# GROUP HETEROGENEITY INFLUENCES COMPLEX AND NOVEL OUTCOMES

by

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# Group heterogeneity influences complex and novel outcomes

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**Abstract**

Research on diversity impacting group performance, especially creativity, has yielded varied, inconsistent outcomes. One initial issue that researchers face is identifying and measuring diversity within groups. Further, groups researchers have suggested that diversity is important when it is task-relevant; however, there is limited research on electronic groups working together over time to solve a creative problem. Additionally, the current body of research fails to address how specifically manipulated diversity impacts group performance over time. The current study aimed to address this gap in the literature by examining individuals assigned to heterogeneous or homogeneous groups. Participants were randomly assigned to these conditions based on variety (cognitive diversity or diversity in knowledge) and examined over the course of three sessions in which the groups worked together (asynchronously) to generate creative solutions to the task of creating the ideal university of the future. Planned analyses revealed no significant differences between groups. Additional exploratory analyses designed to examine possible differences based on cognitive diversity revealed significant differences between groups for cognitive processes content included in the final product. Theoretical conclusions, practical applications, and future directions for researchers are discussed.

Group Heterogeneity Influences Complex and Novel Outcomes

Many groups researchers have focused on how group dynamics and group composition influence various outcomes. However, investigating groups, especially groups over time, has proven a challenging endeavor. Securing real-world groups is an obvious difficulty; apart from this, retaining groups in the laboratory for an extended period of time also proves challenging. Participant attrition remains a factor in maintaining groups over time. In the current design, participants were recruited based on functional diversity characteristics and examined in an electronic, asynchronous environment. The purpose of this study was to examine the influence of group heterogeneity (a functional diversity characteristic) on group processes and performance outcomes. The design of this study is novel and addresses a gap in the literature aimed at better understanding how diversity, through group heterogeneity, influences group outcomes, especially group creativity and integrative complexity.

**Creativity and Brainstorming**

Creativity is defined as the development of ideas that are simultaneously novel and useful (Amabile, 1983). Researchers have spent years studying creativity at the individual level (e.g., Simonton, 2014). Within the past three decades, researchers have investigated the social dynamics and group processes that influence creativity at the group level (e.g., Amabile, 1983; Brown & Paulus, 2002; Paulus & Brown, 2007). Researchers have proposed a variety of theoretical models related to creativity (Amabile, 1996; Mumford, Mobley, Uhlman, Reiter-Palmon, & Doares, 1991; Osborn, 1953; Treffinger & Isaksen, 1992), but there are typically four processes that are agreed upon: problem identification, information gathering, idea generation, and idea evaluation. At the group level, researchers have focused on collaborative idea generation through brainstorming followed by coding ideas for quantity and novelty (Kohn,

Paulus, & Choi, 2011). Quantity, or the number of ideas generated, is an important metric as researchers have shown that it is related to novelty (Diehl & Stroebe, 1987; Mullen, Johnson, & Salas, 1991; Paulus, Kohn, & Arditti, 2011). Typically, novelty is coded by trained human raters using a Likert-type scale. After reading the corpus of ideas, the human raters are trained to recognize ideas that occur less often as relatively more novel. Many researchers have focused on how group dynamics impact the rate and quality of idea generation, and the subsequent novelty of ideas.

Diehl and Stroebe (1987) showed how the performance of groups can be hindered by various constraints such as production blocking and evaluation apprehension. In an effort to overcome some of these constraints, some researchers have turned to methods such as brainwriting or electronic brainstorming (Dennis & Valacich, 1993; Dennis & Williams, 2003; De Rosa, Smith, & Hantula, 2007). Brainwriting - generating ideas in a group by writing them down and passing them around - has been shown to increase the quantity of ideas generated (Brown & Paulus, 2002). Electronic brainstorming refers to using an electronic means, such as a chat forum, to generate ideas as a group. Barauh and Paulus (2016) found that electronic brainstorming groups generated more novel ideas and had less productivity loss than did e-nominal groups.

These advances notwithstanding, measuring the creativity of groups working together over time proves challenging. Many researchers choose to explore other design options due to the nature of group work. Some of the many challenges include reliably coding the ideas and products generated by the groups, and measuring the group structural features and interaction dynamics that may correlate with those. The current research design, which experimentally manipulated group heterogeneity and examined electronic groups over time, is a novel design for

group creativity research. Utilizing this design, groups generated literally thousands of ideas and over one hundred final products. As discussed below, the data were coded by human raters over the course of several months for group interaction dynamics, individual ideas, and features of the final product with the aim of examining the impact of the experimental group condition (heterogeneous vs. homogeneous) on various outcomes.

**Group Heterogeneity**

Research on the importance of group composition and group diversity has increased, especially as organizations have seen an increase in diverse work groups (Moreland, 2013). Although there have been multiple reviews which cover how diversity affects group outcomes, the measurement of diversity varies greatly and the outcomes are inconsistent (Salazar, Feitosa, & Salas, 2017; van Dijk, van Engen, & van Knippenberg, 2012; van Knippenberg & Schippers, 2007). One way to examine the diversity of a group is through group heterogeneity or the extent to which a group varies along a certain trait or dimension. Harrison and Klein (2007) have identified three types of diversity that represent differences along a value dimension (separation), in types of knowledge (variety), and in status or resource allocation (disparity). As group heterogeneity can be determined or measured using a number of personal dimensions such as age, race, expertise, or political orientation, it is important for researchers to clearly articulate and operationalize the type of diversity being examined through group heterogeneity.

Nijstad and De Dreu (2002) argued that homogeneous groups were unlikely to bring unique knowledge to a task. They found decreased performance of homogeneous groups compared to nominal groups. Heterogeneous groups generated more non-overlapping ideas, leading to increased divergent thinking. Additionally, researchers have shown that group heterogeneity of demographic diversity enhanced creativity (Paulus & van der Zee, 2015). In a

study examining age heterogeneity of social networks, Lev-Ari and Shao (2017) found that higher heterogeneity was related to better performance. Specifically, age heterogeneity positively predicted lexical production and prediction such that individuals who reported greater network age heterogeneity showed quicker lexical choice reactions (creating names for pictures) and lexical predictions (predicting how others might name the pictures). Researchers have posited that a crucial variable is the extent to which the diversity variable is relevant to the creative task (Coursey, Paulus, Williams, & Kenworthy, 2017). That is, when group heterogeneity is relevant to the creative task, it should positively influence the outcomes (i.e., increased idea generation, increased novelty).

In examining group heterogeneity, researchers may choose to use surface-level diversity (visible differences such as age, gender, or race) or deep-level diversity (non-visible differences such as political identification or religion). Previous researchers have examined deep-level characteristics through group heterogeneity of cognitive diversity; that is, researchers measured group members' perceived difference in knowledge and skills, beliefs, thinking styles, and world view (van der Vegt & Janssen, 2003). Within these heterogeneous groups, task interdependence positively predicted innovative behavior.

**Cognitive Diversity**

As a starting point for cognitive diversity research, Mohammed and Ringseis (2001) measured the extent to which individuals believed their group members were engaging in cognitive processes: inquiring about others' reasons, incorporating perspectives, accepting others' views. Mohammed and Ringseis found that engaging in these processes was positively related to shared assumptions and argued that exchanging information and engaging in cognitively diverse discourse influences outcomes. Although this research did not provide a

direct measure of cognitive diversity, it provided impetus for continued research on the diversity of shared knowledge and exchange of information in groups. Cognitive diversity, as measured using van der Vegt and Janssen's (2003) scale, has been shown to be associated with team performance. For example, Liao and Long (2016) found that cognitive diversity had a significant and positive effect on team performance. Team performance was measured subjectively by individuals rating aspects of performance such as quantity and quality of work accomplished. These results were consistent with previous research by Kilduff, Angelmar, and Mehra (2002) who also found cognitive diversity to predict team performance. Interestingly, Kilduff et al. found that the degree of ambiguity, a measured component of cognitive diversity, had the strongest (and negative) impact on team performance. This measures the extent to which group members remained ambiguous throughout their task; higher levels of ambiguity negatively predicted team performance. Additionally, Liao and Long found that alertness mediated the relationship between cognitive diversity and team performance. Alertness was comprised of three dimensions: information accumulation, information transformation, and information selection. Each of these dimensions were found to be significant, positive mediators of the relationship between cognitive diversity and team performance.

One way to measure cognitive diversity (as replicated in the current study), is through examining the expertise diversity of the group members through educational background. Martins, Schilpzand, Kirkman, Ivanaj, and Ivanaj (2012) investigated the effects of both expertise diversity (college major) and expertness diversity (cumulative grade point average) of students assigned to groups in a class project with a team performance outcome measured by assigned project grade. They found a complicated relationship between the different forms of cognitive diversity and team performance. At low levels of psychological safety (feeling of

safety in interpersonal risk taking), the relationship between expertise diversity and team performance (grade assigned to project) was positive but the relationship between expertness diversity and team performance was negative. When psychological safety was low, expertise diversity or college major was related to higher grades on the project while expertness diversity or the cumulative grade point average was related to lower grades on the project. As Martins et al. discussed, it is interesting to find support in favor of lower psychological safety; however, they explained that the type of diversity measured (expertness) was a disparity diversity measure which has different implications as compared to a variety type of diversity. The researchers argued that since disparity diversity assumes unequal capabilities among group members, this differs from previous findings where equal capabilities among members were assumed. This was not the only study revealing the complex nature of cognitive diversity. In an experimental setting Sauer, Felsing, Franke, and Ruttiner (2007) found that cognitive diversity, measured as system understanding, was beneficial for performance; however, cognitive diversity as measured by specialization had no effect on outcomes. Additionally, there was no effect of either type of cognitive diversity on team conflict (teams had low-levels of conflict overall). One important factor is that the participants did not enter the study as cognitively diverse in regards to the task (operating a computer-based spacecraft system); instead, the researchers provided specialized training to provide differences in both system understanding and system specialization and placed them in groups of two following the training. Regardless, the studies discussed above shed light on the possibility that cognitive diversity can, in some instances, impact group outcomes. Measuring a more specific group outcome, creativity, should reveal that cognitive diversity will impact creative outcomes in some manner.

**Creative outcomes in groups.** In fact, additional researchers examining cognitive diversity have found links to creative performance. In a study that examined self-report measures of creativity, Mitchell, Nicholas, and Boyle (2002) found that openness to cognitive diversity significantly predicted the subjective performance ratings. This relationship was mediated by self-reported decision comprehensiveness (the extent to which the group discussed and weighed decisions). This study was interesting that the researchers did not directly measure either cognitive diversity nor creativity; instead, these findings shed light on the perceptions of team members, showing that there is an important relationship between being open to cognitively diverse teams, perceiving an adequate discussion prior to decisions making, and believing that the outcomes were creative.

Shin, Kim, Lee, and Bian (2012) found that high levels of creative self-efficacy moderated the relationship between team cognitive diversity and individual creativity. The relationship between team cognitive diversity and individual creativity was only positive when individual creative self-efficacy was high. At low levels of creative self-efficacy the relationship was not significant. A similar pattern emerged for transformational leadership such that the relationship between team cognitive diversity and individual creativity was, again, positive only at high levels of transformational leadership, and the relationship became insignificant at low levels of transformational leadership. Further, Wang, Kim, and Lee (2016) found an interesting relationship between team cognitive diversity and team-level creativity. Specifically, they found that transformational leadership moderated the relationship between cognitive diversity and team creativity through team intrinsic motivation. A similar pattern emerged in that there was a positive relationship between cognitive diversity and team creativity at high levels of

transformational leadership; additionally, Wang et al. found that the relationship was negative at low levels of transformational leadership.

Kurtzberg (2005) found a complex relationship between cognitive diversity and creative outcomes. Across two studies, she found that cognitive diversity was related to an objective measure of creativity but discovered a more interesting relationship with subjective ratings and affective measures. The objective measure of creative performance, fluency or idea generation, was positively related to team cognitive diversity; however, the subjective ratings of performance revealed that teams with greater diversity had decreased positive affect and self-rated creativity. This study revealed an interesting pattern of the benefits and challenges that may emerge when studying cognitive diversity and creativity.

**Challenges.** Although some of the research presented above focused on the positive results regarding cognitive diversity, some have stated that functionally diverse teams must first overcome differences which can initially hinder performance (Cronin & Weingart, 2007). Specifically, diverse teams working together, especially those with high cognitive diversity, might not be "speaking the same language" which will lead to decreased production initially. As Cronin and Weingart (2007) discussed, previous researchers have identified many factors that might lead to decreased performance of groups with expertise diversity (such as information sharing issues or feelings of safety in the group), but the researchers argue that the mixed findings of cognitive diversity affecting group performance are likely due to representational gaps (inconsistent problem definition among team members). That is, although the team members are highly advanced in their own specialties, the information does not transfer appropriately, leading to the decreased likelihood that another member of the team will understand and integrate any information shared. As highlighted by this research, creative

problem solving is not as simple as putting a group of experts from various fields together. Understandably, a psychologist and an engineer, when beginning a project together, might not use the same language or define problems in a similar manner leading to, at least initially, representational gaps which may hinder performance.

One issue regarding group diversity is that current research practices encourage, even require in some instances, that researchers conduct interdisciplinary research, especially in the social sciences, to stay on the cutting edge. However, this practice is not without cost. As Leahey, Beckman, and Stanko (2017) discussed, conducting interdisciplinary research is a relatively high-risk endeavor. One reason is that, when spanning disciplines, the production of work may suffer; that is, the work generated may be of lower quality and harder to produce in some ways. Leahy et al. determined that interdisciplinary work is typically more challenging for researchers to produce since they must attempt to understand and interpret information from outside of their field of study. Additionally, it might not be received well by the audience since the interdisciplinary nature makes it a challenge to categorize.

Leahey et al. (2017) reported that just as it is challenging to produce this work, finding an audience that is interested in taking the time to understand the cross-over of field work might prove taxing. However, if the work is accepted by the intended audience, then, based on the work of Leahey et al., researchers who engage in interdisciplinary research tend to have improved visibility in the scientific community but with a cost of decreased production. That is, the increased visibility may not outweigh the production penalty in terms of publication count. Over time, researchers focused on interdisciplinary work tend to have fewer publications; however, these papers received increased citations. Furthermore, the increased time to publication was found not to be a product of review but instead directly related to the challenges associated with

working in interdisciplinary teams such as communication issues and coordinating work efforts. The authors noted that this varies across disciplines, and certain fields, such as life sciences, are more receptive to interdisciplinary research, leading to the likelihood of increased benefits when engaging in interdisciplinary research compared to fields such as electrical engineering. The issues of interdisciplinary teamwork are not simple and there is much to consider with respect to

**Moving forward.** Interdisciplinary teams might be formed with the intention of generating creative or innovative products. This type of benefit was not addressed by Leahy et al. (2017) when discussing risk-reward analysis of interdisciplinary research. However, as researchers have found, heterogeneous groups might have an advantage in generating a greater number of unique ideas (divergent thinking), but homogeneous groups might be more successful during the convergent phases of creativity (such as selecting a final product (Nijstad & De Dreu, 2002; Stroebe, Nijstad, & Rietzschel, 2010; Thomas, 1999). Paletz, Pavisic, Miron-Spektor, and Lin (2014) discussed the need for researchers to understand the variables that may mediate or moderate the relationship between diverse teams and creative outcomes. Since that time there have been some published studies presenting mediator and moderator relationships (discussed above), but the research is still limited. Although Paletz et al. did not find a set rule for when and how to facilitate creativity within teams, important factors for researchers and teams to be aware of were identified, including how creativity is being measured, the team processes at play, and the relevance of the team diversity to the task. Reiter-Palmon and Leone (2017) reiterated these important aspects of attempting to have successful team creativity, stating that teams can outperform individuals under certain conditions but these factors (social processes or socioemotional factors) must be recognized by researchers/team members. Reiter-Palmon and Leone further argued that teams are unable to take advantage of their diversity if ideas are either

not shared or are misunderstood (i.e., representational gaps) which may lead to conflict. They concluded that at present the inconsistent and limited research on diverse teams, beyond that of idea generation, makes drawing conclusions somewhat challenging.

Further, researchers who have examined the literature for how cognitive diversity influences team-level outcomes have reported that when examining cognitive diversity, some areas need more research before drawing conclusions (Mello & Rentsch, 2015). Specifically, in a literature review examining various types of cognitive diversity, Mello and Rentsch reported mixed findings. For example, studies examining trait-like cognitive diversity, which includes stable cognitive variables such as cognitive ability, style, or personality, which are reportedly stable over time, have shown inconsistent results. Developmental cognitive diversity includes variables such as personal values and worldviews. Most research on developmental cognitive diversity has focused on values and value diversity. Mello and Rentsch found that this typically leads to increased conflict. Acquired cognitive diversity refers to variables that tend to be more context-specific and can be influenced by individual or outside forces; these include knowledge, skills, attitudes, and perceptions. The authors provided job satisfaction as an example of acquired cognitive diversity which could easily change based on a new position or organization. The research on acquired cognitive diversity has yielded mixed results. In some cases, acquired cognitive diversity inhibited affective processes while in others it resulted in facilitated affective processes. Lastly, exposed cognitive diversity refers to the easiest manipulated or least stable form of cognitive diversity. In an experimental setting, this might consist of introducing a participant to a training prior to beginning a task. The research on exposed cognitive diversity has shown that under certain some behavioral changes were noted, such as communication; however, the results are still mixed (as an example see above work by Sauer et al., 2007). As an

example, teams that were trained to have diverse knowledge about a system outperformed teams with homogenous knowledge of the system, but this only occurred when complexity of the task was high.

Mello and Rentsch (2015) pointed out that the literature is rampant with various measurements of cognitive diversity, which makes comparing findings challenging. However, researchers have drawn some conclusions based on meta-analytic findings. Specifically, in their meta-analysis, van Dijk, et al. (2012) found that job-related diversity was positively related to innovation. Hülsheger, Salgado, and Anderson (2009) also found that, across 10 studies, job-relevant diversity was positively related to team innovation in the workplace. Hülsheger et al. further examined a non-relevant diversity measure, background diversity, and found that it was not related to team innovation. This differs from van Dijk et al. who reported a positive relationship between demographic diversity and innovation.

Again, group heterogeneity, when relevant to the task, is expected to increase performance including group member exchange, as assessed through a variety of measures, including social network analysis, which will be discussed in more detail below. Currently, there is relatively little research on experimentally manipulated functionally diverse teams. Although researchers have examined correlational designs, the current project is one of very few to experimentally test the effects of functional diversity. Through recruiting students by specific areas of study, groups possessed diversity according to their members' respective university majors. Following Harrison and Klein (2007), the similarities or differences between the participants were based on their area of study or knowledge, which is referred to as variety. This variety diversity characteristic was relevant to the task of creating the ideal university of the future. Although this task has been used by researchers previously, assigning participants to

groups that were heterogeneous (different majors) or homogeneous (similar majors) allowed for the diversity of college major to be relevant to the task and represents a novel extension of previous studies on this same task. In this study, group heterogeneity was expected to influence the group member exchange process in a variety of ways.

**Group Member Exchange**

Traditional research on the group member exchange process tends to focus on the communication and information exchange between members of a group. In a brainwriting scenario, Paulus and Yang (2000) found that groups that exchanged information/ideas showed enhanced creativity. In an electronic environment, one way to capture this exchange is through counting the number of exchange points. That is, counting the number of ideas generated by each group member as well as the elaborations or replies made to those original ideas. Additionally, depending on the task or instructions, researchers might be interested in participants voting for ideas that are good or feasible. As discussed above, these ideas might be coded not only for quantity but also for a variety of researcher-interested variables such as novelty, categories, or quality. However, in some instances, examining the group member exchange beyond these variables can be helpful when attempting to answer different questions about the group interaction.

Researchers have taken strides to improve the measurement of group member exchange processes, such as communicating with certain group members or citing self-generated ideas. One means of examining these relationships is through social network analysis. Researchers have used social network analysis to examine networks that exist in social structures and have measured the individual performance (referred to as nodes or actors) as well as the relationships and connections between all of the individuals (referred to as edges, links, ties, or other terms),

and how these relate to outcomes such as creativity (McKay, Grygiel, & Karwowski, 2017). As McKay et al. (2017) discussed, social network analysis allows researchers the freedom to first determine how to measure nodes (as individuals, groups, countries, etc.) and ties (relationships based on a researcher's determined variable such as friendship or communication) as well as to examine the variables as either predictors or outcome variables. Keeping this in mind, researchers must identify which factors are used to determine these variables. That is, researchers theoretically determine which factor is assessed, although the language (nodes, ties, etc.) remains the same.

One manner of measuring the group member exchange process in social network analysis is through network density. This refers to how densely the nodes are tied or how many connections are being made among those that are able to be made. Network density is calculated by taking the proportion of actual ties that are made out of the possible ties available (Faust, 2006). Densely tied networks are those that are participating in a reciprocal group member exchange which allows for information to be shared; theoretically, these groups are more cohesive. According to Zhou, Shin, Brass, Choi, and Zhang (2009), this type of network may facilitate creativity since the possibility of diverse idea exchange is high. However, the research on network density impacting creative outcomes is limited. Jiang, Zhang, and Zhou (2016) found that groups with high creativity began with lower density as the groups formed but which increased in density over time. The final result was that highly creative groups had highly dense networks at the end of their project phase. A dense network is related to group members engaging in the presented ideas through reading, elaborating on, and potentially incorporating them in creating a final product at the conclusion of the study. However, even with exposure to

diverse ideas, not every group member will be able to integrate and elaborate on them successfully.

**Integrative Complexity**

Individuals exposed to a variety of diverse ideas have the opportunity to evaluate and incorporate ideas as they see fit. Integrative complexity refers to an individual fairly acknowledging competing perspectives and integrating or merging the perspectives together (Suedfeld, Tetlock, & Streufert, 1992). When measured, integrative complexity captures the complex nature of human thought. Higher scores of integrative complexity reflect an increased ability to incorporate both dialectical and elaborative complexity. Conway et al. (2008) defined dialectical complexity as the ability of an individual to recognize competing perspectives on a topic. More simply, this could be recognizing that there are both good and bad aspects to a topic. Additionally, Conway et al. identified elaborative complexity as an individual expanding on a singular topic in a complex way. That is, an individual focuses on differentiated ideas that are similar in valence such as expanding on multiple negative perspectives of an idea. There has been very little research on integrative complexity in group performance/group dynamics research. However, the previous research that has been conducted has shown that integrative complexity was important for a variety of outcomes including an increase in effective information seeking and better team performance (Streufert & Nogami, 1989). Other research has shown that an increase in culture diversity (biculturalism) leads to increased levels of integrative complexity (Tadmor, Galinsky, & Maddux, 2012). Following this line of research, heterogeneous group environments are expected to lead to increased integrative complexity, compared to homogeneous group environments.

**The Current Project**

The current project aimed to understand how group heterogeneity impacted the novelty and complexity of group creativity outcomes. As discussed above, research to date has not explored experimentally manipulated group heterogeneity based on the functional or variety diversity of individual group members. This study, based on a larger National Science Foundation (NSF) grant-funded project, has been conducted to further understand creativity in groups. As a member of the team, I was instrumental in designing the current study, including creating the task, managing data collection, and managing the coding process. All variables discussed below have been reliably coded over the course of this project.

Again, the current study is unique in that participants were randomly assigned to asynchronous groups that were either heterogeneous or homogeneous and were examined over several sessions. Theoretically, this design is intended to mimic teams that interact electronically across time and space such as a global team communicating via e-mail about projects (e.g., Ocker, Hiltz, Turoff, & Fjermestad, 1995). As very little is known about these groups, this study adds applied value by informing organizational practices for diverse groups.

## Hypotheses

**Hypothesis one.** Group heterogeneity will influence the group member exchange process. As discussed above, previous research has shown that heterogeneous groups outperformed homogeneous groups in idea generation (Nijstad & De Dreu, 2002). Additionally, Paulus (2000) discussed the potential benefits of heterogeneous groups, including increased idea generation. Further, although the research is not robust, the interesting findings discussed above by Martins et al. (2012) regarding expertise diversity (measured by college major), require further exploration.

***Hypothesis 1a.*** Heterogeneous groups will generate a greater number of ideas, elaborations, and votes, compared to homogeneous groups.

***Hypothesis 1b.*** Heterogeneous groups will have a greater number of ideas, elaborations, and votes per session (examined at session 1, session 2, and session 3), compared to homogeneous groups.

**Hypothesis two.** Group fluency will positively predict network density. Group fluency, the mean number of words generated in a word association task, is discussed in more detail below. As group members generate a greater number of ideas, the potential for connections increases. As group members respond to and connect with others, their network becomes more dense. Although there are no direct studies which examine the link between individual fluency and network density, this hypothesis will help to further understand a factor that may be associated with greater network density.

**Hypothesis three.** Group heterogeneity will influence the content of the final product. Research on group heterogeneity impacting various types of semantic content is fairly limited. Lev-Ari and Shao (2017) presented a case in which networks with increased heterogeneity had improved performance on lexical tasks. As heterogeneous groups provide diverse content to the discussion, the group members have additional information to incorporate that will likely differ semantically from their homogeneous counterparts.

***Hypothesis 3***. Heterogeneous groups will have a greater amount of affect words, positive emotion words, and negative emotion words used in the final products, compared to homogeneous groups.

**Hypothesis Four.** Network density will mediate the relationship between group condition and final product outcomes. Again, heterogeneous groups have the advantage of

potentially introducing novel and diverse content to their group members (Nijstad & De Dreu, 2002). Similar to the group member exchange process discussed in hypothesis one, a dense social network is reflective of group members making connections. Theoretically, increased connections of group members should lead to increased exposure of diverse ideas (in the heterogeneous condition). As cognitive diversity research (discussed above) has shown that increased cognitive diversity can lead to increased creativity, the theory follows that a cognitively diverse and dense network should lead to improved outcomes in novelty and complexity of final products.

***Hypothesis 4a.*** The relationship between condition (heterogeneous/homogeneous) and final product integrative complexity will be mediated by network density.

***Hypothesis 4b.*** The relationship between condition (heterogeneous/homogeneous) and final product novelty will be mediated by network density.

## Methods

### Participants

Participants were 163 undergraduate and graduate students (102 females and 61 males) who received $40 in gift cards in exchange for full participation, and received gift cards in decreasing amounts based on lesser participation levels. The mean age of participants was 24.25 (SD = 5.95). Ethnic composition of participants was 44.8% Asian, 20.2% Caucasian, 11% African-American, 16% Hispanic or Latino, 7.3% American Indian or Alaska Native, Native Hawaiian or Other Pacific Islander, or Other/Multiracial, and 0.6% declined to answer.

### Procedures

Participants were recruited via IRB- and university-approved flyers and e-mails describing the opportunity to receive up to $40 in gift cards in exchange for research

participation taking place in the laboratory and online. Upon contacting the researchers, participants received a response that the study would be conducted in the lab for session one and online for sessions two and three over the course of three weeks (see Appendix A for e-mail response).

**Session One.** Participants entered the lab for session one, consented to the study, and were randomly assigned to be in homogeneous or heterogeneous groups of four based on majors by college (e.g., college of science, college of engineering). Participants completed a word association task (referred to as Fluency hereafter) by generating as many related responses to a word stimulus as possible. Participants were presented with 10 words (e.g., science, engineering, business, etc.) for 60 seconds each. Following this, participants completed a survey then, using an online discussion board, individually generated ideas to create the ideal university of the future for 20 minutes (See Appendix B for instructions). The discussion board was a closed simple machines forum website which enabled group members to post ideas and reply to each other without outside members having access to the discussion board. Participants were thanked for their time and instructed to await an e-mail prior to beginning session two.

**Session Two.** In session two, the individual ideas of participants were merged into a single discussion board and participants received notification to begin session two. Participants were instructed to first read all of the ideas and vote on good ideas. Next, participants were instructed to post original ideas as well as build/elaborate on ideas throughout the second session (see Appendix C for full instructions). Participants were instructed that they had one week to complete session two and were able to enter the discussion board as often as they liked during that time. Participants received reminder emails to complete the session prior to the onset of session three.

**Session Three.** In session three, participants were instructed to vote on good ideas from the new ideas generated during session two as well as build/elaborate on group members ideas (see Appendix D for full instructions). Again, participants had one week to complete session three.

**Study Conclusion.** Following session three, each participant completed a broad overview of the ideal university of the future (referred to as the final product) based on the content from the discussion board. Once this overview was returned to researchers via email, the participant completed a final survey and received their gift card.

**Participant Attrition and Archival Study Information**

As discussed above, 163 participants consented to the study. Following the first session (in which all 163 individuals participated), participants had eight requirements (voting, elaborating on ides, completing survey, etc.) throughout the study which gave way to attrition. Participants had the opportunity to continue with the study even if a previous requirement had lapsed. That is, if a participant missed elaborating in Session 2, the participant still had the opportunity to continue in Session 3 if the group had not yet completed the study. Due to this, attrition is less straightforward than is typical for research. Overall, the study began with 163 participants and ended with 104 participants completing the final survey. However, as participants were able to return to the study, this final number does not accurately represent the number of participants at each phase of the study. Additionally, participant data collection was restricted to the long semesters due to the challenges of securing groups during the semester breaks. Data collection began in the fall of 2014 and ended in the spring of 2016. In the fall of 2015, interest in the study seemed to slow. In order to increase participation, the inclusion criteria were changed to allow all students at the university, regardless of year, the opportunity to

participate. Initially, only students at the graduate or senior level were eligible, but this change helped to increase recruitment and interest in the study. Although there were nearly 60 participants that declined to continue participation, there were no significant difference in participant loss based on condition assignment. A group was considered successful if at least two members completed the entirety of the study. Analysis were conducted for both the number of participants remaining in the group as well as successful group completion, and no significant differences between condition were found (see Figure 1).

Additionally, it should be noted that this study was presented as archival in nature. Although no data analysis had been performed prior to this paper, the data were collected in previous years and coded as discussed below. As with any archival study, this process did not allow for changes to the study design, only to the coding and/or analysis of data.

**Materials**

Participants used a non-public, researcher-operated discussion board via simple machines forum (http://utanetworks.net/smf/) to generate ideas. The participants were provided with user names reflective of their college and major (e.g., Science: Psychology, Liberal Arts: History) which were, nevertheless, anonymous. Participants only interacted electronically and did not meet with their group in person. Although session one was conducted asynchronously, participants did not have access to other members' ideas until the asynchronous session two occurred.

Prior to each session, participants were provided with rules for brainstorming by Osborn (1957) to not criticize any ideas, that wild ideas are desired, to generate as many ideas as possible, stay on task and build on or combine ideas. These rules were presented prior to the

participants receiving the prompt for the brainstorming task and remained available for viewing throughout the brainstorming task (Appendix D).

## Experimental Variable

**Group Heterogeneity.** Participants were randomly assigned to one of two experimental conditions: heterogeneous groups or homogeneous groups. Heterogeneous groups consisted of individuals that were all from different colleges (e.g., college of science, college of engineering) while homogeneous groups consisted of individuals from the same college. There were a total of 19 heterogenous groups and 22 homogeneous groups that began the study and 14 heterogeneous groups and 17 homogeneous groups that completed the study entirely.

## Dependent Variables

**Group Fluency.** Group fluency was determined by calculating the mean number of words generated for each group during the associative brainstorming task described above. Participants were presented with instructions to generate as many related responses to a word stimulus as possible. Participants were presented with 10 stimulus words for 60 seconds each. The mean for group fluency was 9.64 (*SD* = 2.54).

**Number of ideas.** Discussion board posts were counted as original ideas after removing duplicates and non-ideas from the sample. Each idea was examined and split into discrete ideas as necessary by trained coders who came to an agreement on every idea. The mean number of ideas per participant was 17.13 (*SD* = 10.49, range 1 to 55) with a total of 2,792 non-redundant ideas generated across all three sessions. At the group level, the mean number of ideas was 17.17 (*SD* = 5.41). The number of ideas was also calculated per session for sessions one (*M* = 11.05, *SD* = 3.02), two (*M* = 2.56, *SD* = 2.57), and three (*M* = 4.96, *SD* = 3.58).

**Number of elaborations.** The number of elaborations was determined by the count of the number of ideas to original posts that each participant generated on the discussion board, removing any identically repeating ideas. This count excluded the non-ideas (e.g., "great idea", "this could work"). Two coders completed the counting until they came to complete agreement on the number. When a discrepancy occurred, the coders would meet with one another to discuss and determine the accurate number of replies generated. If the coders were unable to come to an agreement, a graduate student trainer met with the coders to discuss the discrepancy until a final decision was made. The mean number of elaborations per participant was 1.63 (*SD* = 2.92, range 0 to 24). At the group level, the mean number of elaborations was 4.62 (*SD* = 3.46). The number of elaborations was also calculated per session for sessions two (*M* = 1.69, *SD* = 1.45), and three (*M* = 4.09, *SD* = 3.22).

**Number of votes.** The number of votes was counted for each group. Number of votes was determined by the number of times an individual voted on an idea, including voting on their own idea. A vote was entered by replying to an idea and typing “#goodidea”. The mean number of votes per participant was 10.28 (*SD* = 8.61, range 0 to 64). At the group level, the mean number of votes was 10.34 (*SD* = 4.71). The number of votes was also calculated per session for sessions two (*M* = 5.99, *SD* = 2.62), and three (*M* = 5.66, *SD* = 3.66).

**Network Statistics.** Network density was measured by calculating the proportion of the number of actual connections made to the number of possible connections available in the network. This was an unweighted, directed network calculated using the replies of the group members. This was calculated at the group level and the mean was .46 (*SD* = .24).

**Linguistic Inquiry Word Count (LIWC).** Each final product was analyzed using the LIWC program (Pennebaker, Booth, Boyd, & Francis, 2015). This program analyzes text by

counting the percentage of words that reflect a specific category. Each group member's final product was cleaned to the specifications of the program. To calculate the LIWC content for each group, all members' final products were placed into a single file for each group then entered into the program. The specific content of interest were words involving affect and cognition. Specifically, affect (*M* = 4.85, *SD* = 1.26), positive emotion (*M* = 4.23, *SD* = 1.24), negative emotion (*M* = .54, *SD* = .36), cognitive process (*M* = 12.65, *SD* = 1.75), insight (*M* = 2.19, *SD* = .78), and differentiation (*M* = 2.55, *SD* = .84) were calculated using the LIWC program. Each of these variables represent a semantic dictionary that includes words with related content to the title word used. For example, cognitive process includes words such as cause, know, ought.

**Final Product Novelty**. At the end of the study, participants individually completed a final product for the ideal university of the future (see Appendix E). Each final product was collected and coded by two independent coders for number of ideas and novelty. Each coder read all of the final products prior to coding. For number of ideas, coders were required to come to complete agreement. From there, the coders independently rated the novelty of 25% of the ideas within the final product and were reliable ($\alpha$ =.771). Each rater then coded half of the remaining ideas. Novelty was coded on a scale from 1 (not novel) to 5 (highly novel). The mean number of ideas, per participant, in the final products was 10.26 (*SD* = 6.04), ranging from 2 to 31. The mean novelty of the final products was 2.88 (*SD* = 0.80), ranging from 1.33 to 5. When combined at the group level, the mean novelty of the final products was 2.88 (*SD* =.55).

**Final Product Complexity.** Integrative complexity (IC) of the final product was coded using an online, automated program. Each final product was uploaded to an online program (http://www.autoic.org; Conway, Conway, Gornick, & Houck, 2014; Houck, Conway, & Gornick, 2014), which provides an automated-IC score on a scale from 1 to 7, which

incorporates both differentiation and integration. A low score (1) would indicate no differentiation while scores of 2-3 would indicate differentiation without integration. Scores of 4-7 indicate levels of both differentiation and integration. The automated-IC system also produced a score for both dialectical (recognizing and incorporating opposing views) and elaborative (multiple dimensions or complex arguments of similar valence) complexity. These components are factored into the total score for integrative complexity; therefore, they are not used independently for analysis in the current study. To calculate the final product complexity at the group level, the means of the individual scores were calculated for the group level ($M$ = 3.69, $SD$ = .77).

## Results

### Data Screening

All variables were analyzed for normality. Means and standard deviations for all variables as a function of experimental condition are presented in Table 1. Data screening revealed no significant deviation from normality, and no data transformations were deemed necessary.

### Hypothesis One

To examine hypothesis one, that group heterogeneity will influence the group member exchange process, two multivariate analyses of variance (MANOVA) were performed. There was no statistically significant difference in the combined dependent variables of number of ideas, elaborations, or votes based on the condition, Wilks' $\Lambda$ = .971, $F$ (3, 37) = .368, $p$ = .776; partial $\eta^2$ = .029. Subsequently, there were no significant differences for any of the tests of between-subjects effects of condition on number of ideas ($F$ (1, 39) = .235, $p$ = .630; partial $\eta^2$ = .006), elaborations ($F$ (1, 39) = .906, $p$ = .347; partial $\eta^2$ = .023), or votes ($F$ (1, 39) = .286, $p$ =

.596; partial $\eta^2$ = .007). Further, to test if heterogeneous groups produced a greater number of ideas, elaborations, and votes per session, an additional MANOVA was conducted. Similarly, there were no significant differences based on condition (Wilks' $\Lambda$ = .860, $F$ (7, 30) = .700, $p$ = .672; partial $\eta^2$ = .140). There were no significant differences for any of the tests of between-subjects effects of condition on number of ideas at session one ($F$ (1, 36) = .079, $p$ = .781; partial $\eta^2$ = .002), number of ideas at session two ($F$ (1, 36) = .419, $p$ = .522; partial $\eta^2$ = .012), number of ideas at session three ($F$ (1, 36) < .001, $p$ = .999; partial $\eta^2$ < .001), number of elaboration at session two ($F$ (1, 36) = .024, $p$ = .876; partial $\eta^2$ = .001), number of elaborations at session three, ($F$ (1, 36) = .1.461, $p$ = .235; partial $\eta^2$ = .039), number of votes at session two, ($F$ (1, 36) = .110, $p$ = .742; partial $\eta^2$ = .003) or number of votes at session three, ($F$ (1, 36) = .463, $p$ = .501; partial $\eta^2$ = .013).

**Hypothesis Two**

A linear regression was conducted to determine if group fluency predicted network density. The results indicated that fluency was not a significant predictor of network density, $b$ = .021, $SE$ = .014, $t$(39) = 1.43, $p$ = .160.

**Hypothesis Three**

Hypothesis three stated that group heterogeneity will influence the content of the final product. To determine if heterogeneous groups had a greater amount of affect words, positive emotion words, and negative emotion words used in the final products compared to homogeneous groups, a multivariate analysis of variance was conducted. There was no statistically significant difference in the combined dependent variables of affect, positive emotion, and negative emotion based on the condition, Wilks' $\Lambda$ = .939, $F$ (1, 36) = .734, $p$ = .539; partial $\eta^2$ = .061. Subsequently, there were no significant differences for any of the tests of

between-subjects effects of condition on affect ($F$ (1, 36) = .004, $p$ = .947; partial $\eta^2$ < .001), positive emotion ($F$ (1, 36) = .055, $p$ = .816; partial $\eta^2$ = .002), or negative emotion ($F$ (1, 36) = .002, $p$ = .905; partial $\eta^2$ < .001).

**Hypothesis Four**

To test the fourth hypothesis that network density will mediate the relationship between group condition and final product outcomes, two mediational analyses were performed. To examine if the relationship between condition and final product integrative complexity was mediated by network diversity (hypothesis 4a), a mediation analysis using PROCESS (Hayes, 2013; Hayes, 2017) was conducted. There was no significant independent variable (condition) to mediator (network density) effect found, $F$(1, 36) = .023, $p$ = .881, BCa CI [-.143, .166][1] . Next, condition and network density were modeled in relation to final product integrative complexity. Neither predicted integrative complexity, $F$(2, 35) = .066, $p$ = .936, BCa [-.460, .585]. Network density did not significantly predict final product integrative complexity after controlling for condition, $b$ = .148, $SE$ = .563, $t$(35) = .263, $p$ = .794, BCa [-.996, 1.292]. Next, the relationship between condition and final product integrative complexity was examined. There was no significant relationship, $F$(1, 36) = .065, $p$ = .801. The direct effect of condition on final product integrative complexity was not significant, $b$ = .063, $SE$ = .257, $t$(36) = .244, $p$ = .801, $P_m$ = .063, BCa [-.450, .579]. Additionally, there was no significant indirect effect of condition on final product integrative complexity through network density, $b$ = .002, $SE$ = .044, BCa CI [-.055, .126]. Since the confidence interval contained zero, this indicates that there was no significant mediation effect.

[1] Bias corrected and accelerated bootstrap confidence limits were used with a 95% confidence interval for 5,000 samples

To determine if the relationship between condition and final product novelty was mediated by network density (hypothesis 4b), a mediation analysis was conducted. Appropriately mirroring the above results, there was no significant independent variable (condition) to mediator (network density) effect found, $F(1, 36) = .023$, $p = .881$, BCa CI [-.143, .166]. Next, condition and network density were modeled in relation to final product novelty. Condition and network density together did not predict final product novelty, $F(2, 35) = 1.029$, $p = .368$, BCa CI [-.161, .571]. Network density did not significantly predict final product novelty after controlling for condition, $b = .333$, $SE = .395$, $t(35) = .844$, $p = .405$, $P_m = .205$, BCa CI [-.161, .571]. Next, the relationship between condition and final product novelty was not significant, $F(1, 36) = 1.358$, $p = .252$, BCa = [-.155, .573]. Condition did not significantly predict final product novelty, $b = .209$, $SE = .179$, $t(36) = 1.165$, $p = .252$. Additionally, there was no significant indirect effect of condition on final product novelty through network density, $b = .004$, $SE = .038$, BCa CI [-.084, 0.079]. Since the confidence interval contained zero, this indicates that there was no significant mediation effect.

**Exploratory Analyses**

To examine the possible differences in cognitive diversity through semantic content, a MANOVA was conducted. As a proxy for cognitive diversity, the content of the final product was analyzed for semantically different cognitive process words, insight words, and differentiation words. There was a significant effect of the independent variable on the combined dependent variables (cognitive process, insight, and differentiation), Wilks' $\Lambda = .738$, $F(3, 34) = 4.015$, $p = .015$, partial $\eta^2 = .262$. There was a significant difference for the tests of between-subjects effects of condition on differentiation, ($F$ (1, 36) = 10.5, $p = .003$; partial $\eta^2 = .226$) but not on cognitive process ($F$ (1, 36) = .002, $p = .962$; partial $\eta^2 < .001$) or insight ($F$ (1, 36) =

.005, $p = .943$; partial $\eta^2 < .001$). Condition was a significant predictor of differentiation in the final products, and this was a unique variable in the model. Heterogeneous groups ($M = 2.994$, $SD = .649$) had higher differentiated content in their final products as compared to the homogeneous groups ($M = 2.199$, $SD = .824$).

To further understand the impact of group fluency on outcome measures, a linear regression was conducted to determine if group fluency predicted integrative complexity. The results indicated that fluency was a significant, negative predictor of integrative complexity, $b = -.012$, $SE = .004$, $t(36) = -2.60$, $p = .013$. Groups with greater fluency had less integratively complex final products. To clarify, group fluency was a mean score group members generation on a word associations task. Therefore, the fluency referred to here was as baseline measure of the group, and not the ideas exposed to the group members following session one.

In order to examine the differences between high performing and low performing groups, a new variable was created using session two and session three number of ideas. This allows for distinction of groups who remained productive throughout the completion of the session. Groups were split into high productivity (above the mean of 3.63) or low productivity (below the mean of 3.63), resulting in 23 high productivity groups and 18 low productivity groups. The output for the analyses was then split by high and low performance to determine if differences exist. To further examine how cognitive diversity impacts group performance outcomes, an additional variable was created to account for the various differences in major. That is, each group could range in the number of majors included. One group may be fully homogeneous in majors resulting in a score of one, while other groups might be fully heterogeneous in major type resulting in a score of four. Each group received a score ranging from one to four based on the number of majors represented in their group. This variable alone was not directly or indirectly

related to any of the target variables described above (such as number of ideas, final product novelty, or integrative complexity). A one-way between-subjects analysis of variance (ANOVA) was conducted to test the effect of group major heterogeneity on elaborations, split by performance level. There was a significant effect only for the high performing groups, $F(3, 19) = 4.406$, $p = .016$ partial $\eta^2 = .41$. Post hoc comparisons using Bonferonni tests indicated that the groups with only one major (M = 9.83, SD = 5.36) generated significantly more elaborations than groups with four majors (M = 2.83, SD = 2.50; $p = .014$). Groups that had one major also approached a significant difference compared to groups with two majors (M = 2.42, SD = 2.50; $p = .050$).

## Discussion

Research on group member diversity impacting creative and complex outcomes is limited. The above study attempted to further understand the degree to which group member diversity impacts these outcomes. Hypothesis one, that group heterogeneity would influence the group member exchange process, was not supported. I predicted that heterogeneous groups would have increased exchange at all phases/sessions of the study; however, this was not the case. Further, hypothesis two predicted that groups with higher baseline fluency would have a more dense network. Again, this hypothesis was not supported. Hypothesis three was designed to determine if, compared to homogeneous groups, heterogeneous groups would produce products with a greater amount of affective content. This hypothesis was not supported. Lastly, hypothesis four examined the relationship between condition and final product outcome measures (novelty and complexity) as mediated by network density. The hypotheses that network density would mediate these relationships were not supported.

Although initially disheartening, these findings were enlightening. In an effort to further understand these relationships, I examined the semantic content of the final products to investigate any potential cognitive differences in the groups' respective texts. I discovered that heterogeneous groups had higher differentiation content in their final products as compared to the homogeneous groups. Differentiation in the LIWC dictionary includes words such as but, else, rather, or hasn't. LIWC examines the word count of text related to categories, meaning that heterogeneous groups had a higher use of differentiation words as compared to their homogeneous counterparts. Although there were no significant differences in integrative complexity, this finding highlights that heterogeneous groups are engaging in a somewhat different word usage pattern compared to homogeneous.

Further exploratory analyses revealed that group fluency was a negative predictor of integrative complexity. Groups with higher levels of fluency at baseline produced lower levels of integrative complexity in their final products. This finding relates back to the discussion that although group members may have access to potentially diverse information, that does not ensure that they will spend cognitive effort to understand and incorporate that information. It could also indicate that groups with high average fluency may have suffered from an overload of information, resulting in final products that were simpler or narrower in scope.

To further examine how cognitive diversity impacts group performance outcomes, an additional variable was created to account for the differences in major (discussed above). This variable was neither directly nor indirectly related to either primary outcome variable (novelty and integrative complexity), and correlations between the number of majors and target variables (all variables described above) revealed no significant findings. However, once the data was split by performance levels, analyses revealed significant relationship between groups with one major

outperforming (via generating elaborations) groups with two or four majors, but not groups with three majors. One important note here is sample size as it violated an assumption of ANOVA. There were limited groups per number of majors included for one (n = 3), two (n = 3), three (n = 5), or four (n = 12) majors.

**Limitations**

As with any study, the current experiment is not without limitations. One initial concern of the current study is the likelihood that the heterogeneity manipulation was not strong or salient enough to induce the desired effects. Specifically, are college students at all grade levels expected to be cognitively diverse? It might be expected that senior-level or graduate students are cognitively diverse in their respective fields, but at the lower level of undergraduates generally, this is unlikely to be the case, and cognitive diversity may not have been manipulated. Possibly, the variable is one more along the lines of "interest" diversity based on anticipated major (assuming all students retained the same field of study). Unfortunately, no manipulation check was in place to ensure the perceived cognitive diversity of participants, despite their usernames giving a clear indication of their area of study.

Additionally, many researchers have discussed the need for problem identification when groups are heterogeneous. In the event that the manipulation was successful, there might have been a disadvantage to participants who were not instructed to spend time understanding or constructing their own views of the creative problem solving task. Instead, participants were presented with the prompt to "Create the ideal university of the future" then asked to generate ideas. Reiter-Palmon and Leone (2017) discussed the need of heterogeneous groups to clearly define problems especially for groups who might have different representations of the problem at hand.

An additional limitation was participant drop out. Although there were no significant differences between conditions in drop out, the rate was still high. Therefore, although the final group members were influenced by their previous members' contributions (every member completed at least session one idea generation), the lack of continued effort may have discouraged others from participating fully. However, no measure of effort or perceptions of group member effort were collected. Further, although some analyses regarding initial discussion board content (session one data) were conducted with the full number of groups that began the study (k = 41; homogeneous 22 and heterogeneous 19), most analyses had a lower number of groups (k = 31; homogenous 17 and heterogeneous 14). This can lead to power issues, especially with advanced analyses such as mediated regression.

Further, although groups were designed to be heterogeneous and homogeneous, some questions arose regarding the homogeneity of certain groups. Group members were determined to be homogeneous if they were in the same university college as their other group member. Therefore, a group comprised of all students from the College of Engineering were considered homogeneous. However, the students could have had four different majors: electrical engineering, computer science, industrial engineering, or biomedical engineering. The same pattern could, and did, emerge for homogeneous groups within the College of Science (for example, majors included biology, psychology, chemistry, and physics). It is possible that these groups were less homogeneous than intended, as compared to groups that included all nursing majors or all education majors.

Previous research on network density by Zhou, Shin, Brass, Choi, and Zhang (2009) measured the strength of ties as well as the density of the network. This was not completed in the current study. This is relevant as they found that the relationship between strength of ties and

creativity was not linear but curvilinear instead. For the current study, strength of ties was not measured but may serve as a potential predictor variable in future analyses to further understand this relationship.

**Applications**

Practitioners and researchers should consider these findings when planning group work/research. First, practitioners need to be understand that some differences between laboratory groups and work teams differ in a few ways. For example, work teams might have much stronger motivations and incentives to be successful, as compared to laboratory groups, such as bonus or salary increases, promotions, and career success. Additionally, teams in a company often work together for a much longer time period than laboratory groups. This might create additional elements, such as social factors that might influence outcomes in a different way than short-term laboratory groups.

In the current climate, there is a push for interdisciplinary teams with the assumption that this will garner creativity; however, as the results above have shown, the relationship between functional diversity and creativity is far from simple. Practitioners in an applied setting would do well to truly consider multiple features of the task, group, and setting before attempting to solve a problem through selecting diverse work teams. If the goal or task of the team is to solve a creative problem or to be innovative, then a few factors must be considered. How is the diversity relevant to the task? As posited by Coursey et al. (2017), a likely necessity is that the diversity construct is relevant to the work task; otherwise, the diversity of the group might hinder performance, possibly overall, but at least initially (Cronin & Weingart, 2007).

Second, and following the above line of thinking, how has the team been trained to understand the problem at hand? As Reiter-Palmon and Leone (2017) discussed, the ill-defined

and ambiguous nature of creative problem solving requires that team members understand and identify the problem together, to ensure they have a shared mental model concerning the process and the goal. Without this consideration, there are many issues that may arise along the way due to team members holding different cognitive representations of the problem and task. Research on transactive memory systems (e.g., Liang, Moreland, & Argote, 1995) would suggest that if heterogeneous teams train on the problem together, then such a shared mental model is likely to develop.

Throughout the processes involved in problem identification and team interaction, it is important that diverse team members have a mutual understanding in communication. That is, when highly cognitively diverse team members communicate, they likely employ vernacular that is uncommon to everyone on the team, leading to confusion or misunderstanding. Practitioners should take note of this and ensure that the shared environment is such that team members feel comfortable seeking clarification. Additionally, practitioners and researchers should consider that not every problem will require a team (or diverse team) perspective, depending on the nature of the problem at hand. Unfortunately, there are no present guidelines to follow for what type of problem can be optimized by forming diverse teams.

Lastly, practitioners and researchers should consider the potential mediators/moderators that may influence diverse teams. Although the mediator examined above (network density) was not significant, previous research has shown that there are mediators that impact group member outcomes. Transformational leadership, psychological safety, and creative self-efficacy have all been discussed above as mediators or moderators that influence creative outcomes in cognitively diverse groups. The key is in understanding that the relationship between cognitive diversity and

creativity is highly complex and requires advanced, theoretically-based planning when forming teams.

**Future Directions and Conclusions**

The findings from the current study have revealed interesting results that should be investigated further such as understanding what other factors might influence performance outcomes. Future research from the current endeavor will include advanced coding of the data to include individual-level coding of idea novelty. With this, analyses should be conducted to determine if individual-level novelty at various phases of the study influence the creativity of the final product. Additionally, researchers should determine how to code the existing fluency data to gauge the cognitive diversity of group members. Currently, there is no semantic analysis program which can analyze the generated words and determine cognitive differences (e.g., different categories, reading level, etc.) in content. The LIWC program, described above, examines word content but was designed for use with paragraph or page length texts. Therefore, LIWC analysis of these words is not appropriate.

Additionally, existing survey data can be matched with participants at the individual level to examine different types of cognitive diversity such as grade point average or hours completed in degree. This might serve as somewhat of a manipulation check for the design as well as help to further clarify the true heterogeneity of the groups (as discussed above in limitations).

Another variable to be measured is the strength of the network ties. Although there was no significant relationship, in any form, with network density, this may be due to the manner in which it was measured. Previous researchers found curvilinear relationships with the strength of network ties and creative outcomes. Although there was no significant relationship with network

density (linear or otherwise), it might be worth the effort to examine the relationship between the strength of ties in the network and key outcomes.

Further analyses should be conducted using hierarchical linear modeling to understand the phenomenon of group heterogeneity and creative and complex outcomes. It is possible that individual differences in creativity and complexity can be seen as a function of the nested group structure. Further, this type of analysis with the additional coded data for individual novelty might prove useful in predicting the novelty and complexity of individual level outcomes for the final product.

Outside of the current data, researchers should continue to consider how group heterogeneity influences novel and complex group outcomes, especially over time. This study was unique in design in that group heterogeneity was manipulated and electronic group interactions were monitored over the course of several weeks. This is no easy feat; however, further understanding of these processes is necessary to guide researchers and practitioners toward practical advice for heterogenous working teams. Researchers would benefit from manipulating and ensuring measurement of cognitive diversity (whether objectively or subjectively) possibly by including manipulation checks. Finally, with adequately powered statistical models, researchers should concurrently examine surface-level diversity variables (such as age, gender) of group members to continue to gain a better understand of the overall impact of different kinds of diversity on group outcomes.

Regardless of the design, however, practitioners and researchers must be prepared to manage the group processes that potentially enhance creativity through diversity, while simultaneously being aware of the processes that may inhibit the desired outcomes.

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# Appendix A

Thank you for your interest in participating in our research study. This discussion group will take place over three sessions lasting a total of approximately 3 hours. Participants will come into the lab for session one (approximately 30-45 minutes), complete session two (approximately 30 minutes) and three (approximately 2 hours over the course of 3-4 days) from home or another location with internet access. Compensation for this research will be $40 in gift cards, spread out over the course of participation. If you are still interested in taking part in the discussion group, please respond to this email and include your year/level in school and major (as well as specialty if applicable).

Thank you,

UTA Networks Lab

# Appendix B

Session One Instructions:

"The goal of this experiment is to create a plan for the ideal university of the future. Your job is to generate as many ideas as possible towards the development of this topic. You will work first individually and then with members of your group (remind them of this group type: same or different major) to complete this task.

In session 1, you and your group members will work independently. You will submit your ideas using a computer by typing them onto an online message board. The creative task will continue in session 2 as a group project: you will be allowed to view your group members' ideas (and they yours). All your communication with your group members will only be about ideas for your topic. Do not worry about perfect spelling or grammar.

When listing ideas to the brainstorming topic, there are some things we want you to keep in mind:

1. **Criticism is ruled out**. Adverse judgment of ideas (own or others') must be withheld. Say everything you think of. Do not worry about what someone else will think about your idea and do not criticize anyone's idea.
2. **Freewheeling is welcome**. The wilder the idea the better. It is easier to tame down than to think up. Do not be afraid to say anything that comes to mind. The further out the idea the better. This will stimulate more and better ideas.
3. **Quantity is wanted**. The greater the number of ideas the more likelihood of good ideas. Come up with as many as you can.

4. **Stay focused on the task**. Concentrate on the problem at hand and avoid engaging in irrelevant thought processes and discussions.
5. **Build on ideas.** Feel free to build on your own ideas or ideas generated by other group members. It is okay to combine two or more ideas to create a new one.

Any questions?"

"You will now be generating ideas on your topic. Your topic is "Create a plan for the ideal university of the future." Generate as many ideas as you can towards the development of this topic. When considering the ideal university of the future, consider the following: how will it be organized and structured, how will learning and research be conducted, how will it be funded. Keep in mind the components that make up this idea including the academic, economic, administrative, physical, social, cultural, and organizational changes. Use only recognized English words in your posts. Do not use made-up words. Please do not restrict yourself to any one aspect. Again, remember to submit each new, individual idea as a separate post. Any questions?"

Appendix C

Session Two instructions:

Now that you have completed session one, you will need to log on to the discussion board to complete session two.

After entering your password, click on the available link titled: “All Participants: Session 2”. Then click on the next topic that appears titled “Session 2: Ideal University”. Spend approximately 10 minutes reading over all of the ideas in this topic. Take note of the number of pages (located in the top left and bottom left corner before and after all of the posts); this is important because you will have to manually select the next page if there are multiple pages of posts. After spending time reading through the ideas, we would like for you to select the ideas which you think are the good ideas. You will do this by selecting the “quote” button located to the right (and slightly above) the post that you are selecting. By selecting this button you will be directed to the “quick reply box”. You will notice that the post you selected has been auto-filled into the “quick reply box”. Please leave this text there, and on the last line of the “quick reply box” you will type #goodidea. You will repeat this process for every idea that you think are good ideas.

After you have spent approximately 10 minutes doing this, spend about twenty minutes elaborating on other ideas and generating new ideas. You may do this at the same time as voting or on a different day. Remember, each new idea should be a separate post. To elaborate on an existing idea, you will again use the “quote” feature. After twenty minutes, please log out and

wait for instructions for session 3. We will begin session 3 once all participants in the group have complete session 2. You are able to continue generating new ideas until session 3 begins.

Discussion board website: utanetworks.net/smf/

Thank you

Appendix D

Session Three Instructions:

Now that you have completed sessions one and two, we will finish the discussion group with session three. We would like for you to firstly log in to the discussion board and read all of the new ideas and elaborations from session 2. You will then select the ideas/elaborations that you think are good ideas. As you have already done this for the session one material, please only focus on the new ideas and elaborations from session 2 (these will begin several posts in and will be noticeable because the first idea from session 2 will have a quote with #goodidea. Begin there and read the remainder of the posts). Again, take note of the number of pages (located in the top left and bottom left corner before and after all of the posts); this is important because you will have to manually select the next page if there are multiple pages of posts. Remember, to quote a post you will select the "quote" button located to the right (and slightly above) the post that you are indicating is a good idea. By selecting this button you will be directed to the "quick reply box". You will notice that the post you selected has been auto-filled into the "quick reply box". You will leave this text there, and on the last line of the "quick reply box" you will type #goodidea. You will repeat this process for every idea that you think is best or most creative. After quoting the ideas that you think are good ideas, we would like for you to spend time over the next 4 days generating new ideas and elaborating on other ideas. Please log in to the discussion board several times a day and spend about 15 minutes or so each time you log in reading the new ideas and making elaborations or generating new ideas. Post as many ideas as you can during this time frame. After the session ends, you will receive a document and survey to complete which will conclude your participation in this research.

Follow this link to the discussion board: utanetworks.net/smf/

Thank you,

## Appendix E

Using the rest of this page, please describe the final product that you and your group members have generated for “The Ideal University of the Future”. Keep in mind the components that make up this idea including the academic, economic, administrative, physical, social, cultural, and organizational changes.

Table 1

*Means and Standard Deviations by Condition with Variable Correlations*

| | Condition M(SD) | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Variable | Heterogeneous | Homogeneous | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
| 1.Fluency | 9.99(1.98) | 9.35(2.95) | - | | | | | | | | | | | | |
| 2.Ideas | 16.73(5.66) | 17.55(5.26) | .09 | - | | | | | | | | | | | |
| 3.S1 Ideas | 11.10(2.55) | 11.01(3.45) | .33* | .53** | - | | | | | | | | | | |
| 4.S2 Ideas | 2.32(2.74) | 2.77(2.47) | -.09 | .65* | .07 | - | | | | | | | | | |
| 5.S3 Ideas | 4.97(4.18) | 4.96(3.13) | -.07 | .71** | .02 | .46** | - | | | | | | | | |
| 6.Elab | 4.07(2.86) | 5.10(3.92) | .27 | .04 | .36* | -.35* | -.28 | - | | | | | | | |
| 7.S2 Elab | 1.68(1.44) | 1.69(1.49) | .28 | -.06 | .27 | -.41* | -.13 | .64** | - | | | | | | |
| 8.S3 Elab | 3.40(2.77) | 4.66(3.51) | .29 | -.09 | .41* | -.33* | -.40* | .85** | .39* | - | | | | | |
| 9.Votes | 9.91(5.28) | 10.70(4.26) | -.15 | .66** | .34* | .45** | .41* | .08 | -.15 | -.08 | - | | | | |
| 10.S2 Votes | 5.82(3.01) | 6.14(2.29) | .07 | .47* | .43** | .26 | .30 | .09 | .11 | .03 | .65** | - | | | |
| 11.S3 Votes | 5.21(3.07) | 6.02(4.11) | -.27 | .43* | .23 | .33* | .39* | -.09 | -.22 | -.06 | .78** | .28 | - | | |
| 12.Density | 0.46(0.23) | 0.47(0.25) | .22 | -.22 | .13 | -.51** | -.45** | .82** | .50** | .66** | .04 | -.04 | -.08 | - | |
| 13. Novelty | 3.00(.61) | 2.79(.50) | .09 | -.05 | -.15 | -.32 | .24 | .17 | .17 | .09 | -.15 | -.13 | -.01 | .14 | - |
| 14. Complex | 3.72(.68) | 3.66(.85) | -.40* | .003 | .02 | -.01 | .01 | .03 | -.07 | -.05 | .31 | .03 | .48** | .05 | .06 |

*Note.* **Correlation is significant at the 0.01 level (2-tailed) *Correlation is significant at the 0.05 level (2-tailed)

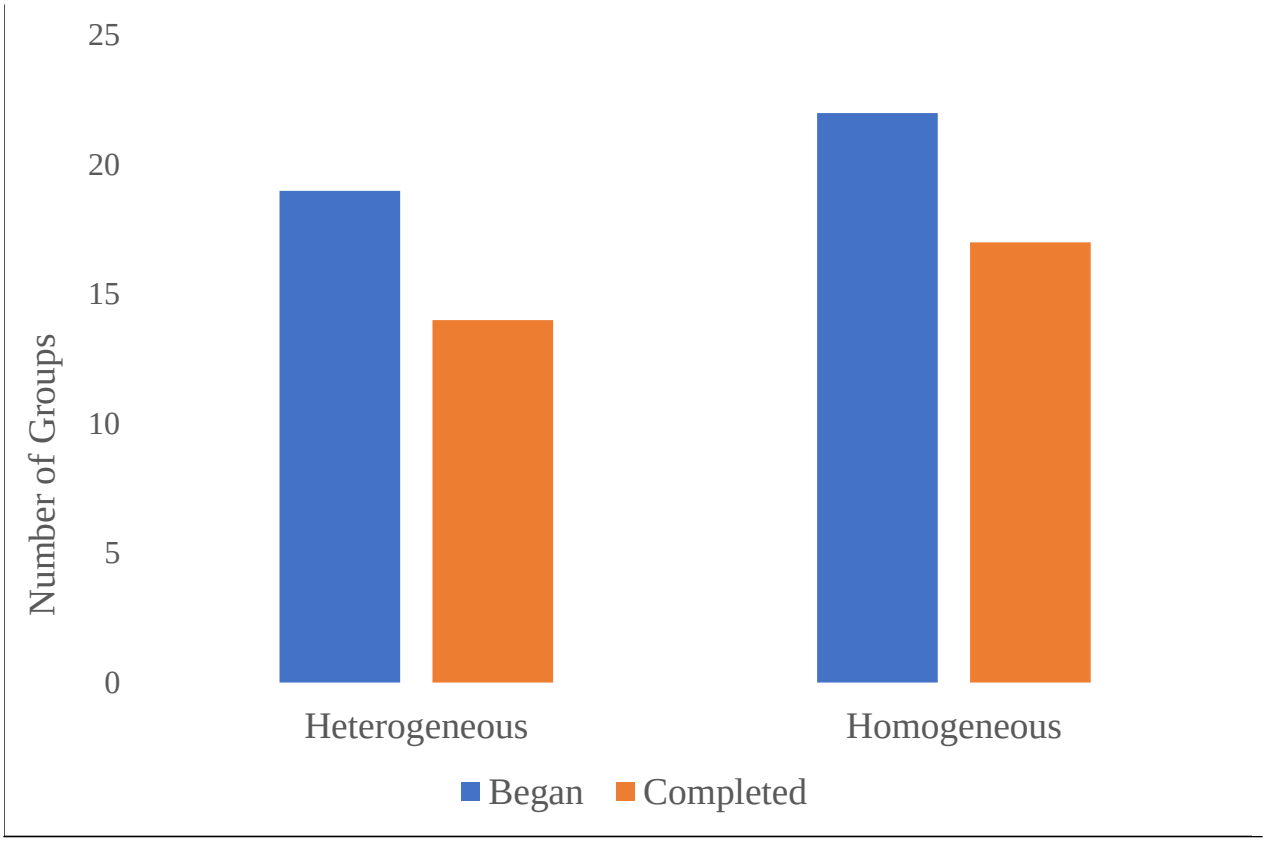


*Figure 1.* Number of groups per condition that began and completed the study. Completion was determined by at least two group members completing through the final phase of the study.