, 2006), citation counts for patents (Fleming, 2001; Fleming et al., 2007; Singh and Fleming, 2010), journal impact factor for collaboration teams (Guimera et al., 2005), and publications and citations to measure creativity of scientists (Simonton, 1999, 2004). These methods share the characteristic that creativity is assessed by experts, consumers, users, or peers, which leans towards an ex post measure of impact.

However, it is important to find indicators that allow us to unpack the concepts of novelty and impact, in order to better understand the drivers of creativity. Although the large-scale evaluation of relative creativity is generally based on the impact of those outcomes, much of the theory of creativity is built on trying to understand what leads to novel outcomes. For example, one stream of research views creativity as an evolutionary search process across a combinatorial space and sees creativity as the novel recombination of elements (Franzoni, 2010; Nelson and Winter, 1982; Schumpeter, 1939; Simonton, 2003). For example, Fleming (2001) argued that patents that combine patent subclasses that have not been combined before can be thought of as creative combinations. Similarly, Uzzi et al. (2013) argued that scientific papers that draw on unusual combinations of journals in their references can be thought of as representing relatively more novel knowledge. This work focuses the measure of creativity on the novelty of the research output.

However, at the same time, there is also substantial work focusing on the impact of the research. From Merton's perspective, citation serves as an elementary building block of the science reward system, and therefore can be viewed as a good proxy for scientific creativity. For a paper, acceptance for publication indicates an acknowledgment of its original contributions to science from peers in the field, but being cited further indicates the peer-recognition of its value and its impact on the scientific community (De Bellis, 2009; Merton, 1973; Simonton, 2004). Prior studies showed that the majority of Nobel laureates were amongst the top 0.1% most-cited authors (Garfield, 1973), and the number of citations was more significant than the number of publications in predicting receipt of awards, appointment to prestigious academic departments, and being widely known in the scientific community (Cole and Cole, 1967).