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Investigating If Multidisciplinary or Homogenous Teams Are More Innovative in a Higher Education Setting

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Investigating if Multidisciplinary or Homogenous Teams Are

More Innovative in a Higher Education Setting

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A thesis submitted to the faculty of
Brigham Young University
in partial fulfillment of the requirements for the degree of

Master of Science

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ABSTRACT

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This study is derived from the claim that multidisciplinary groups are more innovative than homogeneous groups; a claim that has flooded the business industry and has become criteria for accreditation in higher education. However, the impact of disciplinary diversity in work groups is a growing area of research; therefore, it is yet to be thoroughly understood.

The purpose of this study is to answer the question: are multidisciplinary teams more innovative than homogenous teams. To accomplish this university students from differing majors were sorted into multidisciplinary and homogeneous groups while participating in a two-day innovation course. The course taught the students about divergent thinking, and invited them to work as teams to develop an innovative product, system or service.

Each groups' final product was independently judged by three experts using the Creative Solutions Diagnosis Scale (CSDS) measuring the innovativeness (functional creativity) of student work. The homogeneous groups out scored the multidisciplinary groups in every category.

Group dynamics have been assessed as also playing a vital role in the successfulness of a diverse group. The Teamwork Quality Questionnaire (TWQ) was used to measure the quality of team interactions, student sentiments, and student attitude. These self-evaluations were used to assess if the group dynamics played a significant role in the functional creativity of the end product by checking for correlation with the results of the CSDS. The findings were inconclusive, meaning they did not correlate.

Despite the findings not aligning with past research, they should be considered important. At a minimum, they describe a context and environment where multidisciplinary groups do not function at the same level as homogenous groups. Accordingly, there is a need to further investigate group formations and function in regards to innovation and creativity production.

We recommend for future research performing a similar study on a larger scale to discover if the findings from this study would vary when tested under similar or varying contexts. It would also be important to analyze how the make up of the group is affecting the students understanding and learning.

Keywords: innovation, functional creativity, multidisciplinary, accreditation.

ACKNOWLEDGEMENTS

After three and a half years of work and study I have come away with many experiences working with students and professionals from many disciplines. From these experiences I have come away with, among other things: a background in origami and app development, understanding of the development and implementation of educational alternate reality gaming, a love for IMAG productions, a drive to create better innovators, and a greater understanding of the world around me and my place in it. Through all of this I have had amazing supporters who have made it possible to juggle the many responsibilities and opportunities allotted to me.

First, I need to thank my family. My wife Heidi for keeping our family and me balanced through all the pandemonium of long days and late nights and my wonderful children Elli, Canyon, Ava, and Lianna for giving me the motivation to see everything through. Second, Geoff Wright for joining me on my escapades into unknown territory and helping me find my way. Third, Caroline and Sterling Hilton for their help with the statistical analysis. Lastly, thank you to the Fritz B. Burns Foundation whose donations throughout my graduate studies made it possible to gain higher education and have allotted me more opportunities than I ever would have had without their help. Thank you.

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1   INTRODUCTION

It is commonly believed that multidisciplinary teams and diverse groups are more effective at creative thinking and problem solving activities than homogenous groups (Alves, 2007; Fay, 2006; Harvey, 2014; West, 2002). Consequently many companies are replacing homogenous groups with multidisciplinary groups (Jackson, 1995). In response to this paradigm shift, many educational institutions are implementing similar pedagogical changes to align with industry practice (Driver, 2001; Christy, 2007; ABET, 2017). The question of whether this paradigm change reflects best practice or whether multidisciplinary teams are more innovative has yet to be thoroughly investigated. This study was designed to examine this question: are multidisciplinary teams more innovative than homogenous teams.

1.1   The Nature of the Problem

In the business world there is a belief that multidisciplinary collaboration culminates in more innovative and creative products. In an effort to properly prepare students for industry, educational institutions are starting to implement the same practice.

This study aims to clarify if multidisciplinary groups in a higher education setting are more innovative than homogenous groups in the same setting. This was tested through observing and evaluating multidisciplinary and homogeneous teams while they participated in an

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innovation course. Data was collected through observations, self and peer assessment, and professional judging of the end products students made while in the innovation course.

1.2 Research Questions

In this study university students from differing majors were sorted into multidisciplinary and homogeneous groups while participating in a two-day innovation course. The course taught the students about divergent thinking, and invited them to work as teams to develop an innovative product, system or service. The purpose of this study is to answer the question: are multidisciplinary teams more innovative than homogenous teams. This question was investigated by analyzing data from observations, questionnaire, and product evaluations.

The research question was answered by analyzing student attitude and achievement using the Teamwork Quality Questionnaire (TWQ) and the Creative Solutions Diagnosis Scale (CSDS). The TWQ was used to measure the quality of team interactions, student sentiments, and student attitude. The CSDS was used to assess student achievement by measuring the innovativeness (functional creativity) of student work.

1.3 Definitions

Across various studies definitions of terms such as *innovation* and *team* have been content area dependent and inconsistent. For this reason, the definitions of those terms (according to this study) are listed below.

1.3.1 Team

Mohrman, Cohen, and Mohrman (1995) defined a team as: "a group of individuals who work together to produce products or deliver services for which they are mutually accountable."

They propose that "Team members share goals and are mutually held accountable for meeting them, they are interdependent in their accomplishment, and they affect the results through their interactions with one another." A multidisciplinary team is then the combining of several academic disciplines in an interdependent approach with the goal to positively affect an end product or delivered services.

1.3.2 Innovation

An accepted definition of innovation is: "unique and useful ideas successfully implemented." (Skaggs, 2012) The CSDS bases its theoretical underpinnings on this definition, but also adds the phrase "functional creativity" to further describe innovation (Cropley, 2012). Lewis (2012) argues that functional creativity, or the mixture of unique and useful ideas, is a result of the combination of divergent and convergent thinking. Figure 1-2 highlights their complementary nature.

Divergent thinking is often referred to as creativity, while convergent thinking is referred to as the process of implementation (Wright, 2017) combination of divergent thinking (creativity) and convergent thinking (implementation) results in innovation.

Skaggs, et al. (2012) write that there is six conditions that help people think innovatively. The conditions are: passion, tolerance for ambiguity, willingness to take risks, curiosity, openness, and variability. Both Skaggs and Wright posit that when the conditions are embedded in an explicitly cyclical innovation model innovation can and will occur more frequently and efficiently. The innovation model Skaggs and Wright subscribe to is known by the acronym: USERS (see figure 1-1). Each letter of USERS represents one of the five key components of innovation with three associated attributes. Understand: observe, experience, inquire and

network; Shape: organize, simplify and clarify; Explore: question, compare and combine;

Refine: visualize, validate and iterate; Share: show, demonstrate and describe.
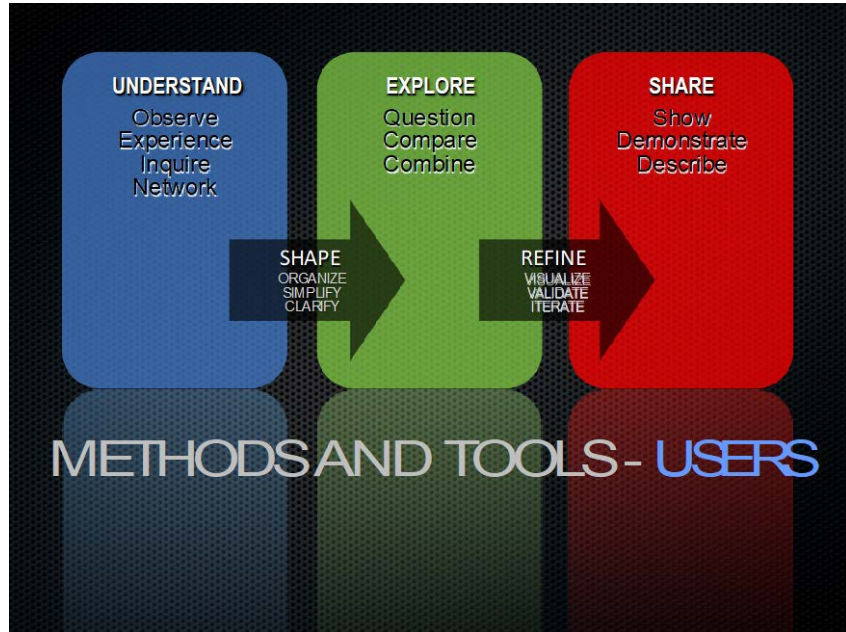
Figure 1-1: Methods and Tools - USERS
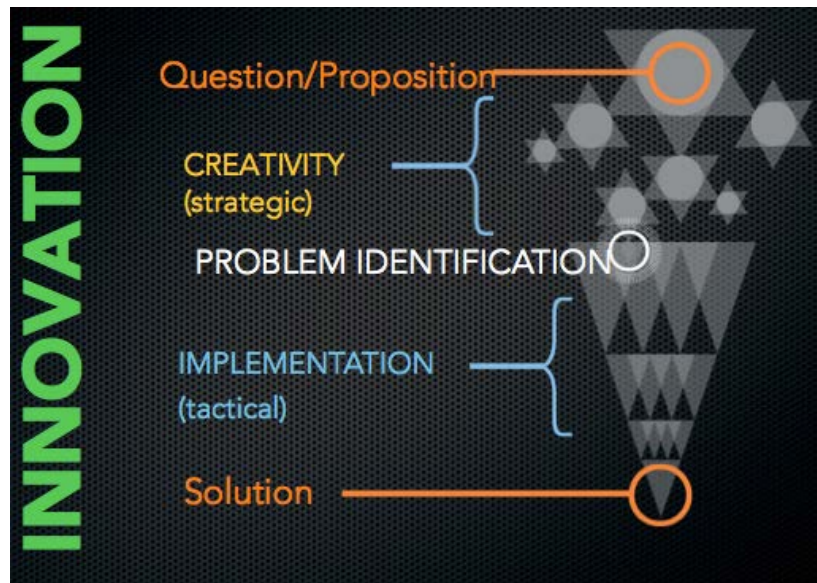
Figure 1-2: Innovation - Divergent and Convergent Thinking

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2   REVIEW OF LITERATURE

Although there is little research investigating the comparison of homogeneous and multidisciplinary team creativity in educational environments, there have been a few research efforts in industry. The impact of disciplinary diversity in work groups has been found to have both enhancing and destructive results (Chen, 2006) yet it has withstood criticism (Alves, 2007). A selection of pertinent studies are presented below, as well as a discussion of how in business teams are often deliberately staffed so that they comprise multiple disciplines – based on the assumption that it will benefit team outcomes. The final discussion of chapter two presents studies where the efforts of the business world regarding multidisciplinary creativity teams are impacting higher education.

2.1   Research

Alves (2007) conducted a research project investigating a multidisciplinary network case study. The network was composed of 11 firms and 10 departments from one university. The goal of the network was to conceive a futuristic house. Alves used focus groups to investigate the quantity and quality of: idea generation, idea convergence, and product development. Their findings suggested that this network enhanced creative processes, enabling product development. However they also concluded that, "when dealing with creativity, innovation and new product

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development there are no clear-cut solutions or ideal approaches." "Organizations need to be creative and innovative in the management of creativity and innovation."

Fay (2006) performed a study that looked at innovative outcomes of ninety-five multidisciplinary teams with 1093 respondents in the health care sector. These teams "introduce innovations for a variety of reasons; for example, to better cope with a high work load, to adapt to a changed environment or to improve the effectiveness of services." Fay assumed the benefits of multidisciplinarity would be beneficial in both the idea generation and implementation stages of innovation in these groups. They also acknowledged that although beneficial to team performance "differences can become a barrier for effective communication and understanding." To overcome this barrier they proposed that high interaction frequency has to take place. Each individual was asked to write down the major change made by the team. These reports were pooled and given to three trained raters who assessed the number of innovations and the quality of those innovations. The team members were also asked to rate the quality of team processes. They discovered that good team processes in multidisciplinary teams did not significantly affect the quantity, but rather the quality of innovations. They concluded that the quality of innovations is contingent upon good team processes.

In his meta-analysis of "research and theory that advance our understanding of creativity and innovation implementation in groups at work" West (2002) referenced what he called "a significant study of innovation in teams." The study West referenced was the UNESCO-sponsored research by Andrews (1979) who gathered data from 1,222 research teams to determine the factors influencing their performance. Diversity was assessed in six areas: projects; interdisciplinary orientations; specialties; funding resources; R & D activities, and

professional functions. Andrew's findings suggested, "that both flexibility of thought and organization, fostered by diversity, do influence team innovation" (West, 2002)

2.2 Business

As the global marketplace becomes more competitive, and as the Internet provides nearly unlimited consumer choices, consumer loyalty is decreasing (2011 Customer Experience Impact Report, 2012). In response, an increasing number of businesses have discovered that consistent innovation is their only sustainable advantage in the marketplace (Miller, 2000). Therefore, companies are trying a myriad of solutions to remain innovative. A popular solution has been to create multidisciplinary teams pulling members from previously segregated areas of the company and a variety of backgrounds with the hope that they will contribute to the development of new and useful ideas (Jackson, 1995).

Two companies that have been at the forefront of this wave of change are IDEO and Pixar Animation Studios. Both of these companies successfully utilize multidisciplinary team collaboration to further their industry. Though both companies have their own terminology and sphere of influence, they have helped advance the movement known as *multidisciplinary innovation and creativity*.

IDEO has organized their multidisciplinary teams as the heart of organizations they call "hot groups" (Kelley, 2005). These multidisciplinary teams are "well rounded and respectful of [their] diversity" having been "drawn from widely divergent disciplines" (Kelley, 2005). The multidisciplinary teams may include specialists from human factors research; business strategy; industrial and interaction design; environments design; mechanical, electrical, software, and manufacturing engineering and more forming what is known as a "greenhouse" of participants (Kelley, 2005). The "greenhouse" is an integration of disciplines focused on the design process

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from ideation to the final product (Kelley, 2005). This is done by creating "neighborhoods," or diverse teams working in close proximity, which allows them to spontaneously meet together in collaboration on a given project (Kelley, 2005).

With its fusion of art and technology, Pixar Animation Studios has been able to transform animated film by finding technology-based solutions to artistic problems (Harvey, 2014). Even with its uniquely blended culture there are many barriers to this type of teamwork. There's the different "languages" spoken by different disciplines, the hierarchy of authority and even the physical distance between offices. In order for creativity like this to function these barriers must be torn down (Catmull, 2008). "Members of any department should be able to approach anyone in another department, hold enough in common to communicate to solve problems and do so without having to go through "proper" channels." (Catmull, 2008) Everyone must be involved and feel free to participate in the creative process. They believe that even, directors should be able to accept and encourage feedback from their staff members and harness that experience. To encourage this, Pixar creates small "incubation" multidisciplinary teams of writers, directors, artists, and storyboarding people to generate and refine story ideas to a point where they can convince the senior filmmakers that those ideas have the potential to be great films (Catmull, 2008). The goal in forming these teams is to put together people who will work effectively together. Because the products they are working on are so premature and in their early development stages the effectiveness of the team is determined by their ability to function as a team to solve problems and make progress.

Companies and organizations from numerous disciplines and nations have picked up on this wave of change from homogeneous, departmentalized functionality, to multidisciplinary, expertise expansion. These include:

(a) Sant Joan de Déu Hospital and Miquel Rius, a stationery manufacturer, who co-designed a more ergonomic backpack for students with compartments that balance the weight, avoid the movement of the contents, and fastens to the child's chest with safety straps (Turiera, 2013).

(b) Comité Colbert is an organization of seventy-five member firms in the luxury good sector that form collaboration teams which work together to innovate. These "working commissions" meet throughout the year to decide on common actions. For example, each year they bring together students from top art and design schools, as well as experts from the field to share with them their vision of luxury from a multidisciplinary, global perspective (Turiera, 2013).

(c) Adidas, the largest sportswear manufacturer in Europe, has begun collaboration with the audio equipment maker Sennheiser, which specializes in microphones, headphones and accessories. With their combined know-how, the two companies have developed high-quality headphones conceived for sports use. The result encompasses four models of headphones that are water- and sweat-resistant, feature a Kevlar cable, and are built to survive extreme conditions (Turiera, 2013).

2.3 Education

Because of business successes such as IDEO and Pixar – where multidisciplinary teams are part of their cultures, the claim that multidisciplinary teams bring more innovation has also permeated the academic world. For example, the Accreditation Board of Engineering and Technology (ABET) is a recognized worldwide leader in assuring quality education and stimulating innovation in applied science, computing, engineering, and engineering technology education. At the time of this study, it had accredited approximately 3,700 programs at nearly

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750 colleges and universities in thirty countries. It uses criteria developed by technical professionals from thirty-four member societies to focus on what students experience and learn (ABET, 2017).

The ABET accreditation criteria for the 2017-2018 academic year contains a general criterion of student learning outcomes. For engineering and applied science programs, students need to have "an ability to function on multidisciplinary teams." (ABET1, 2017; ABET3, 2017) This same criterion existed for engineering and technology and computing programs, but has recently been changed to "an ability to function effectively as a member of a technical team" (ABET4, 2017) and "an ability to function effectively on a team…an ability to communicate effectively with a range of audiences." (ABET2, 2017)

Because ABET requires multidisciplinary collaboration, there is a general assumption that multidisciplinary collaboration is beneficial in higher education. However, that assumption is part of the justification for this study. At present, there are no studies attached to these ABET requirements that have statistical evidence supporting claims that multidisciplinary teams are more effective than homogenous team work or siloes (individual work). The requirements appear to result from the general assumptions, opinions and trends of business and industry.

Ohio State University (OSU) and Louisiana State University (LSU) have created projects to meet the ABET multidisciplinary team requirements including "Teams without borders." These schools have projects where engineering students are organized into various multidisciplinary groups including one with non-engineers from the College of Agriculture. Ann Christy (OSU) and Marybeth Lima (LSU) formulated these projects into case studies in their article Developing Creativity and Multidisciplinary Approaches in Teaching Engineering Problem-solving (2007). Although the case study does not analyze the *Functional Creativity* of

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the student end product it does give an insight into how this concept of multidisciplinary teamwork is being implemented in higher education.

Case study 1: paring non-engineers with engineering students.

At OSU, two professors (one an engineer and the other an environmental scientist) co-developed and co-taught an engineering course and a technology management course on the subject of waste management. These two courses attracted students from both departmental majors plus students from other departments (e.g. animal science, environmental science and public health) and working professionals seeking continuing education credit. Team projects were interdisciplinary with each team's deliverable being a poster presented at a reception on the last day of class.

The first two years of offering these courses were challenging due to the different cultures and expectations of the diverse student populations and problems with team dynamics. By the third year a successful approach had been achieved which included introductory exercises on engineers' and mangers' roles, structuring the project work for each course into weekly assignments and encouraging students to share their weekly reports with the other member of their team. Student feedback showed marked improvement in satisfaction including comments such as: "The group project illustrated the importance of working in conjunction with other professionals to complement one another's skills.".

Christy and Lima conclude that,

> "Student projects that feature "teams without borders" and that favor multidisciplinary approaches provide student centered learning opportunities and help prepare students for their future. Establishing and using such tools will allow students to develop their own creativity thereby enabling them to solve complex problems."

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2.4   Assessing Innovation

There are many methods and tools that have been created to assess creativity and innovation. However all of the creativity and innovation assessments found "lack in: (1) assessing the entire innovation process, (2) assessing the innovation process on an individual level, and (3) assessing an individual's change or growth in the innovation process" (Lewis, 2011). There are also many additional factors that come into play when multiple individuals are involved in the creative process. Because of this no stand alone assessment sufficiently covers multidisciplinary team innovation. From the numerous criteria, facets, and characteristics that have been suggested to assess the quality of team processes, creativity, and innovation the Consensual Assessment Technique (CAT), Creative Solutions Diagnosis Scale (CSDS) and Teamwork Quality Questionnaire (TWQ) were selected because they covered the specific needs of the study being a team created innovative product. The CAT focuses on evaluating an innovative product to reflect that of an evaluation in the "real world" (Amabile, 1982) which is the desire of ABET in establishing its standards for accreditation (ABET2, 2017). The result of the class being an end product, the CSDS was chosen as it has been found a valid instrument for evaluating the functional creativity of a product even by non expert judges (Cropley, 2012). The TWQ lastly represents the team factor of the course thoroughly evaluating the many facets encompassed in a team's make-up (Hoegl, 2004). Through combining these tools and techniques we attempted to better collect the requisite data to evaluate multidisciplinary team innovation.

2.4.1   Consensual Assessment Technique

One way of measuring creativity in innovation is by using the Consensual Assessment Technique (CAT). This technique, which is well known among creativity researchers (Kaufman, 2008), states that a product or response is only as creative as appropriate observers independently

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agree it is creative. Accordingly, experts in the field being evaluated are asked to independently judge the creativity of a product or response (Amabile, 1982). It is judged as creative to the extent that, "it is both novel and appropriate, useful, [and a] correct or valuable response to the task at hand" (Amabile, 1990). The reason this technique was chosen for our particular study is it has the ability to take a task that is representative of what is being done in the "real-world" and evaluate its creativity in the same manner it would be done in that "real-world" environment (Amabile, 1982).

2.4.2   Creative Solutions Diagnosis Scale

A recently revised tool known as the Creative Solutions Diagnosis Scale (CSDS) (see Appendix A-1) was developed to assess the functional creativity of a product (Copely, 2005). Copley and Kaufman (2012) made the revision when attempting to work around what they saw as a limitation of the CAT. The revision eliminated six redundant items from the thirty-item scale, as well as validated that it was reliable even for non-expert judges. The remaining twenty-four items are divided across five categories: relevance and effectiveness, problematization, propulsion, elegance, and genesis. Each item is rated using a 5-point Likert scale (ranging from "not at all" through "somewhat" to "very much") to indicate how creative each product is (Cropley, 2012).

2.4.3   The Quality of Teamwork

How to analyze the effectiveness of a team is a heavily studied subject. In their chapter *Understanding the Dynamics of Diversity in Decision-Making Teams* Jackson et al. (1995) present a vertically arrayed construct to reflect three levels of analysis: individual, interpersonal, and team (see Appendix A-4). They state that this "general causal model acknowledges the

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importance of macro level phenomena that characterize the embedding societal and organizational contexts." (Jackson, 1995)

Human behavior in teams is conceptualized as activities, interactions, and sentiments (Hoegl, 2001). According to Hoegl, activities (observable actions of individuals) that students will be engaged in can be measured by the quantity of "actions taken", meaning the frequency of interactions, contact or communication between the individuals in the team, and the student's sentiments (emotions, motivations and attitudes). In order to obtain a holistic understanding of the quality of teamwork the individual characteristics of each participating student, interpersonal interactions between the students, and team dynamics need be considered.

2.4.3.1 Individual

"The individual level of analysis is included as an aspect of diversity because individual differences in various attributes, when present in a team, department, or organization, create diversity" (Jackson, 1995). The diversity brought by the individual can range from personal beliefs to physical appearance. With such a brief allotment of class time in the Innovation Boot Camp and the fast paced course work that goes with it, a focus on readily detectable individual attributes was taken into account. These include chosen major of study, educational level, sex, culture (race, ethnicity, national origin), and age.

2.4.3.2 Interpersonal

The interpersonal element of a collaborative team can be looked at through interactions or "connectedness" of the team members (Hoegl, 2001). This can be measured by the frequency of contact or communication between the individuals in the team for the duration of the project. This includes any communication maintained in and out of class time.

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2.4.3.3 Team

Hoegl and Gemuenden (2001) have broken down team interactions into a quality scale of six facets: communication, coordination, balance of member contributions, mutual support, effort and cohesion which comprise what they call "performance-relevant measures of team internal interaction." These six teamwork quality facets embrace elements of both task-related and social interaction within teams (Cummings, 1978).

Hoegl and Proserpio (2004) propose that highly collaborative teams display behaviors related to all six teamwork quality facets.

> "In teams with high teamwork quality, team members openly communicate relevant information (Katz, 1988), coordinate their individual activities (Adler, 1995; Faraj, 2000), ensure that all team members can contribute their knowledge to their full potential (Seers, 1989), mutually support each other in team discussion and individual task work (Tjosvold, 1984; Cooke, 1994), establish and maintain work norms of high effort (Hackman, 1987; Weingart, 1992), and foster an adequate level of team cohesion where team members maintain the group (Mullen, 1994; Gully, 1995)."

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3 METHODOLOGY

In the methodology section a description of the Innovation Boot Camp course will be provided. Then the method for forming the various groups will be explained. Followed by a description of the data collection methods, which were discussed previously in section two. The analysis of the data collected is discussed in section four.

3.1 The Innovation Boot Camp

An innovation course titled TECH 312: Innovation Boot Camp is offered to all students at Brigham Young University (BYU) and is required for undergraduate business students and those in the school of technology. On the full day session (Saturday) of the two day course, students are taught the principles of divergent thinking and work as teams to problem find, problem refine, and problem solve. They then collaborate, outside of class, until the following Thursday evening, culminating in the development of their own innovative product that they then present to a panel of judges (their professor and two teaching assistants).

3.2 Pre-Course Questionnaire

The BYU "Innovation Boot Camp" averages twenty to twenty-five students per camp. Students from a myriad of majors participate in the course. For the purpose of this study, two sections of this course were chosen to participate totaling fifty-two students. A pre-course

questionnaire was administered to the students to obtain basic demographic information and their chosen major of study. The purpose of this questionnaire was to help divide the classes into teams in an attempt to mimic what industry is doing to create multidisciplinary collaboration (i.e., organizing teams based on techne diversity or "different entrepreneurial sectors and science and technology institutions," (Alves, 2007)). The Boot Camp course typically organizes the class participants into four to five groups. Each group was organized so that they were either multidisciplinary or homogeneous totaling two homogeneous and seven multidisciplinary groups.

The homogeneous group for the first course was formed from students studying Manufacturing Engineering Technology and for the second course was formed from those studying Information Technology. The remaining multidisciplinary teams were formed including students from the following majors: Accounting, Applied Physics, Applied Statistics, Athletic Training, Computer Science, Economics, English, Information Technology, Literature/Film/Culture, Manufacturing Engineering Technology, Middle East Studies/Arabic, Music Education (K-12 General Music), Physics, Political Science, Pre-Management, Psychology, Public Health, Technology and Engineering Education, and Undeclared. The factors of education level and sex were also considered and an attempt to maintain an even distribution of these factors was made but not emphasized (see Appendix A-2 – Group Formations). The factors of national origin and age due to a lack of response on the pre-course questionnaire were unable to be included in the process of team organization.

3.3   Data Collection

The research methodology used in this study included: qualitative observations, video recordings of participant interactions, the use of expert judges and rubrics, and finally self and

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peer evaluations of all participants. Both the pre and post course questionnaires were distributed and collected via electronic means outside of class time. The three judges, their scoring directly inputted into a digital rubric, rated the student's products independently.

3.3.1   Course Observations

During the instructional day of the course (Saturday), video recordings of the participants' interpersonal and team interactions were obtained by mounting cameras to the white boards used by each group to obtain an observation that could be reviewed and evaluated at a later date. After the analysis of the post-course questionnaire the primary researcher reviewed the video footage using the modified TWQ facets to look for contributing and inhibiting factors that denoted successful quality team interactions and verification of the students' response to the TWQ to gain further understanding of their reasoning. This was done to help assess the contributing factors influencing and related to a teams ability to innovate.

3.3.2   Final Product Evaluations

At the end of the course each group submitted a final innovation product that was assessed, using the revised CSDS that was discussed in section 2.3.2 (see also Appendix A-1). The evaluation was performed by three judges expert in evaluating innovation: one an Assistant Professor of Entrepreneurship, the second the chair for the Innovation Boot camp, and the third a three year teaching assistant for the boot camp. This was done without the judges' knowledge of the differing groups to measure the creative quality of the products between homogenous and multidisciplinary.

3.3.3 Teamwork Quality Evaluations

The students then completed a post course questionnaire (TWQ) in which they evaluated their team, team members, and themselves (the TWQ is discussed in section 2.3.3, see also Appendix A-3). This helped clarify the student perspective of the three components to human behavior in relation to their team (Hoegl, 2001). The video collected during the course was then utilized in conjunction with the TWQ facets to evaluate the accuracy of their own assessment.

4   DATA AND ANALYSIS

The findings presented in chapter 4 are grouped into two sections. Section 1 describes the findings from the Creative Solutions Diagnosis Scale (CSDS), and Section 2 presents the findings from the Teamwork Quality Questionnaire (TWQ). The CSDS was used to determine whether homogeneous or multidisciplinary groups are more innovative, while the TWQ was used to evaluate the quality of team (group) work.

4.1   Creative Solutions Diagnosis Scale

In the analysis of the data from the Creative Solutions Diagnosis Scale (CSDS) we looked at the validity of three things: the averages of the CSDS ratings between the two courses, the averages between the three judges CSDS ratings, and the difference of means between the homogeneous and multidisciplinary group ratings from the CSDS. The difference between the courses was found statistically insignificant. The difference between the three judges was found statistically insignificant. Because the findings of the course and judge comparisons were statistically insignificant, the analysis of the homogeneous and multidisciplinary groups was viable. Meaning, if the judges' scores or the courses were significantly different then comparing the two groups would not have been valid. The results from the subsequent comparison between the homogeneous and multidisciplinary groups revealed that homogenous groups were more innovative than multidisciplinary.

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4.1.1 Statistical Analysis

During the data analysis an effort was made to assure that the three judges and the two separate course sections were not significantly differing or effecting our conclusions. By averaging the product ratings across judges and courses the worry was minimized, but as an extra assurance their effect on the findings was built into the statistical analysis as seen in Figure 4-1.

Statistical Formula used for Analysis
Judge (Jj)   j= 1,2,3
Class (Cc)   c= 1,2
Make-up (Mm)   m = 1,2
Group G(mc)g   g= 1,2,3,4,5
Jj + Cc + JCjc + Mm + JMjm + CMcm + JCMjcm + G(mc)g + JG(mc)gj

Figure 4-1: Statistical Formula Used for Analysis

4.1.2 Findings

There was no statistically significant difference between the judges' rating, although the judges' ratings are different. There was also no statistically significant difference between the performances of the two courses even though Course 1 tended toward lower ratings than Course 2.

There was a statistically significant difference in the average total rating between the homogenous and multidisciplinary groups ($F(8) = 54.53$, $p = .018$). This means that

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homogeneous groups were rated overall higher on their final products' functional creativity than those of multidisciplinary groups.

4.1.3 Observations from Descriptive Statistics

As seen in Table 1, homogeneous groups were consistently rated on average higher than multidisciplinary groups in every category. These differences ranged from .03 (Problemization) to .68 (Genesis) representing the lowest and highest difference of means between the homogenous and multidisciplinary groups.

Table 1: Descriptive Statistics of CSDS Outcomes for Both of the Two Group Make-ups

CSDS Category	Make-up	Mean of Averaged Ratings	Difference of Means
Relevance & Effectiveness	Homogeneous	4.056	.4
	Multidisciplinary	3.651	
Problemization	Homogeneous	3.444	.03
	Multidisciplinary	3.413	
Propulsion	Homogeneous	3.400	.35
	Multidisciplinary	3.057	
Elegance:	Homogeneous	3.619	.07
	Multidisciplinary	3.544	
Genesis	Homogeneous	3.194	.68
	Multidisciplinary	2.516	
CSDS Total Rating	Homogeneous	3.543	.31
	Multidisciplinary	3.236	

Table 2 shows the means of the averaged ratings by CSDS category, and the difference between the means for the two courses. The average difference of the mean CSDS ratings was

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not statistically significant (F(26) = 0.36). The mean differences within each category of the CSDS ranged from a lowest difference of .24 (propulsion) to a highest difference of .39 (elegance) (see table 2).

Table 2: Descriptive Statistics of CSDS Outcomes for Both of the Two Courses

CSDS Category	Course	Mean of Averaged Ratings	Difference of Means
Relevance & Effectiveness	Course1 Course2	3.556 3.889	.33
Problemization	Course1 Course2	3.222 3.578	.35
Propulsion	Course1 Course2	3.000 3.240	.24
Elegance:	Course1 Course2	3.345 3.734	.39
Genesis	Course1 Course2	2.667 2.667	.0
CSDS Total Rating	Course1 Course2	3.158 3.421	.27

Table 3 shows the means of the averaged ratings by CSDS category, and the difference between the means for the three judges. The average difference of the mean CSDS ratings was not statistically significant. However, Judge 2 and Judge 3 reported essentially the same rating, whereas Judge 1 reported a lower rating – with a difference of .4. Thus suggesting that even with a validated rubric the judging of functional creativity is still a human endeavor and the rating is dependent upon the values and opinions of the one rating it, making the need of more than one judge necessary.

Table 3: Descriptive Statistics of CSDS Outcomes for Each of the Three Judges

CSDS Category	Judge	Mean of Averaged Ratings	Difference of Means
Relevance & Effectiveness	1	3.556	
	2	3.741	.4
	3	3.926	
Problemization	1	3.185	
	2	3.444	.5
	3	3.630	
Propulsion	1	2.778	
	2	3.489	.7
	3	3.133	
Elegance:	1	3.302	
	2	3.873	.5
	3	3.508	
Genesis	1	2.389	
	2	2.648	.6
	3	2.963	
CSDS Total Rating	1	3.042	
	2	3.439	.4
	3	3.432	

Additional notable observations were also identified as the data was analyzed. The data presented in Table 3 reveals that the CSDS categories of Propulsion and Genesis held the largest difference of means at .7 and .6, making them potentially the most disputed categories among the judges as far as the mean of their average ratings. This may support the findings of Cropley and Kaufman (2012) that Genesis and Propulsion have a strong positive correlation. However this also signifies that an understanding of Genesis and Propulsion may be less solidified among experts of differing backgrounds. Both of these categories relate to new knowledge, ideas and solutions—"Propulsion [is more] concerned with novelty, as it relates to the problem in hand,

whereas Genesis is concerned more with future novelty and possibilities" (Cropley, 2012). Both are dependent on an individual's opinion of novelty. For example, in these same categories for the averaged ratings of the two groups, Propulsion (.35) and Genesis (.68) were among the greatest difference of means (see Table 1). The homogenous groups, due to their shared background, may have shared a deeper understanding of the novelty of their product as it relates to their subject matter therefore presenting it as such.

4.2   Teamwork Quality Questionnaire

Group dynamics have been assessed as playing a vital role in the successfulness of a diverse group (Chen, 2006). The Teamwork Quality Questionnaire (TWQ) was used to assess if the group dynamics played a significant role in the functional creativity of the end product. To do this the results of the TWQ were compared with the CSDS analyses to determine corollary effect. If the quality of the teamwork affected their CSDS scores then it would be important to further analyze the impact of team or group make-ups, and their interactions. However, the comparison between the TWQ and CSDS were inconclusive, meaning they did not correlate.

4.2.1   Statistical Analysis

The TWQ was checked for correlation by comparing the averaged final rating of the groups' innovative product with the CSDS Average Final Rating. It was checked to see if their opinion of their team's ability to function as a team and their product rating from the judges correlated with one another.

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4.2.2 Findings

The groups' ability to function as a team played a visible role in their end successfulness. However, the TWQ had no statistically significant correlation with the average final rating of the group's innovative products.

4.2.3 Observations from Descriptive Statistics

There is a visible negative pattern in the data collected from the TWQ (Figure 2) when compared with their CSDS ratings. The team members who felt their group was less effective tended toward a higher final rating on their innovative product. In Contrast, those who felt their team was high functioning created a final product that tended toward a lower rating from the judges.
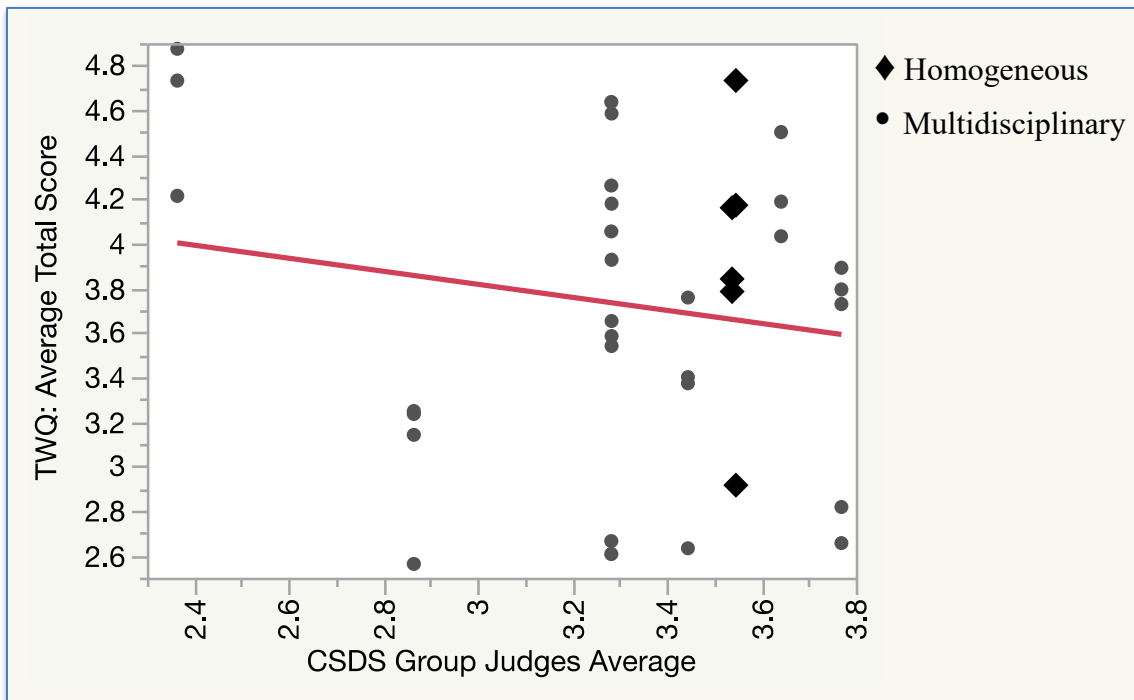

Figure 4-2: Regression Plot of the CSDS and TWQ

In Figure 4.2 we observe that the group of students that self-evaluated as having high quality teamwork (1. frequent communication within the team; 2. There were mediators through whom much communication was conducted. 3. The work done on subtasks within the product was closely harmonized. For example, all members were assigned a different aspect of the product to further research, and each group member immediately set to work researching and sharing their findings with each other. 4. The team members helped and supported each other as best they could as recognized by the sharing of phones for research purposes due to all members not having their own personal device. 5. There was a balance of member contributions in discussion and idea sharing. 6. Suggestions and contributions of team members were discussed and further developed.) were also that which received the lowest CSDS rating. The irony is that this group who self-evaluated as having high quality teamwork, did indeed meet the TWQ of being a high work quality team. Yet, the products they created received low CSDS ratings.

The team that received the highest rating from the judges on their final product, yet whose members self-evaluated their teamwork as being low quality, also a multidisciplinary group, was further analyzed using the video footage collected during class. This team was seen to have accurately depicted their quality of teamwork as low. For example, the team members failed to consistently communicate and share their ideas. As per class design, there was not really a mediator conducting the discussions. Discussion resulted from a "provide input as desired" type progression, and more time was spent in reflection verses active discussion. This created a feeling that information or opinions were being withheld. For example, when working on subtasks a small group of the students would tackle the task as the others observed and later gave their opinion on the conclusions. Suggesting there was a varying degree of commitment among the group members. It seems as though there was consistently at least one member who

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disengaged from the discussion or task at hand be it by a personal texting conversation, external distractions or what would appear to be boredom. In contradiction to the findings of Fay (2006), despite the apparent low teamwork quality, this team performed the highest among all teams as measured by the CSDS.

4.3   Discussion

There are many possible factors that could have effected or caused the homogeneous groups to be more successful in innovating a product than the multidisciplinary groups. First, the length of the Innovation Boot Camp may have been too short. Because the course is only two class sessions (total instructional hours: ten hours) across the span of just under a week it may represent too short of a timeframe for the effects of multidisciplinarity to benefit innovation. In fact the short time period may actual hinder the ability of each group to innovate due to unfamiliarity with each other (meaning an issue of intrapersonal relations).

Being an introductory course many students participating may have been unfamiliar (and or uncomfortable) with the concept of collaborating with group members from different backgrounds, including majors. For example, when working with a group of engineering students who were collaborating with the curators of the university art museum, the students created a prototype of an exhibit piece and provided demonstration and explanation to the curators of its function and educational benefit. Yet the curators could not visualize the end product due to the rudimentary nature of the prototype and the materials utilized (scotch tape, cardboard, paper clips). The end result was a rejection of the display by the curators even though the concept was judged to be innovative (novel and useful). The engineering students quickly learned if they presented a painted, visually appealing model it was immediately easier for the

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curators to visualize how the display could fit within the available space and would be more easily accepted for the future exhibit.

Additionally, the homogeneous groups, although unfamiliar with one another, they shared a common background knowledge and seemed to utilized it to connect and innovate at a deeper level of joined understanding. For example the end product created by the Information Technology homogeneous group from the second course was a mobile application that interacted with a specially designed cell phone case to track and aid in the collection of blood sugar levels for diabetics. All of these students not only had common ground in their understanding in regards to the technology used for their solution but also each held a personal relationship with someone dealing with diabetes that fueled their desire to innovate.

The second finding involves students understanding what it means (and how to) collaborate. Meaning, those who had good teamwork yet received lower ratings on their end product may have lacked the ability to collaborate. They were successful in going through the motions or activities that comprise an effective team and may have tried very hard to work together but there may have been a break between doing and understanding. This may have occurred due to the unfamiliarity with the content or depth of knowledge as discussed earlier but could also be due to simply a lack of innovative ideas at the time. In contrast, those who didn't exhibit good teamwork yet received higher ratings on their end product may have had team members who took control of the final project, either because of their personality, lack of group interest, or because of other factors. Regardless of the reason, they all point to their inability to collaborate effectively. In reviewing the video footage a small partition of students from within the group tended to exhibit more constant effort towards the task at hand. The small portion of

the group may have been successful despite the group as a whole not functioning well together.

Both of these phenomena suggest there is a need for further investigation of group dynamics.

5   CONCLUSIONS

5.1   Nature of the Problem

It is commonly believed that multidisciplinary teams and diverse groups are more effective at creative thinking and problem solving activities than homogenous groups (Alves, 2007; Fay, 2006; Harvey, 2014; West, 2002). Consequently many companies are replacing homogenous groups with multidisciplinary groups (Jackson, 1995). In response to this paradigm shift, many educational institutions are implementing similar pedagogical changes to align with industry practice (Driver, 2001; ABET, 2017).

The Accreditation Board of Engineering and Technology (ABET) is the organization responsible for monitoring, evaluating and certifying the quality of engineering (and related) education programs. The ABET accreditation criteria for the 2017-2018 academic year contains a general criterion of student learning outcomes. For engineering and applied science programs, students need to have "an ability to function on multidisciplinary teams." (ABET1, 2017; ABET3, 2017)

At present there are no studies attached to these ABET requirements that support statistical evidence. Rather ABET uses criteria developed by the opinions and trends of technical professionals from thirty-four member societies (ABET, 2017). Because accreditation boards are requiring multidisciplinary collaboration, there is a general assumption that multidisciplinary

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collaboration is beneficial in higher education. However, that exact assumption is part of the justification for this study.

The purpose of this study was to answer the question: are multidisciplinary teams more innovative than homogenous teams. To study this university students from differing majors were sorted into multidisciplinary and homogeneous groups while participating in a two-day innovation course. The course taught the students about divergent thinking, and invited them to work as teams to develop an innovative product, system or service.

5.2   Prior Research

With the observed benefits and complications of multidisciplinary teamwork in both industry and education it has become an area of significant study. With it being an area of study only beginning to be understood, the majority of these studies have been focused on identifying valid working instruments to analyze the innovativeness or "Functional Creativity."

In *Understanding the Dynamics of Diversity in Decision-Making Teams* Jackson (1995) present a vertically arrayed construct "to reflect three levels of analysis: individual, interpersonal, and team." "This general causal model acknowledges the importance of macro level phenomena that characterize the embedding societal and organizational contexts."

"The individual level of analysis is included as an aspect of diversity because individual differences in various attributes, when present in a team, department, or organization, create diversity" (Jackson, 1995). The interpersonal element of a collaborative team can be looked at through interactions or "connectedness" of the team members (Hoegl, 2001). This can be measured by the frequency of contact or communication between the individuals in the team for the duration of the project. Hoegl and Gemuenden have broken down team interactions into a quality scale of six facets: communication, coordination, balance of member contributions,

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mutual support, effort and cohesion which comprise what they call "performance-relevant measures of team internal interaction." These six teamwork quality facets embrace elements of both task-related and social interaction within teams (Cummings, 1978).

5.3 Methodology

In this study university students from differing majors were sorted into multidisciplinary and homogeneous groups while participating in a two-day innovation course. For the purpose of this study, a pre-course questionnaire was administered to the students to obtain basic demographic information and their chosen major of study. The purpose of this questionnaire was to help divide the class into teams in an attempt to mimic what industry is doing to create multidisciplinary collaboration (i.e., organizing teams based on "different entrepreneurial sectors and science and technology institutions," (Alves, 2007)).

The research methodology used in this study included: qualitative observations, video recordings of participant interactions, the use of expert judges and rubrics (CSDS) as well as self and peer assessments of all participants (TWQ).

5.4 Analysis

A statistical analysis was conducted to analyze the three judges' ratings of each groups' final product. These ratings were generated using the Creative Solutions Diagnosis Scale (CSDS) and to eliminate any bias were averaged across the three judges. A variation of a randomized block design was used for statistical analysis, revealing a statistically significant difference between the averaged final judges ratings of the homogeneous and the multidisciplinary groups.

The Teamwork Quality Questionnaire (TWQ), which was answered by the students after the completion of the course, was analyzed using descriptive statistics, and later compared to the

CSDS analyses checking for any correlation. The TWQ had no statistically significant correlation with the average final rating of the groups' innovative products.

5.5 Limitations

There were three pertinent delimitations to this study. They are discussed in turn below.

First, due to the open enrollment nature of the Innovation Boot camp course we were unable to control the variety of student majors in the course. This left us to create the homogenous groups from the elected major with the largest population of enrolled students being Information Technology and Manufacturing Engineering. The rest of the class population was then organized into as balanced of multidisciplinary teams as could be arranged given the enrolled students.

Second, in order to allow the judges to rate the student product independently they could not be present for the product presentations made by the teams but had to give their rating based off of what information was made available through each groups slide presentation. The thoroughness, or the lack there of, provided by the students on these information slides may have affected their product rating, leaving the judges to interpret the functional creativity based off of their understanding of the product.

Third, due to a digital data file becoming corrupted it became necessary for the students from Course 1 to retake the post course questionnaire one month after completing the course rather than immediately following the course as initially planned. Due to the extended timeframe between completion of the course and retaking the post course questionnaire the responses provided may have become skewed.

Fourth, the boot camp being an introductory course, the context of innovation and multidisciplinary collaboration are new to the inexperienced students who have not been

thoroughly trained to work effectively in such situations. This may have lead to an inability to express themselves as would be necessary for successful innovation.

5.6   Conclusions

With the homogeneous groups outperforming the multidisciplinary groups, and the quality of teamwork not playing a significant role in the functional creativity of the groups' end product. Accordingly, the findings of this study contradict the findings, conclusions and assumptions of others who suggest that multidisciplinary groups produce more innovative ideas (Fay, 2006; Harvey, 2014; West, 2002).

Despite the findings not aligning with past research, they should be considered important. At a minimum, they describe a context and environment where multidisciplinary groups do not function at the same level as homogenous groups. And although the findings cannot be generalized to industry or all educational settings, in light of what they suggest, those who feel there is a need to replace high functioning homogeneous teams with multidisciplinary teams should do so with some trepidation or at least not assume that without proper training it will work. This study clearly reveals that in some contexts homogenous teams outperform multidisciplinary teams when measuring for functional creativity. Accordingly, there is a need to further investigate group formations and function in regards to innovation and creativity production.

5.7   Recommendations for Further Study

We recommend performing a similar study on a larger scale to discover if the findings from this study would vary when tested under similar or varying contexts. It would also be important to analyze how the make up of the group is affecting the students understanding and

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learning. For example, does multidisciplinary group work improve student learning? It would also be beneficial to look at educational groups in different contexts such as those spanning an entire semester or even a full year, as well as junior or senior capstone courses in contrast to our two-day introductory course.

REFERENCES

Alves, J., M. J. Marques, I. Saur, and P. Marques. 2007. "Creativity and Innovation through Multidisciplinary and Multisectoral Cooperation." *Creativity and Innovation Management* 16 (1): 27–34. doi:10.1111/j.1467-8691.2007.00417.x.

Amabile, T. M. 1982. "The Social Psychology of Creativity: A Consensual Assessment Technique." *JOURNAL OF PERSONALITY AND SOCIAL PSYCHOLOGY* 43 (5): 997–1013. http://www.hbs.edu/faculty/Pages/item.aspx?num=7355.

Amabile, T.M. 1990. *Within You, without You: The Social Psychology of Creativity, and Beyond.* Edited by M. A. Runco and R. S. Albert. *Theories of Creativity*. SAGE Publications.

Andrews, F.M. 1979. Scientific productivity. Cambridge: Cambridge Univer- sity Press.

Catmull, E. 2008. "How Pixar Fosters Collective Creativity." *Harvard Business Review* 86 (9): 64–72.

Chen, M. 2006. "Understanding the Benefits and Detriments of Conflict on Team Creativity Process." *Creativity and Innovation Management* 15 (1): 105–16. doi:10.1111/j.1467-8691.2006.00373.x.

Christy, A., and M. Lima. 2007. "Developing Creativity and Multidisciplinary Approaches in Teaching Engineering Problem-Solving." *International Journal of Engineering Education* 23 (4): 636–44. http://www.ingentaconnect.com/content/intjee/ijee/2007/00000023/00000004/art00004.

"CRITERIA FOR ACCREDITING APPLIED AND NATURAL SCIENCE PROGRAMS." 2017. www.abet.org.

"CRITERIA FOR ACCREDITING COMPUTING PROGRAMS." 2017. www.abet.org.

"CRITERIA FOR ACCREDITING ENGINEERING PROGRAMS." 2017. www.abet.org.

"CRITERIA FOR ACCREDITING ENGINEERING TECHNOLOGY PROGRAMS." 2017. www.abet.org.

Cropley, D. H., and J. C. Kaufman. 2012. "Measuring Functional Creativity: Non-Expert Raters and the Creative Solution Diagnosis Scale." *The Journal of Creative Behavior* 46 (2): 119–37. doi:10.1002/jocb.9.

Driver, M. 2001. "Fostering Creativity in Business Education : Developing Creative Classroom Environments to Provide Students With Critical Workplace." *Journal of Education for Business* 77 (1): 28–33.

Fay, D., C. Borrill, Z. Amir, R. Haward, and M. West. 2006. "Getting the Most out of Multidisciplinary Teams:A Multi-Sample Study on Team Innovation in Health Care." *Journal of Occupational and Organizational Psychology*, no. 79: 553–67. doi:10.1348/096317905X72128.

Harvey, S. 2014. "Creative Synthesis: Exploring the Process of Extraordinary Group Creativity." *Academy of Management Review* 39 (3): 324–43. doi:10.5465/amr.2012.0224.

Hoegl, M., and H. G. Gemuenden. 2001. "Teamwork Quality and the Success of Innovative Projects." *Organization Science* 12 (March 2015): 435–49. doi:10.1287/orsc.12.4.435.10635.

Jackson, S. E., K. E. May, and K. Whitney. 1995. "Understanding the Dynamics of Diversity in Decision-Making Teams." In *Team Effectiveness and Decision Making in Organizations*, edited by R. A. Guzzo and E. Salas, 204–61. San Francisco, CA: Jossey-Bass.

Kelley, T., and J. Littman. 2005. *The Art of Innovation: Lessons in Creativity from IDEO, America's Leading Design Firm*. 1st Editio. New York, NY: Doubleday.

Lewis, T. 2011. "Creativity and Innovation : A Comparative Analysis of Assessment Measures for the Domains of Technology , Engineering , and Business." Brigham Young University.

Lewis, T. and G. A. Wright. 2012. "How does Creativity Complement Today's Currency of Innovation?," Journal of Strategic Innovation and Sustainability, Vol. 7, Iss. 3, pp. 9 - 15

Mohrman, S. A., S. G. Cohen, and A. M. Mohrman, Jr. 1995. *Designing team-based organizations: new forms for knowledge work.* 1 st edition ed. San Francisco, CA: Jossey-Bass.

Skaggs, P., R. Fry, and G. Wright. 2012. "Creating a Mindset for Innovation." In IDSA Education Symposium. Boston.

Turiera, T. and Cros, S. (2013). *CO Business 50 examples of business collaboration*. [ebook] Barcelona: CO-Society - Infonomia, pp.13,17,37. Available at: http://www.co-society.com/wp-content/uploads/CO_business_2013.pdf [Accessed 20 Sept. 2017].

"Vision and Mission | ABET." 2017. Accessed September 19. http://www.abet.org/about-abet/vision-and-mission/.

West, M. A. 2002. "Sparkling Fountains or Stagnant Ponds: An Integrative Model of Creativity and Innovation Implementation in Work Groups." *Applied Psychology* 51 (3): 355–87. doi:10.1111/1464-0597.00951.

Wright, G. 2017. In Press, *Technology and Engineering Teacher*.

2011 Customer Experience Impact Report. (2012). [ebook] Redwood Shores, CA: Oracle Corporation. Available at: http://www.oracle.com/us/products/applications/cust-exp-impact-report-epss-1560493.pdf [Accessed 2 Nov. 2017].

APPENDIX A   DATA COLLECTION TOOLS

A-1   Creative Solutions Diagnosis Scale

Revised Creative Solution Diagnosis Scale

Criterion of Creativity	Indicator	SCALE	not at all - somewhat - very much 1 - 2 - 3 - 4 - 5
Relevance & Effectiveness	**PERFORMANCE** (the solution does what it is supposed to do)		1 - 2 - 3 - 4 - 5
	APPROPRIATENESS (the solution fits within task constraints)		1 - 2 - 3 - 4 - 5
	CORRECTNESS (the solution accurately reflects conventional knowledge and/or techniques)		1 - 2 - 3 - 4 - 5
Problematization	**PRESCRIPTION** (the solution shows how existing solutions could be improved)		1 - 2 - 3 - 4 - 5
	PROGNOSIS (the solution helps the beholder to anticipate likely effects of changes)		1 - 2 - 3 - 4 - 5
	DIAGNOSIS (the solution draws attention to shortcomings in other existing solutions)		1 - 2 - 3 - 4 - 5
Propulsion	**REDEFINITION** (the solution helps the beholder see new and different ways of using the solution)		1 - 2 - 3 - 4 - 5
	REINITIATION (the solution indicates a radically new approach)		1 - 2 - 3 - 4 - 5
	GENERATION (the solution offers a fundamentally new perspective on possible solutions)		1 - 2 - 3 - 4 - 5
	REDIRECTION (the solution shows how to extend the known in a new direction)		1 - 2 - 3 - 4 - 5
	COMBINATION (the solution makes use of new mixture(s) of existing elements)		1 - 2 - 3 - 4 - 5
Elegance	**PLEASINGNESS** (the beholder finds the solution neat, well-done)		1 - 2 - 3 - 4 - 5
	COMPLETENESS (the solution is well worked out and "rounded")		1 - 2 - 3 - 4 - 5
	SUSTAINABILITY (the solution is environmentally friendly)		1 - 2 - 3 - 4 - 5
	GRACEFULNESS (the solution well-proportioned, nicely formed)		1 - 2 - 3 - 4 - 5
	CONVINCINGNESS (the beholder sees the solution as skillfully executed, well-finished)		1 - 2 - 3 - 4 - 5
	HARMONIOUSNESS (the elements of the solution fit together in a consistent way)		1 - 2 - 3 - 4 - 5
	SAFETY (the solution is safe to use)		1 - 2 - 3 - 4 - 5
Genesis	**VISION** (the solution suggests new norms for judging other solutions existing or new)		1 - 2 - 3 - 4 - 5
	TRANSFERABILITY (the solution offers ideas for solving apparently unrelated problems)		1 - 2 - 3 - 4 - 5
	SEMINALITY (the solution draws attention to previously unnoticed problems)		1 - 2 - 3 - 4 - 5
	PATHFINDING (the solution opens up a new conceptualization of the issues)		1 - 2 - 3 - 4 - 5
	GERMINALITY (the solution suggests new ways of looking at existing problems)		1 - 2 - 3 - 4 - 5
	FOUNDATIONALITY (the solution suggests a novel basis for further work)		1 - 2 - 3 - 4 - 5

A-2 Group Formations

Course 1: Homogeneous

Chosen Major	Education Level	Sex
Manufacturing Engineering Technology	Sophomore	Male
Manufacturing Engineering Technology	Junior	Male
Manufacturing Engineering Technology	Junior	Male
Manufacturing Engineering Technology	Senior	Male
Manufacturing Engineering Technology	Junior	Male
Manufacturing Engineering Technology	Junior	Male

Course 2: Homogeneous

Chosen Major	Education Level	Sex
Information Technology	Freshman	Female
Information Technology	Junior	Male
Information Technology	Junior	Male
Information Technology	Freshman	Male
Information Technology	Senior	Male

Course 1: Multidisciplinary

Chosen Major	Education Level	Sex
Psychology	Junior	Female
Physics	Sophomore	Male
Industrial Design	Junior	Male
Information Technology	Junior	Male
English	Senior	Female
Literature/Film/Culture	Senior	Male

Course 2: Multidisciplinary

Chosen Major	Education Level	Sex
Undeclared	Freshman	Female
Marriage and Family Studies	Senior	Female
Pre-Management	Sophomore	Male
Manufacturing Engineering	Senior	Male
English	Sophomore	Male
Information Technology	Senior	Male

Course 1: Multidisciplinary

Chosen Major	Education Level	Sex
Information Technology	Junior	Female
Computer science	Junior	Male
Technology engineering and education	Junior	Male
Middle East Studies/Arabic	Sophomore	Male
Entrepreneurship	Junior	Male
Industrial Design Premajor	Sophomore	Female

Course 2: Multidisciplinary

Chosen Major	Education Level	Sex
Public Health	Sophomore	Female
Manufacturing Engineering Technology	Sophomore	Male
Computer Science	Junior	Female
Manufacturing Engineering Technology	Senior	Male
Tech & Engineering Education Premajor	Senior	Female

Course 1: Multidisciplinary

Chosen Major	Education Level	Sex
Chemical Engineering	Sophomore	Female
Computer Science	Freshman	Male
Accounting	Junior	Male
Applied Statistics	Senior	Male
Information Technology	Junior	Male
Pre-Management Core	Junior	Male
Political Science	Junior	Male

Course 2: Multidisciplinary

Chosen Major	Education Level	Sex
Information Technology	Junior	Female
Economics	Junior	Female
Computer Science	Freshman	Male
Mechanical Engineering Pre-Professional	Senior	Male
Athletic Training	Senior	Female

Course 2: Multidisciplinary

Chosen Major	Education Level	Sex
IT	Sophomore	Male
Manufacturing Engineering	Junior	Male
Applied Physics	Senior	Male
Open-Major	Sophomore	Male
Music Ed (K-12 General Music) Premajor	Freshman	Female

A-3 Pre-Course Questionnaire

1. **First Name** *

   _____

2. **Last Name** *

   _____

3. **I have read and understood the above consent and desire of my own free will to participate in this study.** *
   Mark only one oval.

   ( ) Yes

   ( ) No

Personal and Demographic Information

4. **Age**
   Mark only one oval.

( ) 18	( ) 22	( ) 26	( ) 30	( ) 34	( ) 38
( ) 19	( ) 23	( ) 27	( ) 31	( ) 35	( ) 39
( ) 20	( ) 24	( ) 28	( ) 32	( ) 36	( ) 40
( ) 21	( ) 25	( ) 29	( ) 33	( ) 37	

5. **Sex**
   Mark only one oval.

   ( ) Male

   ( ) Female

6. **National Origin**
   Mark only one oval.

   ( ) American Indian or Alaskan Native

   ( ) Asian

   ( ) Black or African American

   ( ) Hispanic or Latino

   ( ) White, Caucasian

   ( ) Hawaiian Native or other Pacific Islander

7. **Education Level**

   Mark only one oval.

   ⬭ Freshman

   ⬭ Sophomore

   ⬭ Junior

   ⬭ Senior

   ⬭ Other: _____

8. **Chosen Major of Study**

   _____

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A-4 Teamwork Quality Questionnaire

Teamwork Quality Questionnaire

Communication	There was frequent communication within the team.
	The team members communicated often in spontaneous meetings, phone conversations, etc.
	The team members communicated mostly directly and personally with each other.
	There were mediators through whom much communication was conducted.(R)
	Project-relevant information was shared openly by all team members.
	Important information was kept away from other team members in certain situations.(R)
	In our team there were conflicts regarding the openness of the information flow.(R)
	The team members were happy with the timeliness in which they received information from other team members.
	The team members were happy with the precision of the information received from other team members.
	The team members were happy with the usefulness of the information received from other team members.
Coordination	The work done on subtasks within the project was closely harmonized.
	There were clear and fully comprehended goals for subtasks within our team.
	The goals for subtasks were accepted by all team members.
	There were conflicting interests in our team regarding subtasks/subgoals.(R)
Balance of Member Contributions	The team recognized the specific potentials (strengths and weaknesses) of individual team members.
	The team members were contributing to the achievement of the team's goals in accordance with their specific potential
	Imbalance of member contributions caused conflicts in our team.(R)
Mutual Support	The team members helped and supported each other as best they could.
	If conflicts came up, they were easily and quickly resolved.
	Discussions and controversies were conducted constructively.
	Suggestions and contributions of team members were respected.
	Suggestions and contributions of team members were discussed and further developed.
	Our team was able to reach consensus regarding important issues.
Effort	Every team member fully pushed the project.
	Every team member made the project their highest priority.
	Our team put much effort into the project.
	There were conflicts regarding the effort that team members put into the project.(R)
Cohesion	It was important to the members of our team to be part of this project. The team did not see anything special in this project .(R)
	The team members were strongly attached to this project.
	The project was important to our team.
	All members were fully integrated in our team.
	There were many personal conflicts in our team.(R)
	There was personal attraction between the members of our team.
	Our team was sticking together.
	The members of our team felt proud to be part of the team.
	Every team member felt responsible for maintaining and protecting the team.

(R) = reverse coded item

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