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An Experimental Investigation of Creativity in Relation to Extracurricular Activity and GPA in Undergraduate Engineering Students

Maria Gonzalez
University of Central Florida

AN EXPERIMENTAL INVESTIGATION OF THE STATE OF CREATIVITY IN RELATION TO EXTRACURRICULAR ACTIVITIES AND GPA IN UNDERGRADUATE ENGINEERING STUDENTS

by

MARIA CRISTINA GONZÁLEZ
B.S. University of Central Florida, 2007
M.S. University of Central Florida, 2010

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ABSTRACT

Measuring creativity for engineering is paramount; previous research has shown that creativity diminishes as students advance through college. This study intends to find possible predictors for creativity in these students. These predictors include GPA, Hobbies, and Extracurriculars while using the Test of Creativity Thinking – Drawing Production (TCT-DP) as a benchmark for creativity. Participants were Junior and Senior year engineering students in Spring 2021. All eligible study participants were provided a TCT-DP and survey to complete. Individual creative ability was assessed from the resulting TCT-DP using a 13 categorical scoring matrix by independently trained evaluators using the scoring guidelines. The accompanying survey was paired with the creativity scores to provide insight into the participants' leisure habits, Grade Point Average (GPA), and demographics. Multiple linear regression models were used to analyze the relationship between predictor variables and creativity. Results indicated that extracurricular activities and hobbies were predictors of creativity primarily through activities related to the Arts, although additional time spent on these activities does not significantly affect this relationship. GPA was also a predictor of creativity by increasing scores across GPA ranges. The results suggest that participation in any extracurricular or hobby category may be a leading predictor more than the time spent performing that activity. More opportunities for students engaged in extracurricular or hobbies, especially if tied into interdisciplinary categories such as the Arts, would, in theory, produce more workplace-valued creative thinking engineers.

This dissertation is dedicated to my grandmother, *Ana Isabel Buitrago*. Thank you for identifying my dyslexia as a learning difference. You made it into a strength and encouraged the passion for learning.

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LIST OF ABBREVIATIONS

Bfd	TCT-DP Sub Score – Boundary breaking that is fragment dependent
Bfi	TCT-DP Sub Score – Boundary breaking that is fragment independent
BSIE	Bachelor of Science in Industrial Engineering
Cl	TCT-DP Sub Score – Connections made with Lines
Cm	TCT-DP Sub Score – Completions
Cn	TCT-DP Sub Score – Continuations
Cth	TCT-DP Sub Score – Connections made to produce a Theme
CS	Creativity Score
ECH	Extracurricular Hours
EGS	Engineering: Support
GPA	Grade Point Average
HH	Hobby Hours
Hu	TCT-DP Sub Score – Humor/Sensitivity
IBM	International Business Machines Corp.=
IRB	Institutional Review Board
Ne	TCT-DP Sub Score – New Elements
Pe	TCT-DP Sub Score – Perspective
SPSS	Statistical Product and Service Solution
STEM	Science, Technology, Engineering and Mathematics
STEAM	Science, Technology, Engineering, Art and Mathematics
TCT-DP	Test of Creative Thinking – Drawing Production
Uca	TCT-DP Sub Score – Unconventionality A
Ucb	TCT-DP Sub Score – Unconventionality B

Ucc	TCT-DP Sub Score – Unconventionality C
Ucd	TCT-DP Sub Score – Unconventionality D

CHAPTER ONE: INTRODUCTION

Background and Context

An essential part of creativity is the human mind. Without it, there would be a void of creativity in the world (Boden, 2004). Engaging in a creative process to solve a problem or design a novel artifact is essential to engineering as a profession, especially to future engineers (Shanna R. Daly, Mosyjowski, & Seifert, 2014; Prahalad & Ramaswamy, 2012). Creativity in engineering students is quickly gaining more attention from researchers as an essential characteristic and aspect of engineering design, as demonstrated by the increased amount of study conducted on the topic in the last few decades (Atwood & Pretz, 2016; Karwowski, Lebuda, & Wisniewska, 2009; Kaufman, Kornilov, Bristol, Tan, & Grigorenko, 2010; Sawyer, 2006). One such study on engineering and creativity took place here at the University of Central Florida. These researchers emphasized that engineers are in the business of creativity and innovation; consequently, building up the creative skills of engineering students to enhance future innovation in their career environments is vital (Bojulaia & Pleasants, 2021; Solá & Hoekstra, 2016). Genco, Hölttä-Otto, and Seepersad (2012) demonstrated the leading indicator of this issue by showing that, while senior students became better at computing through their mandatory college coursework, they lost the creative faculties more present in their freshmen counterparts.

Creativity and critical thinking are essential 21st-century skills required for math, science, music, dance, cuisine, running a family, or engineering, yet common belief has them as mutually exclusive (Azzam, 2009). Research in the cognitive and neurosciences has identified emotion's role in creativity, cognition, learning, and decision-making, but as creativity is critical to the arts, it must play an equally crucial part in the sciences (Immordino-Yang, 2008; Immordino-Yang & Damasio, 2007). This disconnection in mentality causes other material to usurp creativity in elementary and higher education. As stated by Sir Ken Robinson, "The real way to improve education is not from the top down; it is from the ground up (Bell, 2015). Additional evidence that correlates with this sentiment is Professor George Land, who found an alarming decline in creativity. He explains how he tested a group of children three to five-year-olds' for divergent thinking, in which 98% of them yielded a "genius in creativity" status. However, only 32% of the same children fell under the same status when tested five years later. Unsurprisingly, the results yielded worse scores with the children five years after that; only 12% had a result of "genius" creativity. Furthermore, and entirely in line with the declining trend, when administered to the same group as adults over 25, only 2% had the "genius rating"(Markides, 2013). Therefore, something must be done in our educational practices to disrupt our students' current lackluster creativity results.

Theoretical Framework

To understand why creativity is so critical yet lacking enrichment in our education system for engineering students, we first need to understand the theory of creativity. This concept is of supreme importance for future engineers since creativity and innovation are keywords found in many job descriptions. For years, there was no real consensus of what creativity was or how it could manifest in an individual. Some cultures believed it to be a divine gift or a sort of guardian spirit (Kozbelt, Beghetto, & Runco, 2010). Thankfully, research has demonstrated creativity to be a skill anyone can possess under appropriate conditions; even more importantly, it will grow and strengthen through continuous exposure and training (Andreasen, 2006; Starko, 2014). Another point raised in recent years is that creativity is hard to recognize in individuals and even harder to encourage. Students have many tools at their disposal, but the tools themselves are not sufficient: it takes creative people to know how to use them (Robinson, 2006). This lack of understanding is where the gap lies in the research on educating students in creativity. How can students exploit their creativity?

To equip engineering students with creativity as a much-needed and sought-after skill. The primary motive for this study is to determine what, if any, factors or predictors are present in students that will help promote and further develop their creative skillset, specifically in the field of engineering. One possible solution lies in utilizing project-based classes, which have previously demonstrated improvements to students' creativity skills (Chunfang, 2012; Court, 1998). Considering this, we will explore methods inspired by project-based learning, i.e., hands-on extracurricular activities that promote and stimulate creativity (Terenzini, Springer, Pascarella, & Nora, 1995; Tsui, 2000). Increasing numbers of institutions recognize creativity's due level of importance, including the Franklin W. Olin College of Engineering (Goldberg & Somerville, 2014), Stanford University (Kelley, 2007), and MIT (Wilczynski, 2015). This research explores the lessons learned from those institutions that have veered away from traditional engineering practices.

Further exploration in this discussion will lead to potential next steps to proactively developing creativity skills. Considering all these variables is where we find the opportunity to investigate extracurricular activities, hobbies, and GPA as possible predictors of creativity within the engineering student. Fantz, Siller, and Demiranda (2011) found that students who participated in engineering classes during middle school and high school and participated in engineering-related hobbies and extracurricular activities showed a higher self-efficacy. Could the same be said for self-efficacy in creativity? Is there a way educators can encourage students toward lifelong learning initiatives that will keep creativity nimble beyond their academic years?

Problem Statement

Could the same benefits of extracurricular activities and coursework lead to improved creativity in the classroom? In the 2008 TED Talk "Play is More Than Fun," Stuart Brown stated that "Feedback from frustrated employers suggest that they are not fully satisfied with the outcoming of professionals' creativity, innovation, and problem-solving skills (which is driven by creativity)." Ergo, companies compensate for what students lack directly after graduating from college through additional training to have better-prepared professionals in their incoming workforce (Brown, May 2008). For example, Terenzini et al. (1995) found benefits from extracurricular activities toward sparking critical thinking in students; when students participated in different disciplines, critical thinking was more apparent. They conclude that the right mixture of extracurricular activities and the proper coursework positively influenced critical thinking.

Relevance and Importance of the Research

A curriculum focused on higher-level mathematics and physics courses rarely encourages creativity in today's engineering classrooms. The teaching and development of creativity as a valuable skill in students is severely lacking in all levels of courses (Shanna R. Daly et al., 2014). Implying the intention to foster creativity is not enough; it should be stated forthrightly to students from day one. Professional Engineers often work with their peers in Marketing, Finance, and Design Departments to develop or improve products. Adequately aligned real-world situations in a course or activities could help students prepare for these collaborative efforts in the workforce. To go a step forward, if critical thinking is positively affected in students by "out-of-class factors" by way of campus culture and social involvement (Terenzini et al., 1995; Tsui, 2000), could the same be true for creativity? Could extracurriculars help students develop these higher-level cognitive skills needed for critical thinking and creativity? Tsui (2000) explained that even though there was a push for higher cognitive thinking abilities in the 1980s and 1990s, institutions still rely heavily on memorization, which does not help retain learned knowledge.

This study seeks to identify specific extracurricular activities and how they might influence students' creativity levels. The second set of parameters explores the relationship between creativity and Grade Point Average (GPA) scores, as Gralewski and Karwowski (2012). According to these researchers, there has not been a meta-data analysis between creativity and school performance.

Research Questions

The following research will explore other possible avenues which could affect creative skill development outside the traditional classroom environment, potentially through extensive project-based learning. The following questions have resulted after carefully considering all the research evidence found in the literature review.

- Could GPA be an indicator of creativity?
- Do predictors exist to suggest higher levels of creative output within engineering through hobbies and extracurriculars?
- Can these predictors and interactions then be exploited to produce more highly creative engineers required in the future workplace?

CHAPTER TWO: LITERATURE REVIEW

Defining Creativity

Creativity is often defined as the generation of useful, valuable, and novel ideas (Paulus & Nijstad, 2003). Two leading theories of creativity include the developmental theory and psychometric theory, as identified in the *Cambridge Handbook of Creativity* (Mayer, 2005). The developmental theory postulates that group learning and instruction can increase creative potential and achievement over time. The psychometric theory focuses on measured assessments of reliability and validity of creativity (Kozbelt et al., 2010), basically stating whether an idea is original and functional. It is possible to diverge so much that it will not be considered useful, albeit novel. Novelty and usefulness are critical aspects of creative engineering design, thus leading to better innovations in the professional field (Andreasen, 2006). Challenging the ideas of "novelty" and "usefulness" is simply not enough to explain creativity in production, which can expand the psychometric theory of creativity in terms of assessing the reliability and validity of the final creative product.

Creativity being a complex and vast concept, these two theories form only a tiny fraction of its definition; for our limited time and to stay within scope, these will be the concentration. Like creativity, they can converge and diverge in their respective methodology. The developmental approach is an internal process unique to each individual. Kozbelt et al. (2010) state that the developmental theory is one of the foundational theories in creativity literature; it focuses on the role frequently dynamic environments can play in fulfilling creative potential over time. Environments are a crucial aspect of this study. When individuals participate in an extracurricular or hobby, they typically do so in a space where they are comfortable, safe, find enjoyment, and feel independent, being in "one's happy place." When left to their own devices, individuals can become autonomous in their conscious thought, allowing them to devise original thoughts (Kozbelt et al.). To have the ability to experiment with original ideas without restrictive oversight. Independence is the best way to enable individuals to play and be creative; environments that support innovative ideas may result from the relaxation and enjoyment of play (Kozbelt et al.).

The psychometric theory is the outward expression and acceptability of that creative process. What may be considered a convergent ideal between these two theories is the subjective nature in which a creative product will be judged, graded, or perceived. It focuses on reliability and validity in the measurement of creativity. Reliability represents a consistency of measurement, and validity means the accuracy of measurement (Kozbelt et al.). Creativity measurements are a vital aspect of this study concerning the reliability and validity of the TCT-DP creative scores, details explored later. Importantly, this theory emphasizes these measurements or indices as unique and distinct from other non-creative talents (Kozbelt et al.) indices, like IQ or even GPA. Establishing the TCT-DP creative scores as unique and distinct from these other measurements allows for clear distinction and analysis in this study. The psychometric theory also explores convergent and divergent thinking within these measurement assessments, especially divergent thinking (Kozbelt et al.). When divergent thinking is allowed, as in the case of the TCT-DP, several new original ideas are possible, some of which may be unique or novel.

Exploring this notion further in creative engineering design is how consumers might ask themselves, “How did we live without this before?” For this to happen, first, it must be registered through the senses; the object must be perceived: perception is the act of detecting stimuli and deciphering their meaning (Nęcka, 2011). The process creates a mental representation of the object. When creating genuinely new ideas regardless of the field, perception is pivotal for the creator and the audience. If perception is not present, an idea cannot take form with its creator nor be understood or appreciated by the target audience.

Creativity would be rendered useless with spectators that are not sensitive to it; it might even cease to exist (Nęcka, 2011). Literature on this topic generally states that the consumer's perception determines if something is valuable, innovative, and impactful to society. Im, Bhat, and Lee (2015) define product creativity as when a new product is uniquely different from a competitor in a meaningful way. This perception can sometimes be a hindrance when left in the hands of corporate executive boards, especially when the interpretation of what is unique and usable is not in sync with the actual consumer experience. These researchers provided the example of RJ Reynolds investing $325 million in developing a "cleaner" way of smoking with their smokeless cigarette, which ultimately failed in their endeavor to have the consumer accept it as a viable alternative. The decision of whether a product is a success or not lies mainly with the consumer to accept or reject the idea (Im et al., 2015). Examples such as RJ Reynolds have given way to a new conundrum of creativity: what exactly does making a creative or innovative product entail, other than usefulness and novelty? It might be missing a further intangible factor or experience for the user.

In our ever-growing complex world, definitions change and evolve as processes become more complex and evolve as well. In this case, a creative product must be useful, novel, and surprising. It is worth considering that the terms directly correlated with creativity may now be both clichéd and antiquated; there is a need to meet new requirements to make a product worthy of "creative" status (Becattini, Borgianni, Cascini, & Rotini, 2017). Becattini et al. argue that "surprise" is when an artifact produces a sense of astonishment. A consumer should be questioning even the possibility of the product. As with the case of RJ Reynolds, however, novelty can still yield results that do not enthuse consumers. Im et al. (2015) contested that novelty is not always enough for a product to be considered creative. Ultimately Becattini et al. and Im et al. arrive at similar conclusions. Im et al. use the term “coolness” when explaining the phenomenal success of the iPod, iPhone, and iPad product lines. Essentially, products can be “cool” while being novel, but novel products are not necessarily cool. Missing the crucial “cool” element might hurt the products’ chances of success. While the denotation of creativity is straightforward, addressing the connotation is abstract when considering what consumers perceive to be novel, useful, or surprising products.

Creativity and Critical Thinking

A concise description of the relationship between creativity and critical thinking skills states: “...whereas creative thinking is carried on by violating accepted principles, critical thinking is carried on by applying accepted principles. Although creative and critical thinking may very well be different sides of the same coin, they are not identical” (as cited by Baker, Rudd, and Pomeroy (2001). Similar to creativity only in that its oversimplified dictionary definition fails to describe the complexity of this abstract notion, critical thinking is the objective analysis of facts to form a judgment. This judgment can be derived from the number of variables that include, but are not limited to, the thinkers' disposition, problem-solving skills, their assumptions, their thinking processes, and how they approach tasks (Stassen, Herrington, & Henderson, 2011). Many agree that the reality of this form of thinking is much more complex than the standard broader characterization (Paul & Elder, 2006; Vejar, 2013). Critical thinking is more closely related to attaining new information and internalizing it. This process is followed by managing the newly acquired material and challenging it with existing information and experience to update the individual’s knowledge base (Vejar, 2013). Critical thinking is the process of learning and constructing rules for production; creativity is recognizing what rules to break and how to conjure something genuinely extraordinary. Creativity requires critical thinking as a foundation, but critical thinking does not always lead to creativity.

Geissler, Edison, and Wayland (2012) attest that traditional classroom environments cannot give way to the acquisition of creativity and critical thinking skills in the limited time of a course. Instead, students can obtain these skills more effectively through active learning and team-based projects. These concepts frequently overlap in how they are learned and developed in an individual's skill set. As the researchers explained, "Group projects, experiential exercises, cooperative learning, learning-centered activities, class discussions, collaborative projects, case projects, simulations, role-playing, and debating are tools for active learning"(Geissler et al., 2012). These activities help both critical thinking and creativity to thrive.

Collaboration in diverse groups forces individuals to consider problems from other interdisciplinary perspectives. With different acquired information coming from each person, enhanced critical thinking occurs for each member, giving way to creativity. This type of collaboration might also address other issues for creative idea generation. Such issues might include but are not limited to individual risk attitudes, the structural presentation of problems, and the flow of creative ideas during the design stage (Toh, 2014). For instance, the structure of design problems influences the designers' ideas, and different questions will lead to various creative solutions (Studer, Yilmaz, Daly, & Seifert, 2016; Vurkac, 2017). For this reason, open-ended questions are imperative in engineering design courses. They provide the freedom that a conventional question does not.

Importance of Creativity in Engineering

As stated by Sir Ken Robinson: "Creativity is now as important in education as literacy, and we should treat it with the same status" (Robinson, 2006). Researchers hold creativity in such high regard that they believe young children should be taught as early as possible (Williams, 2002). Although it is an argued subject, the reality is vastly different; schools do not teach, appreciate, or support creativity (Gralewski & Karwowski, 2012;

Sawyer, 2006). In many regards, the education model has strayed from encouraging creativity and instead focuses increasingly on more rigid structures of logic and memorization. This practice gains momentum as schools emphasize STEM (Science, Technology, Engineering, and Math) (Abdekhodaee & Steele, 2012), while the Arts become obsolete via budget cuts in many regions. It sometimes seems the focus of educating well-rounded students is a practice from the past, along with the importance of balancing logic with creative expression (Bojulaia & Pleasants, 2021). Engaging in a creative process to solve a problem or design a novel invention is essential to engineering as a profession, particularly for future engineers (Shanna R. Daly et al., 2014).

It is common to believe that creativity and logical thinking are mutually exclusive. The truth is that there cannot be one without the other. Students should be well-educated enough in their chosen field to have the necessary domain knowledge that enables them to attack any challenges actively and confidently they encounter. Simultaneously, challenging the boundaries of logical thinking, a creative leap is crucial to encourage new and unique thought. High levels of achievement in a particular field do not typically occur without devoting hundreds, rather thousands of hours to serious training. Creation is not linear; it is iterative (Harris, 2013; Sönmez, 2013). There is a correlation between creativity and mastery of specific domain knowledge (Csikszentmihalyi, 1999). True mastery may take up to or exceed ten thousand hours of practice (Ericsson, 1998; Questlove, 2019). Therefore, creativity in a field will take time to manifest itself.

Industrial leaders have long expressed mounting concern about the impact of traditional engineering education on the creative potential of future engineers (i.e., lacking design capability or creativity) and an appreciation for considering alternatives (Ogot & Okudan, 2006). Those involved in engineering education theorize that engineering students are not comfortable with creative thinking; this leads to much concern (National Academy of, 2004; Zeki, 1999). Numerous studies emphasize the need to support engineering students in their ability to think creatively (Clough, 2004; Shanna R. Daly et al., 2014; Felder, Woods, Stice, & Rugarcia, 2000; Sheppard, Macatangay, Colby, & Sullivan, 2008). Without this encouragement, the engineering fields will have a void of novel and revolutionary creation for demand, thus stunting the stimulation to economies (Cornelissen, 2013; Steinwart & Ziegler, 2014); to achieve this, engineering students need thoroughly prepared educators. It is not enough to only instruct students to be more creative; this may create a sense of intimidation or resistance. Possible ways to mitigate this issue could include developing creative strategies to assist with active engagement in learning, such as simulation, spaced education, and educational gaming (Steelman, 2014).

Therefore, a more critical element is to provide students with these skills to ask creative induced questions in the future. An environment where students can conclude organically is necessary for their innovative development (D. Z. Meyer & Avery, 2010). The query of what a science classroom should look like is clear, but the actual procedure of designing one into fruition is complicated (D. Meyer, 2012). Problem-solving is heavily dependent on domain knowledge (Kilgour, 2006). To ask precise questions on their own to begin deciphering the problem presented, students need foundational domain knowledge of the subject matter in question. By asking the right question with multiple possible answers, they will more likely provide creative solutions. These critical thinking factors are essential for the domain knowledge needed to be creative within an individual's field.

The need to prepare engineering students to be creative thinkers, analytical, and technically capable is paramount (Conwell, Catalano, & Beard, 1993; Katehi & Ross, 2007). Researchers have examined some suggestions to help creativity thrive; engineering students might be introduced to artists' perspectives via initiatives to increase STEAM learning (Science, Technology, Engineering, Art and Mathematics) (Steelman, 2014).

Interdisciplinary routes can provide creative insights; the Arts look at the world from a different viewpoint than science; when artists create, they ask specific fundamental questions. When creating a painting, drawing, or sculpture of a bed, the artist starts with a straightforward inquiry: 'What is a bed?' Beds are not the same all around the world. A designer may not design the same bed style for an Asian audience as they would for an audience in the United States (Hoekstra, Fall 2015). Introduction to an artistic background adds a new perspective to the equation. Costantino, Kellam, Cramond, and Crowder (2010)incorporated art lessons into their curriculum along with critical sessions. Their work added creative thinking strategies into an engineering course that focused on an open-ended design problem related to sustainability and food within the local community. The students' feedback regarding their newfound knowledge was promising. One student stated, "I never once thought that art and engineering would go hand in hand... but seeing the problem in a different light led to multiple solutions, whereas, without this perspective, there may have only been one solution or no solutions"(Costantino et al., 2010). This common misconception makes it seem that Art and Science are diametrically opposed. Individuals can better understand this incorrect notion through personal experience or deep research.

An example presented by (Lasky & Yoon, 2011) contained a lesson in which the class made shoes. Students needed to protect "feet" from the elements during the creative process. Students could break down the problem to the most open-ended point possible. For example, what does it mean to protect the foot and what materials provide protection, i.e., plastic, cloth, steel. Trying materials not automatically associated with a shoe makes for an open-ended discussion. As professionals, engineers design products to meet specific criteria and often must stay within technical boundaries, without the opportunity to add a creative twist. It is all very logical and mechanical, but as eloquently stated by a student in a parallel study, "The Arts give us a rich life; you want more than a sustainable life" (Daly et al., 2014). By enriching their creative skills through the Arts, individuals develop sensitivity to enhance their other work, creating a skill set that gives way to more active problem-solving. The students echoed this sentiment in one of our previous studies (Costantino et al., 2010) “If you lose yourself in research, then you’ll find the problem.” This empowerment provides students with a certain level of confidence that fuels creativity.

Creativity Does Not Work Alone

Students also need to learn the necessary skills to grow their domain knowledge independently once they join the workforce (White, Wood, & Jensen, 2012). The perfect balance is utmost in order to practice these skills. The problem-solving process cannot be too straightforward, or it will become a thoughtless exercise rather than one that sparks innovation. With too complex a problem, the students’ advancements in the solution-developing process will stall, as they may not have the necessary experience to deal with the conundrum (D. Z. Meyer & Avery, 2010). As stated, trying to recreate this type of problem-solving scenario in a classroom setting compared to the professional world presents a challenge. Scientists and engineers often use trial and error to research and find innovative solutions. Due to time constraints, resources, and the lack of readily available opportunities to practice, trial and error is a more challenging feat in a classroom environment. Additionally, the financial constraints are vastly different for professionals than for instructors and students.

Change is often slow in academia, even with some efforts underway to implement these methods in traditional engineering courses. Engineering is a particularly conservative discipline (Daly et al., 2014). Researchers argue that open-ended projects have multiple possible solutions; thus, they allow students to generate more creative ideas (Baillie & Walker, 1998; Ishii, Suzuki, Fujiyoshi, Fujii, & Kozawa, 2006; Jablokow, 2001). One additional positive element for open-ended projects is the opportunity for students to reflect on their creative processes as they work through a project, thereby discovering new ways to improve their creativity. The company IDEO uses the skill of acquiring new domain knowledge down to a science: they can ask these questions and execute the answers for new projects presented to them (Kelley, 2007).

Tom Kelley (2007) recounted how one of IDEO's most notable projects featured on ABC's *Nightline* came to be. The task at hand, innovate the typical shopping cart. They split up into groups looking at safety, preventing theft, and how different individuals interact with the carts. For example, how does the experience of consumers differ from the shop owners to the experience of the repairman? The team came back together and shared their findings. At that point, they all went home for an incubation period and came back fresh to attack the problem again the following day. This is where ideas flew in a "focused chaos" approach, followed by a mock-up session from each team. From here, they knew that they would not necessarily stick with one idea. With the mentality that "no idea is so good that it can't be improved upon," they spent another day making a final prototype, taking all ideas from the mock-ups into consideration. Seemingly overnight, an innovative take on an old, boring idea, the shopping cart. This approach gave way to a modern modular cart with different baskets and advanced features catered to multiple audiences. This example of project-based work may make space for creativity and innovation in engineering design.

How Project-Based Work Could Be the Key to Success

Brainstorming is a tool coined by Osborn (1953). He first described it as a group activity, but over time this has not proven to be quite as effective as first believed. While this method may still be effective in some forums, it lacks the desired synergistic effect in many design situations. Specifically, groups working together do not produce any higher quantity or quality of solutions in the brainstorming environment than a group of individuals generates working alone (Mullen, Johnson, & Salas, 1991). Further research shows that brainstorming can work if conducted in a particular style. After raising the open-ended question and acquiring the initial set of necessary domain knowledge, the individual or group must make way for all ideas no matter how impractical and encourage participation from all group members. However, this proves difficult for some creative individuals within a group. At least at times, creative people may appear hermetic, attempting to avoid stimulating overload (Martindale, 1999).

In “Making Space for the Act of Making: Creativity in the Engineering Classroom," an instructor implemented traditional brainstorming methods but also provided students with a variety of types of information-gathering experiences (working with clients or doing research) to seed different idea generation (Lasky & Yoon, 2011). The students who accomplished this process met with the clinicians in a problem statement meeting. The students then brainstormed to find potential solutions. Often, what lowers the quality of a brainstorming session is the threat of others' judgments on the ideas proposed by an individual. Moreover, group brainstorming sessions originated to increase creative output, but they often have the opposite effect. Economic theories also offer a testable hypothesis about creative efforts. They predict, for instance, that larger groups will inhibit brainstorming because the costs of being different, and therefore original, is higher when the audience is large (Martindale, 1999). Researchers believe this is due to the heightened cortical arousal in the disinhibition framework, which accompanies the group-session work environment (Kaufman et al., 2010; Lindgren & Lindgren, 1965). Kaufman et al. expand on the point, stating that creative people show lower levels of cortical arousal, thus giving way for creative thought and procedure.

Improved methods of making space for creativity might include giving students time to brainstorm and explore new ideas on their own first. Even without using any form of punishment for new ideas, such as criticism, students still feel peer pressure not to have a “dumb” idea regardless of how innovatively promising it might be (Lasky & Yoon, 2011). Brainstorming can be a useful working tool for students armed with the domain knowledge and liberated from the inhibitions of feeling judged. As many professionals now agree, a particular methodology exists for effective brainstorming. A crucial takeaway from observing group brainstorming sessions could be how instructors could create groups for students to succeed. Students could brainstorm independently, thus removing the first idea bias, and come together to share and compare notes (Hoekstra, Fall 2015).

Regardless of the industry, the professional workforce increasingly utilizes interdisciplinary teamwork. Students are becoming more aware that working with other disciplines proves to be progressively more important as they prepare to enter the workforce (Demir, 2016). Demir describes four crucial findings from his fieldwork studies dealing with industrial design students. First, they recognize how vital interdisciplinary teamwork is for their degree and are open to this type of collaboration. Secondly, they concur that this type of relationship with other majors better prepares them for the future after their studies. Next, they feel responsible for introducing and explaining their vocation to other disciplines, leading to self-reflection on their occupation and self-confidence as future professionals. Finally, the experience changes the students’ perspectives on interdisciplinary work to the extent that they may become advocates and actively urge this collaboration with other fields.

Investigating how other masteries deal with creativity offers a different perspective on why interdisciplinary work is imperative. All disciplines deal with similar or unique constraints for creative output. Vurkac (2017) explains how the Arts also deal with problem-solving under constraints for their creative outcomes, such as the desire to provide authentic and high-quality experiences, constantly dealing with budget cuts, and other limited resources. Daly et al. (2016) introduced a strong argument for how other disciplines view the creative process. The researchers referenced Kazerounian and Foley (2007) and analyzed the ten principles of creativity as follows:

1. Keep an open mind
2. Ambiguity is good
3. Iterative process including idea incubation
4. Reward for creativity
5. Lead by example
6. Learning to fail
7. Encouraging risk
8. Search for multiple answers
9. Internal motivation
10. Ownership of learning

Daly and colleagues then surveyed students and instructors across disciplines and encountered a discouraging finding: engineering students only identified with one of the creativity principles present in their curricula -- internal motivation. Other science students only identified with four of the ten: ambiguity is good, a reward for creativity, encouraging risk, and ownership of learning. By comparison, students in the humanities related to most principles, only failing to recognize two: ambiguity is good and learning to fail. Therefore, there is a strong argument that interdisciplinary work at a college level could close the gap of creative understanding for engineers and better develop their creative skills in this ever-evolving profession.

While engineers must have strong skills in math and logic, they should ideally also possess an intuition for design. Per Daly et al. (2016), “Intuition is an internal sense of direction based on accumulated experience that is often difficult to describe in rational terms” (as cited in (Klein, 1999). Creative prototyping could be the tool to help engineers develop that natural intuition. Research suggests that making objects in the classroom is the best way to help students think creatively (Do & Gross, 2007; Jacucci & Wagner, 2007). In several classes, instructors specifically expressed desired results regarding students' ability to play and explore things that interested them, regardless of practical considerations (Daly et al., 2014). Learning to go beyond their immediate impressions to investigate conflicting ideas, develop ideas through repeated attempts, and respond to failure are essential in students' creative endeavors (Shanna R. Daly et al., 2014; Treffinger, Young, Selby, & Shepardson, 2002).

Creative Teaching Theories

Several creativity theorists suggest teachers need help to construct creative learning environments that make space for innovation within their classrooms (Do & Gross, 2007; Jacucci & Wagner, 2007; Lasky & Yoon, 2011). Additionally, there is an existing disconnect between students and teachers, and there are certain aspects of creativity that the engineering world cannot place in tangible forms. For example, a common negative connotation of risk-taking is unacceptable in engineering, but risk-taking is necessary for creativity. Therefore students feel that creativity is not encouraged, and professors feel precisely the opposite (Shanna R. Daly et al., 2014). Research shows that learning environments are best when teachers support creative learning through hands-on activities (Barry & Kanematsu, 2008). The distinction between "teaching creatively and teaching for creativity" (Azzam, 2009) should be made clear to understand how to help young engineers master skills to help them in their professional journeys. Teaching creatively requires the teachers themselves to use their own creative skills to make the subject matter more interesting. Creative teachers succeed with their students because they can connect the lesson plans to students' interests. Azzam (2009) distinguishes this from 'teaching *for* creativity,' specialized curriculum to encourage students to think creatively themselves. Encouraging experimentation and innovation without providing answers can do this. Providing these tools is essential to finding new, unorthodox answers and possible solutions.

With creative teaching theories, come creative teaching misconceptions. Robinson and Aronica (2016), along with Azzam (2009), have discredited the claim that creativity belongs to “special people”; instead, it is a skill that can be improved with discipline and requires daily education. Similarly, researchers explain two unwillingly created mindsets for students: the fixed mindset and the growth mindset (Barry & Kanematsu; Dweck, 2008). When individuals believe intelligence is static, a heightened fear of failure is present; the students stop being adventurous in their mentality to attack the problem at hand. What is the point of trying if obstacles will stand in their way? Students will actively avoid challenges, efforts are fruitless, and there is no such thing as constructive criticism -- their peers and superiors are judging them. Conversely, with the growth mindset, intelligence is like a muscle to work, exercise, and develop to one's desired potential. Here, students embrace challenges, obstacles are to be conquered and defeated with effort and persistence, constructive criticism is key to learning, and inspiration comes from those who have succeeded before.

Researchers criticize engineering classes for having a "cookbook" approach, meaning they process the ingredients in a prescribed fashion. This mentality works when a regimented process can be followed to a technical solution but fails when innovative solutions are required (Acar, 1998). As any good cook might confirm, exciting and satisfying solutions prove challenging to achieve without creativity.

The research on this topic shows that sufficient domain knowledge has a well-documented impact on creative performance. So why then do upper-level students show reduced levels of creativity compared to their freshmen counterparts (Genco et al., 2012)? What might they be missing from the formula to creative success? Knowing the impact of domain knowledge on creativity (Waks & Merdler, 2003), the need for modern and conventional curricula within any given concentration is understandable. Current practices allow students to be more independent and hands-on; formal studies provide the essential knowledge they need to understand the complexity of their work and not be hindered by new challenges. An updated curriculum could provide a partnership between these two elements, not to create constant competition between modern and conventional methods but enhance both.

Teams and Prototyping

An additional idea for fostering creativity is creating teams that align individuals with similar approaches and interests to the problem. This collaboration will ensure that the students/colleagues respond faster to a meeting of the minds and propel their possible solutions. Again, this is not always the case. In traditional academic and corporate practices, teams are often assigned, not taking peoples' interests in mind. Instructors and managers tend to look at peoples' strengths, but coupled with piquing interests, they could yield a higher level of creativity. IDEO has a particular way to create teams which they refer to as "Hot Teams" (Kelley, 2007); no one gets "assigned to a studio." They do things differently; they dedicate time out of their Monday morning meeting to have leaders describe the work that they find interesting. Managers wanted to prevent the awful feeling of getting picked for a particular project that did not pique their interest. The leaders first chose a location at the Palo Alto campus. After that, all employees voted by "secret ballot" their first and second picks for studios. This process was so successful that they could accommodate everyone's first choice. They practiced the same exercise three years later to give the employees the chance to shift around and have the opportunity to work on different teams. Their employees could grow and develop hot teams with unique capabilities, as stated by their managers. IDEO combines interest with strengths, but it also combines standard practices. They have proved a particular type of empowerment when an individual is part of the team and ideology they favor.

Prototyping could lead to the road of openness to creativity. Intuition is an internal sense of direction based on accumulated experience that is often difficult to describe in rational terms; creative prototyping could be the tool to help engineers with that natural intuition (Shanna R. Daly et al., 2014; Klein, 1999, 2002). Research suggests that making objects in the classroom is the best way to help students think creatively (Do & Gross, 2007; Jacucci & Wagner, 2007). In several classes, instructors specifically expressed desired results regarding students' ability to play and explore things that interested them, regardless of practical considerations (Shanna R. Daly et al., 2014). Learning to go beyond the immediate impression to investigate conflicting ideas, continuing through repeated attempts, and responding to failure is essential in creative endeavors (Treffinger et al., 2002). Daly et al. gather that creativity is not knowing the answer, but rather it is creating one. Creating these non-existing answers is paramount for engineers; the traditional engineering curriculum depends on finding the "right" answer. Not only does prototyping provide that tangible exposure to a possible answer, but it also takes us back to our roots of childhood; children innately like to build and test, and that is what scientists and engineers do (Lasky & Yoon, 2011). If a picture is worth a thousand words, a prototype is worth a thousand pictures (Kelley, 2007). As with anything in life, it is not enough to merely have the proper tools to achieve a task; the most crucial aspect is to know how to exploit these tools effectively to their maximum potential. That is where the instructors' ability to facilitate these tools is vital, but also, they must recognize when creativity is at hand and set it free in their environment. By supporting teams' freedom, they will accomplish tasks and provide tangible results of creativity.

Could Extracurricular Activity Help Creativity Performance?

Students may acquire basic and complex knowledge by learning the conventional curriculum within a particular concentration. However, adding extracurricular activities could enhance that knowledge through more active participation (Rawat, Rastogi, Jaiswal, & Nigam, 2014). These activities can aid students in applying theories developed in the classroom. Rawat et al. also suggest that students develop personality-enhancing traits such as leadership, communication, social and entrepreneurial skills, and other valuable characteristics through these avenues. These traits then influence the students' persistence, self-confidence, and self-efficacy, making way for the creative process.

Rawat et al. (2014) also found a positive association between extracurricular activities and academic performance. This study will further explore the possibility of a promising relationship between extracurriculars and creativity. Unlike project-based classes, extracurricular activities have the benefit of additional available time. Since there is a finite amount of time within a semester, projects conducted for a course are usually limited in scope (Mountain, 2000). Otherwise, the projects do not have the chance to come to fruition. This time constraint has influenced some institutions of higher learning to gravitate towards extracurricular educational opportunities, as in the case of MIT, Stanford University, and the Franklin W. Olin College of Engineering. Mountain explains that developing an unstructured long-term project, created by students but facilitated by faculty members, provides an environment where students and faculty are partners working toward the same goal. Students will strive for a project that can stimulate passion rather than just meeting a course requirement.

Grey, Parker, and Gordon (2018) hypothesized that another factor that prevents creativity from flourishing in the classroom is the extrinsic value grades and assessments bring to the table. Students often view grades as an extrinsic motivator; thus, being concerned about how a grade may be negatively affected will suppress creativity altogether. Research also shows that creativity is hindered by different circumstances, for example, in competitions with a materialistic or monetary value reward (Grey et al., 2018). Therefore this outside-of-the-box thinking is significantly more challenging to achieve due to the extrinsic pressure (Glucksberg, 1962). Consequently, in a study involving toddlers, these children showed more motivation when they received a surprise reward or no reward than their counterparts who knew they would receive a prize (Lepper, Greene, & Nisbett, 1973). Considering the different effects extrinsic and intrinsic motivators may provide an individual, research argues that extracurriculars and hobbies can give way to creativity in a given field. These activities are pursued more for personal passion, giving way to intrinsic motivation and making space for creativity (Grey et al., 2018). Thus, allowing the skill of creativity to develop and strengthen, translate, and overflow into other aspects of life, including academics.

Association between Academics and Creativity

Arguably creativity is a predictor of both adult professionals' success and students' academic achievements and GPA (Milgram & Hong, 1993). In older studies, although not widespread, there has been a correlation between students' creativity and their grades (Gralewski & Karwowski, 2012). If creativity can differentiate between higher and lower performance, it could prove its validity and importance (Freund & Holling, 2008). Researchers often collect data from lower-level education participants; thus, randomly sampling students for creativity is challenging. Socio-economic bias is present and affects academic achievement levels from one school to the next, and other demographical bias from school to school, city to city, country to country (Goldstein, 2011). Without enough studies to provide proper insight, there is a gap in the research for the predictive value of creativity (Freund & Holling, 2008). Research can agree that the relationship between GPA and creativity is vastly complicated. Gralewski and Karwowski (2012) address the need for a meta-analysis of this research but acknowledge the general consensus of a positive yet weak relationship between students' creative ability and school grades.

The mixed findings regarding creativity and academic achievement may be partly due to an unclear understanding of how much higher education institutions encourage and reward creativity in students. A study by Daly, Mrozowski, and Seifert (2014) found that most educational programs do not deliberately evaluate academic work based on creativity. Critical thinking is a more common goal of higher education, but some researchers see creative thinking as an essential component of thinking. For example, Halpern (2013) has argued that critical thinking includes problem-solving and brainstorming solutions, both of which involve creativity. Thus, the question still stands, could GPA be a strong predictor for creativity?

"In times of change, it is the learners who will inherit the earth while the learned will find themselves beautifully equipped for a world that no longer exists" (Burton, 2007). Hence, it is paramount to ready our engineering students with a curriculum designed to prepare them for the future's predictable unpredictability. The key for this curriculum is to stray away from strict and rigid conventional engineering philosophy and instead create a creative environment in which students' imaginations can be free to create. If graduates wish to compete in a global economy successfully, curricula must be updated to include creativity and innovation as crucial professional skills (Hodge, 2007).

CHAPTER THREE: METHODOLOGY

Through personal experience as an Engineering undergraduate and graduate student, in addition to enrolling in art-related courses for personal enrichment, and a deep dive into further understanding of creativity, a research question was formulated. How do different activities undertaken by students affect their creative output? The focus of this design experiment will investigate the relationship between engineering students' creativity and the influence of extracurricular activities, hobbies, and grade point average (GPA). This study aims to add helpful information to the literature on the topic of engineering students' creativity. According to research, this demographic tends to be underrepresented when studying creativity (Clough, 2004; Shanna R. Daly et al., 2014; Felder, Woods, Stice, & Rugarcia, 2000; Sheppard, Macatangay, Colby, & Sullivan, 2008). Researchers provided the participants with a creativity test and an accompanying survey to investigate whether certain activities influenced student creativity fluidity. This study is a non-experimental quantitative study using a Linear Regression design. Linear regression is a statistical tool used to predict a linear relationship between the independent variables and a single dependent variable. In the case of one independent variable, a simple linear regression will be utilized. This study will analyze multiple independent variables as individual simple regression models.

Before any data collection took place, the institutional review board (IRB) provided all written and formal approvals. A copy of the IRB Approval is enclosed in the appendix. In line with IRB policy, the removal of self-identification information of the student was obligatory. Removing the identifiers was especially critical in the data transfer to the test evaluators to provide an unbiased evaluation. The evaluators were only able to have access to de-identified study data. Data was received and collected through Excel spreadsheets and analyzed through SPSS (Statistical Product and Service Solutions). SPSS is an IBM software package used for statistical analysis. The experiment and data collection occurred during the Spring 2021 semester at The University of Central Florida.

This experiment aimed to find a relationship between engineering students' creativity and possible predictors such as extracurricular activities, hobbies, and GPA. This experiment included additional variables for demographical data, but its primary function is to find possible predictors that yield higher creativity scores. A detailed methodology of the experiment follows.

Research Participants

For this study, 123 study participants from a senior level undergraduate engineering course were recruited (EGS 4624 Engineering Innovation and Leadership) during the Spring 2021 semester. Many of these students maintained senior class standing within the university; the study also included junior classmates. This particular course is identified as a university requirement for the Bachelor of Science Industrial Engineering (BSIE) degree and only as an elective for other Engineering majors. At the time of the study, most students in the course were pursuing degrees in Industrial Engineering. Although the population concentration was within a specific degree major, the sample of creativity scores obtained was adequate within its representation of the College of Engineering at the University of Central Florida. Researchers obtained written consent from students that were eligible to participate.

Procedure

Due to the Covid-19 global pandemic, which was still prevalent during initial data collection, many tasks had to be adjusted and conducted in a virtual environment. All changes to procedures were reviewed and approved by IRB before the study proceeded. Through the University's approved virtual lecture system, WebCourses, the students had access to all necessary material for the study. As part of the briefing process on their participation, students had full access to all documentation. During the virtual lecture, it was clearly stated to students that participation was entirely voluntary. Their grade in the course would be positively affected through the opportunity for extra credit but would not be negatively affected in any way through failure to participate. Researchers communicated that students would receive ten extra credit points to incentivize participation in the study. Per IRB, if the participants desired the extra credit points but did not wish to be a part of the study, an alternative assignment was offered.

The instructions specified to participants that any personal information collected would be assigned a new set of non-descript identifiers to hide their identities. This method would keep the information linked but strip it of the students' personal information. Researchers informed students that if they were to decide that they did not wish to participate in the research at any point, there would be no consequence for doing so; the material would be disposed of appropriately. After thoroughly addressing this matter and confirming that the participants were comfortable with the explanation, they were instructed to complete and return the provided consent form with the study material. Any questions were answered as comprehensively as possible without compromising the integrity of the study per IRB requirements.

Following the briefing, investigators instructed students to complete the creative drawing portion of the experiment. The drawing portion, known as the 'Test for Creative Thinking – Drawing Production,' will be identified as the TCT-DP. Additional details for the TCT-DP are covered later in this chapter. This test consists of an incomplete drawing that the students were to finish. Instructions led students to take the drawing provided and treat it as if an artist had been called away before completing it; their job was to make it into a complete piece. Following the drawing portion of the experiment, researchers instructed students to take a quick survey that completed the experimental material. This survey included questions regarding GPA, thoughts on the current engineering curriculum, recognition of their creativity, and finally, what extracurricular, hobbies, and employment they were actively undertaking. Both sets of data were packaged together as a single testing unit.

The instructor and researcher set a deadline of one week for turning in completed material. In total, the briefing of the study took approximately fifteen minutes at the beginning of regularly scheduled class time. The course resumed all normal operations following these activities. Data collection began the day after the assignment due date.

Data Collection

An appropriate creativity test is paramount to properly evaluate the participants' creative skills in this study, remove the subjective nature of creativity, and apply a measurable score. K. Urban and Jellen (1986) designed the TCT-DP to meet these measurable goals. Furthermore, empirical studies in creativity support the TCT-DP as an accepted model on individual creative ability (K. K. Urban, 2005).

Traditional creativity research has long been defined through the characteristics of fluency, flexibility, originality, and elaboration (Jellen & Bugingo, 1989), with the general understanding that creativity solely exists to generate new and novel ideas. Sola, Hoekstra, Fiore, and McCauley (2017) have summarized the TCT-DP variables and their relationships to traditional and current creativity research. The figure below shows these definitions and their direct links to the TCT-DP variable counterparts.

TCT-DP Variables	TCT-DP Variables	Elements Linked to Research	General Definition	Studies Supporting Elements
Cn	Continuations	Fluency[a]	Ability to generate many ideas	
Cm	Completions	Elaboration	Ability to add to ideas to improve them	(Guilford, 1967a; Guilford, Creativity, 1950; Guilford, Three faces of intellect., 1959; Cropley, 2000; Clapham, 1997; Clapham & Schuster, 1992; Runco, Millar, Acar, & Cramond, 2010; Kim, 2011; Cramond, Matthews-Morgan, Bandalos, & Zuo, 2005)
Cl	Connections made with Lines	Flexibility	Ability to generate different types of ideas or ideas from multiple perspectives	
Pe	Perspective	Elaboration	Ability to add to ideas to improve them	
Uca	Unconventionality A	Curiosity[a,b]	Need to explore and understand the known and unknown	(Harrison, 2016; Hunter, Abraham, Hunter, Goldberg, & Eastwood, 2016; Windahl, 2017; Litman, 2005)
Ne	New Elements	Originality	Ability to generate novel ideas	
Ucb	Unconventionality B	Originality	Ability to generate novel ideas	(George & Zhou, 2001; Wutrich & Bates, 2001; Furham, 1999; Perrine & Brodersen, 2005; Dollinger, Urban, & James, 2004; Feist, 2010)
Ucd	Unconventionality C	Originality	Ability to generate novel ideas	
Cth	Connections made to produce a Theme	Synthesis[b]	Ability to coalesce multiple ideas into one	(Runco & Nemiro, 1994; Belski, 2009; English, 1997; Lai, Roan, Greenberg, & Yang, 2008; Ozyurt & Ozyurt, 2015; Wakefield, 1985; Rostan, 1994)
Bfd	Boundary Breaking Fragment Dependent	Detectability[b]	Ability to detect changes, cues and patterns within problem	
Hu	Humor	Sensitivity[b]	Capacity for emotional transference	(Genco, Johnson, Holtta-Otto, & Conner Seepersad, 2011; Chan & Schunn, 2014; Gardner & Winner, 1982; Piirto, 2004; Kohn, Paulus, & Korde, 2011; Mednick, 1962)
Ucc	Unconventionality C	Passion[b]	Ability to express concepts important to the individual	
Bfi	Boundary Breaking Fragment Independent	Risk[b]	Ability to take action in the face of the unknown	(Eisenman, 1987; Pankove & Kogan, 1968; Sternberg, 2012; Steele, McIntosh, & Higgs, 2016; Tyagi, Hanoch, Hall, Runco, & Denham, 2017; McClelland, 1963)

Note: [a]Traditionally categorized as flexibility. [b]Not traditional measures in the evaluation of creativity within current creativity literature, but suggested as new measures for creativity measurement by Jellen and Bugingo (1989). Definitions and supporting literature have been generated by the researcher with reference to measurement intent and literature referring to these characteristics of creative individuals.

Figure 1: Links and Definitions for TCT-DP Measures

For this study, the TCT-DP was provided to study participants for completion. It measures individual creativity by evaluating 13 categories using a scoring matrix and adding all the points for one final cumulative score. The maximum possible point value obtained within this scoring system was 66 points. Researchers instructed students to take the drawing provided and complete the sketch; their job was to make a new original piece. The resulting drawings are then evaluated based on 13 unique identifiers that make up the TCT-DP guidelines for grading. All the pictures provided to the participants contain the same six non-specific forms in an identical presentation.

The 13 categories used to evaluate the TCT-DP were:

- Continuations (CN)
- Completions (Cm)
- New Elements (Ne)
- Connections made with Lines (Cl)
- Connections made that contribute to a Theme (Cth)
- Boundary Breaking being fragment dependent (Bfd)
- Boundary Breaking being fragment independent (Bfi)
- Perspective (Pe)
- Humor (Hu)
- Unconventionality A (Uca)
- Unconventionality B (Ucb)
- Unconventionality C
- Unconventionality D (Ucd)

Three thoroughly trained evaluators scored all 123 TCT-DP. The recruited evaluators met from different fields, including Engineering, Graphic Design, and Language Arts. They comprised of multicultural backgrounds and included two males and one female. These individuals provided a diverse perspective for evaluating creativity within the scoring of the TCT-DP. The evaluators used the scoring guidelines provided in the following table to discuss and agree on all scores. After the initial test scores, the evaluators showed consistency in their scoring results. The three evaluators' scores were then averaged into a single metric; it was then used as the dependent variable for statistical analysis. The agreement between the evaluators provides direct validity to the TCT-DP test and the study. Below is Table 1, The Grading Matrix, which all three evaluators used for grading the drawings.

Figure 2: Example of a Blank TCT-DP Drawing this is the exact drawing that all 123 study participants received for completion. Figure 3 is an example of a low-scoring drawing; the participant used the element to draw independent and unrelated ideas. The theory behind this evaluation is to create one cohesive drawing from all the elements. Additionally, this drawing failed to think "out of the box" literally; the drawing does not break the established square boundary where most of the elements are contained. Finally, the participant maintained a 2D drawing, and no attempt was present to add perspective to the drawing. Conversely, figure 4 is an example of a high-scoring drawing. In this drawing, elements are connected both physically and thematically. The participant breaks the boundaries to create a holistic drawing with elements of surrealism and perspective.

Table 1
Grading Matrix

TCT-DP Scoring Matrix					
Acronym	**Name**	**Definition**	**Criteria**	**Point Assessment**	**Max Score**
Cn	Continuations	Using or extending the 6 picture fragments	Adding to each of the 6 fragments (semi-circle, curved line, right angle, point, broken line, small open square); has the subject acknowledge the fragments	1 pt each	6
Cm	Completions	Completing, adding to, or repeating the fragments	Adding to each of the 6 fragments; broken line becomes longer than 6"	1 pt each	6
Ne	New Elements	New independent elements	New independent elements are present; if repeated only 2 pts	1pt each	6
Cl	Connections made with Lines	Drawn connections between continued or new elements	Independent figures touch each other or are interconnected	1 pt each	6
Cth	Connections made that contribute to a theme	Do the pictures create a cohesive theme	Figures that same a theme get 1 pt each, If 2 'Ne' share a theme with a fragment 3 pts, Abstract and holistic themes get 6 pts	1pt thematic connect., 3pts thematic connect. with 'Ne', 6 pts Holistic themes	6
Bfd	Boundary breaking being fragment dependent	Is the open square fragment addressed	If this fragment is completed 3 points, If altered 6 pts	0,3, or 6	6
Bfi	Boundary breaking being fragment independent	Does the picture go outside the boundary	3 pts for minor portion , 6 pts significant portion	0,3, or 6	6
Pe	Perspective	What view is given by the subject	Are 3D elements present	1pt per 3D element, 2pts Depth & Distance, 6 pts Holistic themes with depth	6
Hu	Humor	Is the subject funny or emotional	Evaluator interpretation	0,2,4,6	6
Uca	Unconventionality A	Unique or novel approach	Physical manipulation i.e., using the drawing sideways, folding, drawing on the opposite side	0 or 3	3
Ucb	Unconventionality B	Unique or novel approach	Is the subject abstract or surreal	0 or 3	3
Ucc	Unconventionality C	Unique or novel approach	Does the subject contain symbols, signs, words, numbers, cartoon-like, artist name does not count	0 or 3	3
Ucd	Unconventionality D	Unique or novel approach	Is it stereotypical; +1 point each for non-stereotypical elements; -1 point for stereotypical elements	1 pt each	3

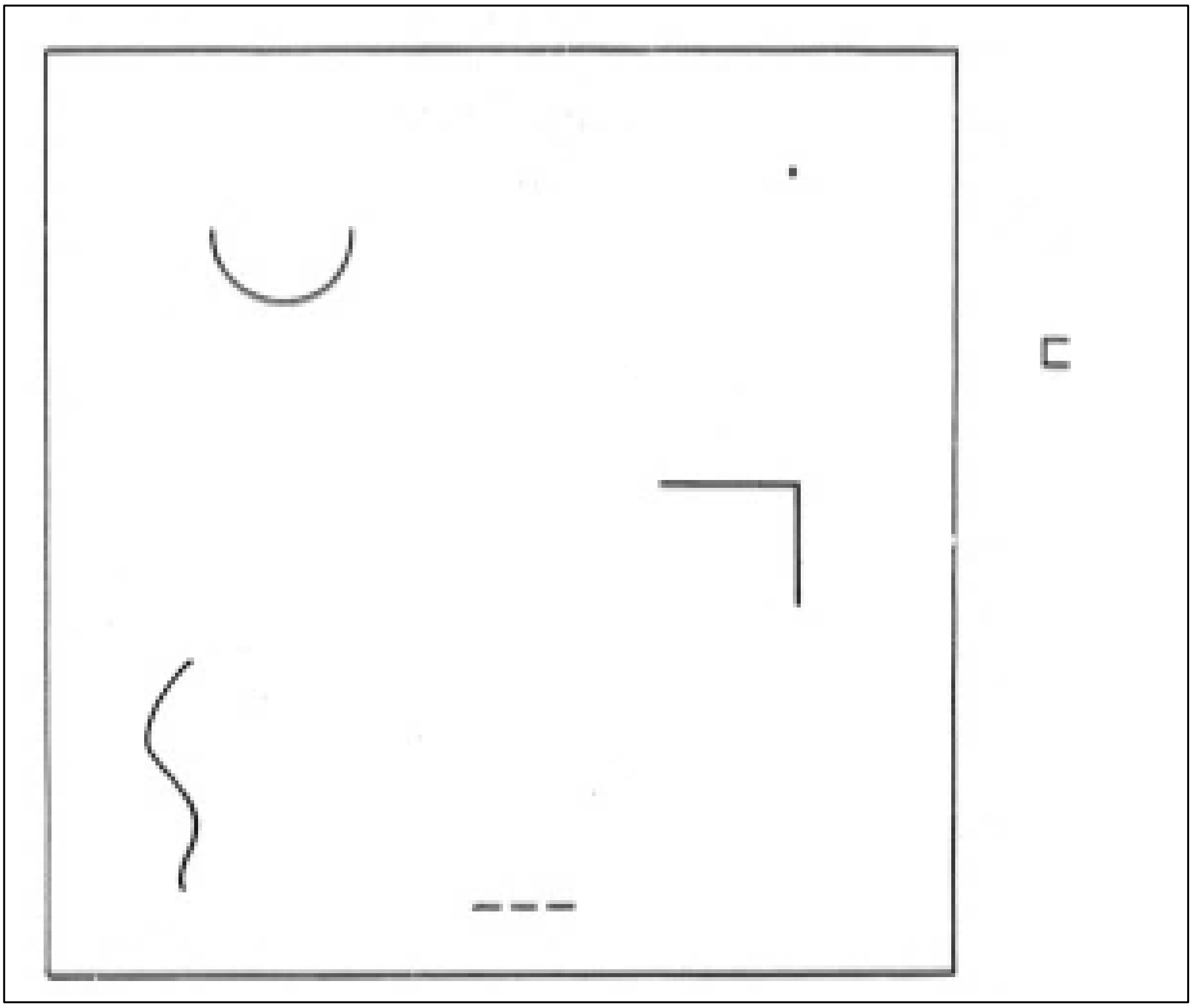

Figure 2: Example of a Blank TCT-DP Drawing

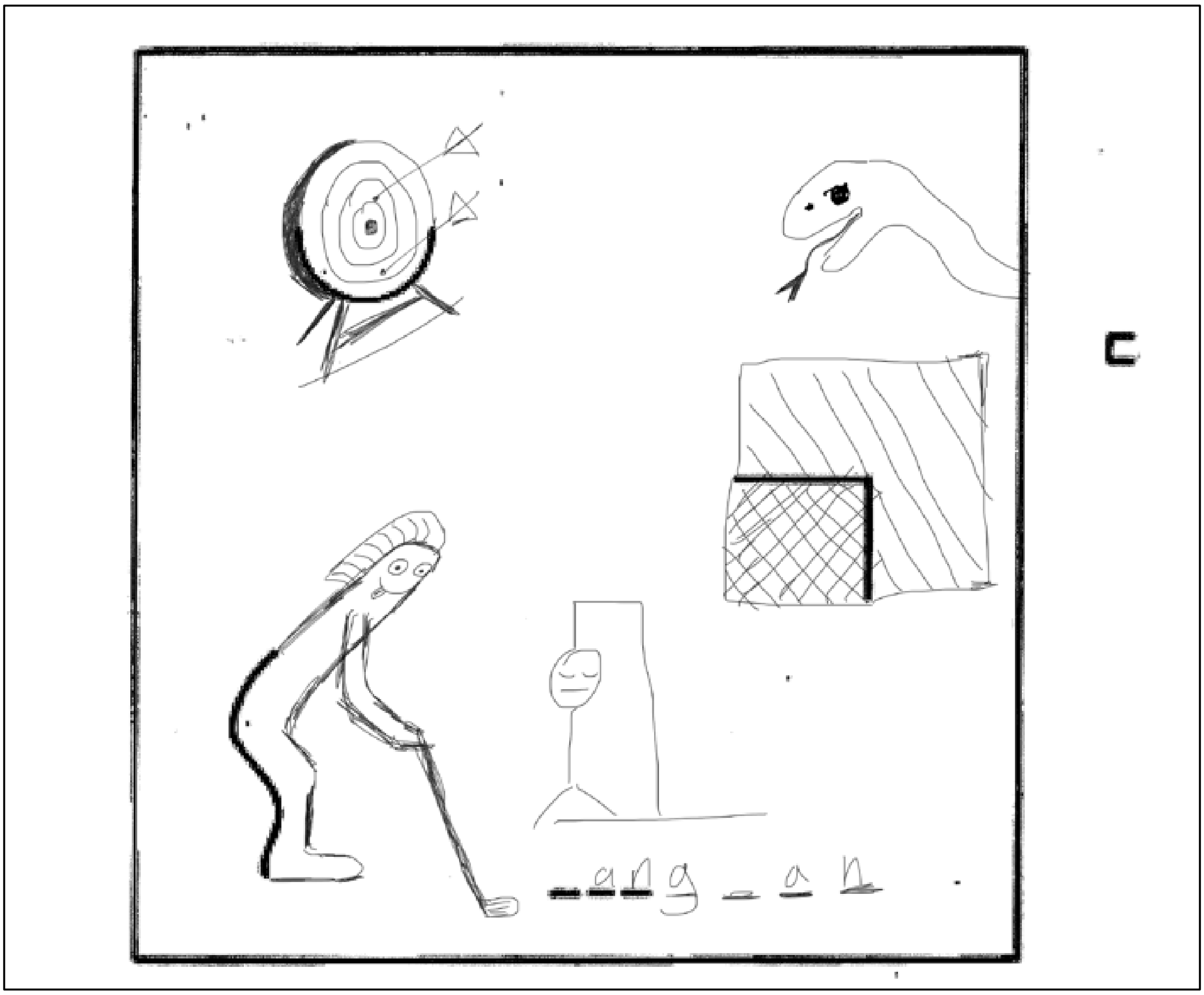

Figure 3: Example of a TCT-DP “Low” Score Drawing

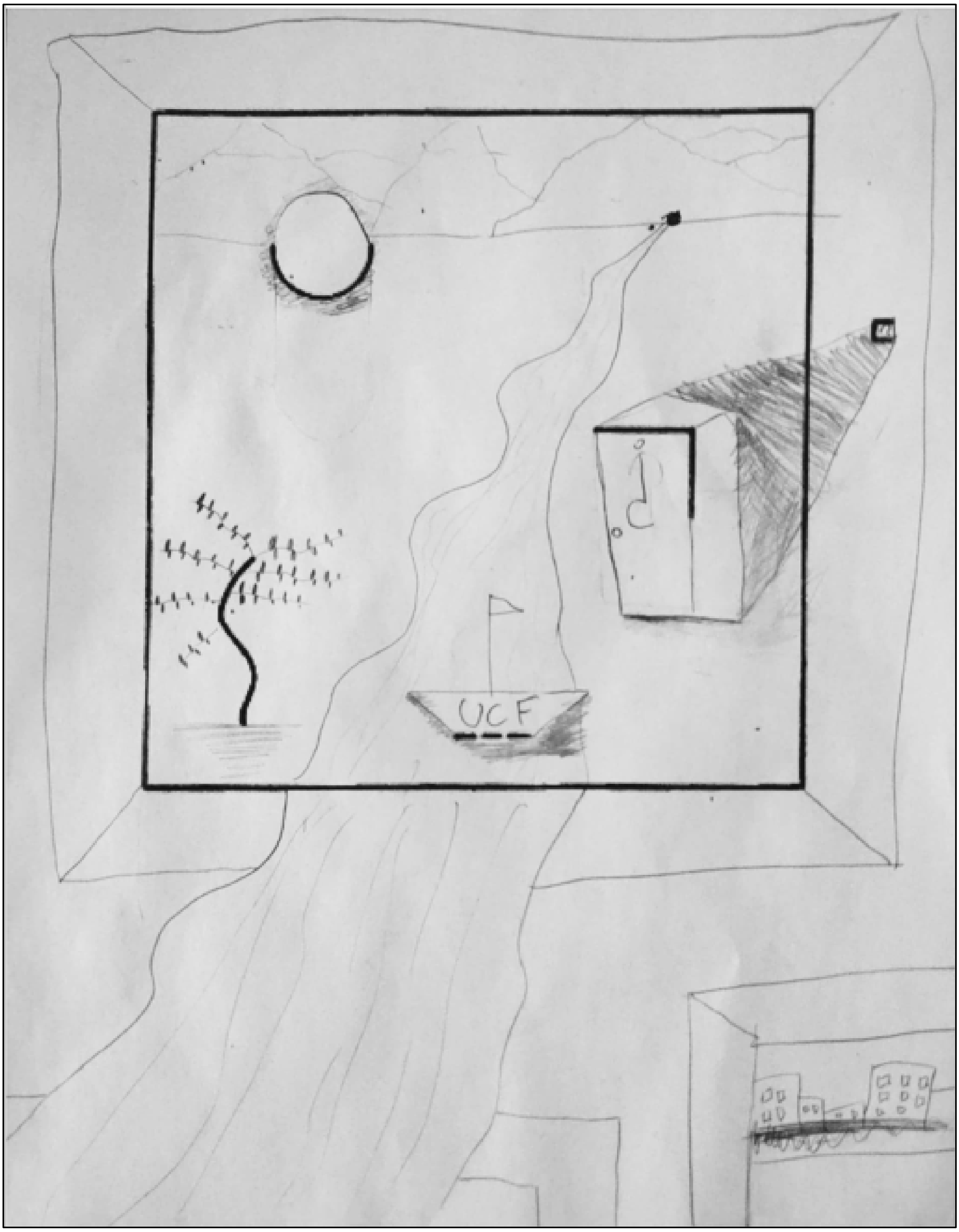

Figure 4: Example of a TCT-DP "High" Score Drawing

After the TCT-DP test, all eligible participants provided the accompanying survey to collect data. A copy of the student survey is enclosed in the appendix. The purpose of the survey was to acquire basic demographics, information to identify any testing bias, and the key independent variables. These key variables became extracurricular activity, extracurricular activity hours spent, hobby activity, hobby activity hours spent, and GPA. Additional questions were provided on the survey but were not further evaluated within the context of this study. These questions provided two benefits, one to hide the true intent of the survey and two to collect additional data that, while not utilized in this study, may prove to be beneficial to future research. By providing these diverse series of questions, the participants would be unable to discern if one element of the survey would be evaluated more critically than others (Tai, 2012). Thus, enabling what is believed to be more open and honest feedback.

Survey questions regarding employment and work-study balance were not directly addressed in the context of this study. Although the data collection led towards a different research path of analysis, the unused data sets have been retained for potential future work. An early finding that enabled the investigation to proceed was the response to a survey question regarding previous exposure to the TCT-DP. All participants answered that they had never been exposed to or taken this examination before, removing the possibility of skewed creativity scores. With key variables now identified from the survey, they were further analyzed using the following criteria for statistical calculation.

Extracurricular Activity – The independent variables were measured based on the responses obtained from the accompanying survey. Responses to Extracurricular activity were provided to the participants as Not Applicable, Athletics, Academic / Professional Organization, Volunteering, Arts, Greek Organization, and Others; these responses were coded as 1 through 7.

Hours spent on Extracurricular Activity per week - The independent variables were measured based on the responses obtained from the accompanying survey. Responses to Hours spent on Extracurricular activity were provided to the participants as: Not Applicable, 0-5 hours, 6-10 hours, 11-15 hours, 16-20 hours, 20+ hours; these responses were respectively coded as 1 through 6.

Hobby Activity- The independent variables were measured based on the responses obtained from the accompanying survey. Responses to Hobby activity were provided to the participants as: Collecting, Making, Activity, Play, Arts, and Other; a table labeled “Hobby Categorization Example” was provided to help participants identify their hobbies into a measurable category ("A Categorised Comprehensive List of Hobbies ★ HobbyCue," December 2017). These responses were respectively coded as 1 through 6.

Hours spent on Hobby Activity per week - The independent variables were measured based on the responses obtained from the accompanying survey. Responses to Hours spent on Hobby activity were provided to the participants as: Not Applicable, 0-5 hours, 6-10 hours, 11-15 hours, 16-20 hours, 20+ hours; these responses were respectively coded as 1 through 6.

Grade Point Average (GPA)- This study classified GPA as a categorical variable for data collection and a continuous variable for analysis using a linear regression model. GPA was categorized and grouped in increments of 0.25 points starting at a GPA of 2.0 up to a GPA of 4.0; this created eight different GPA groupings for analysis. These groups were respectively coded as 1 through 8.

Design

This study determined that utilizing a linear regression statistical analysis would provide the most beneficial insight. According to Montgomery (2017), a simple linear regression model will utilize coefficients within a linear function to provide a response (dependent variable) from predictor variables or regressors (independent variables). These coefficients will define the intercept of the plane and the expected change in the dependent variable given the per unit change in the predictor. The linear regression model will generally reflect the following format: $y = \beta_o + \beta_1 x$. In the case of this study, the linear regression model will be used to determine the coefficient values representing the creativity scores assigned to the categorical responses to Extracurricular activity and Hobby activity. This approach will also be expanded to provide a best fit linear regression curve to model the independent variable relationships for extracurricular activity time spent, hobby activity time spent, and GPA. If several independent variables are significant, additional analysis will also be performed to perform a linear regression model with only the statistically significant variables. Finally, a residual analysis to determine the predicted model strength will determine whether independent predictors of creativity score are indeed present.

Since the data used within this study is mainly categorical (ordinal), some additional considerations need to be accounted for to accurately model for linear regression. The first is the use of dummy variables due to the limitation that nominal independent variables cannot be directly entered to perform this analysis. SPSS provides the necessary resources to perform this function within the software efficiently. The second consideration is midpoint scoring. (Powers & Xie, 2008), identifies that midpoint scoring can be applied when ordinal variables resulting from categorical measures of variables are conceptually continuous. For example, in this study activity, hours for extracurricular and hobby were collected initially as intervals of hours: 0-5, 6-10, 11-15, 16-20, and more than 20. Since the ordinal variable is a discretized version of a continuous variable, the endpoints and intervals of each category are easily known. By applying the midpoint between the intervals, the representative average value of all cases falling within the interval can be determined and used for more discrete analysis. This approach was used for the activity hours and GPA.

Using categorical survey responses over exact numeric values provided certain advantages during data collection. A few of these reasons, as summarized by Ali (May 15, 2019), include:

Data consistency - categorical ranges assures responses are consistent with minimal data validation

Ease of response – easier for the respondent to simply choose from an option of ranges rather than enter an exact value

Respondent comfort – some respondents may not be comfortable providing exact numeric values, making the overall survey feel less intrusive

Statistical research shows no consensus on what approach to use to determine sample size in studies with linear regression (Brooks & Barcikowski, 2012; Dupont & Plummer Jr, 1998; Hsieh, Bloch, & Larsen, 1998). One statistical guideline states that for a correlation or regression model with independent variables, no less than 50 subjects should participate (VanVoorhis & Morgan, 2007). The rule of thumb states that the number of subjects used for testing multiple correlation studies should follow $N > 50+8m$ (where m is the number of independent variables). In testing individual predictors, the sample size is derived by $N > 104+m$. In the case of this study, the latter equation can be used to justify the number of samples obtained for reliability (Green, 1991). Following the sample size recommendation and our approach of 5 independent variables under analysis, the formula would yield a result of 109 subjects, which is less than the actual number of subjects obtained for this study at 123.

By using this statistical method, the TCT-DP data were analyzed and compared against predictor variables to determine if they contributed to the dependent or outcome variable. This research identified one dependent or outcome variable. The dependent variable in this study was the TCT-DP score. Five independent or predictor variables were also characterized as categorical and studied for their contribution to the outcome variable. The independent variables in this research are Hobby activity, Extracurricular activity, Hours spent on Hobby, Hours spent on extracurricular, and GPA. The independent variables were measured based on the responses from the accompanying survey provided to the study participants.

Linear regression helps answer the question of the relationship between a dependent variable response given the independent variable. In the context of this research, do the independent variables of hobby, extracurricular activity, and GPA increase or decrease the resulting TCT-DP score. Consequentially, are any of the subcategories of the independent variables more influential in that prediction?

Data collected from the TCT-DP and accompanying survey was analyzed using the Linear Regression and Regression Curve Estimation tests available through the SPSS software. The analyses were evaluated based on a degree of certainty, alpha in the 95th percentile, and a two-tailed significance test. The Linear Regression analysis through the application of ANOVA (Analysis of Variance) will individually evaluate the five independent variables for statistical significance.

Selection Bias

Bias via the selection of participants is how erroneous data can embed itself into the study. Participants who volunteered were from an existing course that is part of the University's requirement for the Bachelor of Science in Industrial Engineering (BSIE) degree. Although other Engineering majors were capable of enrollment in this course, only a few students of alternative concentrations were present in this study. At no time were participants removed from the study unless they provided a specific request.

Researcher and Evaluator Bias

In order to remove researcher bias, evaluators were provided official training material for the TCT-DP examination. At no time during the training, consensus, or grading was the researcher present. As with any evaluation that requires manual assessment, there will be tendencies for bias. The evaluators went through extensive training on the creativity test's procedures and ideologies to compensate for said bias. The evaluators selected trained using example tests and following the prescribed TCT-DP guidelines for grading the drawing assessments. After training, ten identical non-descript exams were provided to all evaluators, all with the same numerical identifiers for documentation. This step was done to provide grading consistency and a reliable sample. Without agreement between the evaluators, the scoring validity and resulting conclusions could be questioned. After the initial trial sample, evaluators were allowed to re-train if scores were found to deviate significantly.

CHAPTER FOUR: RESULTS

This study contributes to the existing literature by examining the relationship of creativity in engineering students within their provided extracurricular activities, hobbies, and GPA responses. These results will indicate that engineering students involved in extracurricular activities and hobbies display higher creativity scores.

Linear regression was used to measure the relationship between output and predictor variables to determine whether students' creativity was affected by their activities outside their academic study. The results presented were calculated based on the research question discussed in Chapter 3 using SPSS Version 28.0 as the statistical software for all calculations in this chapter (IBM Corp. Released 2021).

The first set of tables show the frequency of the independent variable responses provided in the surveys. These categorical frequency tables provided the foundation for building the linear regression analysis. Presented below are the descriptive statistics for the independent variables.

Extracurricular Activity Distribution Results

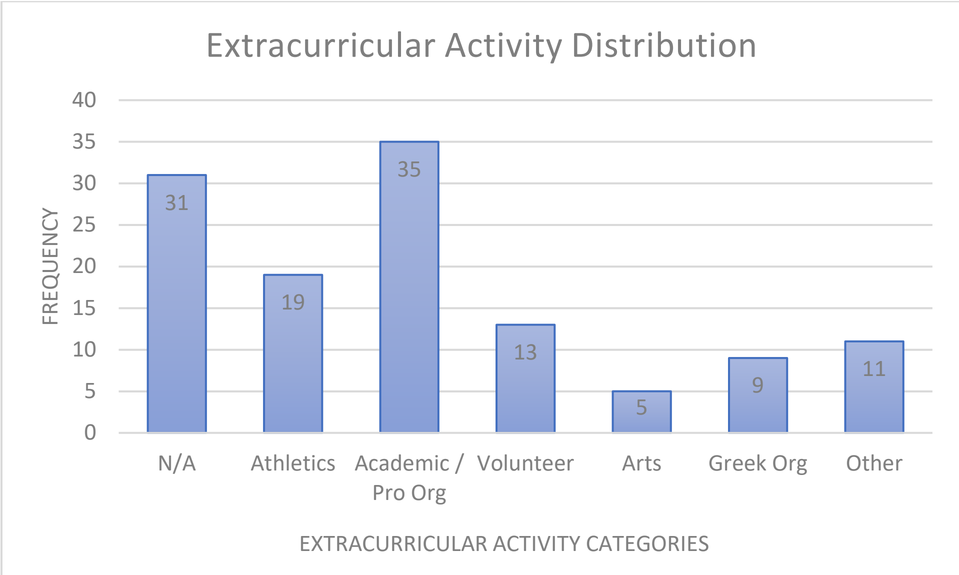

Figure 5: Extracurricular Activity Distribution

Figure 5 shows the extracurricular activity distribution obtained from the survey. The highest number of responses were provided for academic and professional organizations. The second-highest category was "not applicable," thus 25% of students were not participating in any activities at all. It is also interesting to note that the smallest category was activities in the "Arts." This ties into the preconceived notion addressed in the literature review that engineers rarely engaged in the arts.

Extracurricular Activity Hour Distribution Results

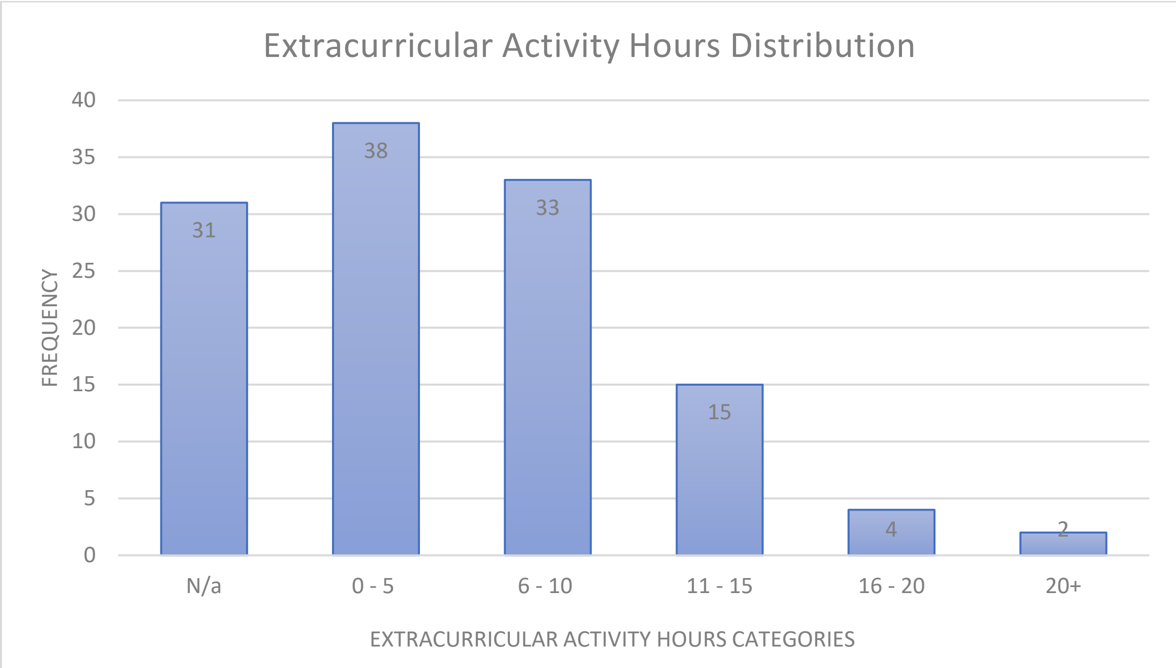

Figure 6: Extracurricular Activity Hours Distribution

Figure 6 shows the extracurricular activity hour distribution obtained from the survey. The highest number of responses were provided for 0-5 hours. The same number of "not applicable" responses matched the same category in the extracurricular activity table. More than 80% of time spent on extracurricular activities fell between 0-10 hours. Conversely, less than 2% of time spent was found in the 20+ category.

Hobby Activity Distribution Results

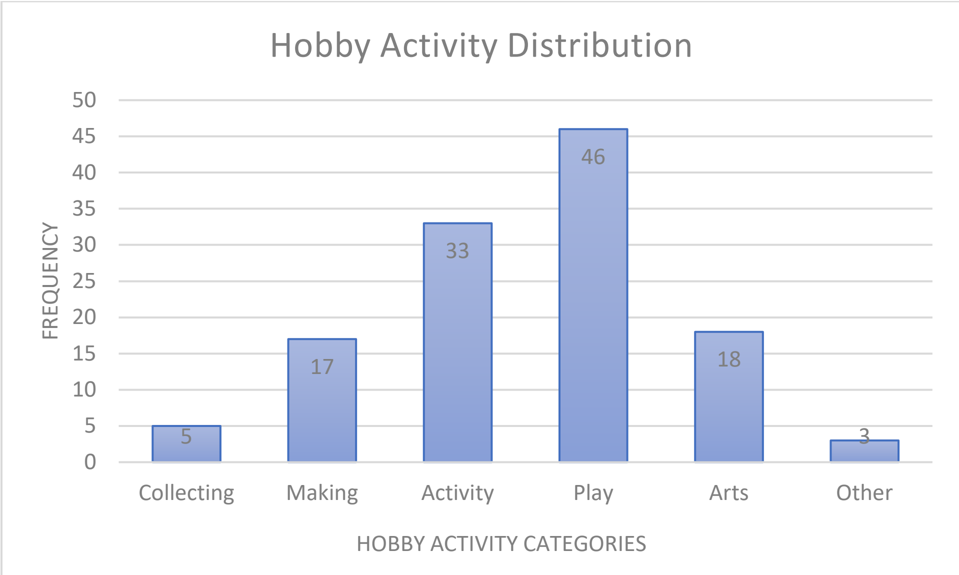

Figure 7: Hobby Activity Distribution

Figure 7 shows the hobby activity distribution obtained from the survey. The highest number of responses were provided for the "Play" category, including time spent playing games, sports, and fitness. The second-highest category was "Activity," which included outdoors, travel, and animals (fishing, hunting, etc.). The following category was "Arts," which included dance, music, theater, visual arts, and literary. The fourth-ranking category was "Making," which included clothing, cooking, gardening, and modeling. This was followed by "Collecting," which included collecting physical items, memorabilia, and spotting (as in bird watching, amateur astronomy, etc.). The remaining results were reported as three in the "Other" category and one that did not provide an answer.

Hobby Activity Hour Distribution Results

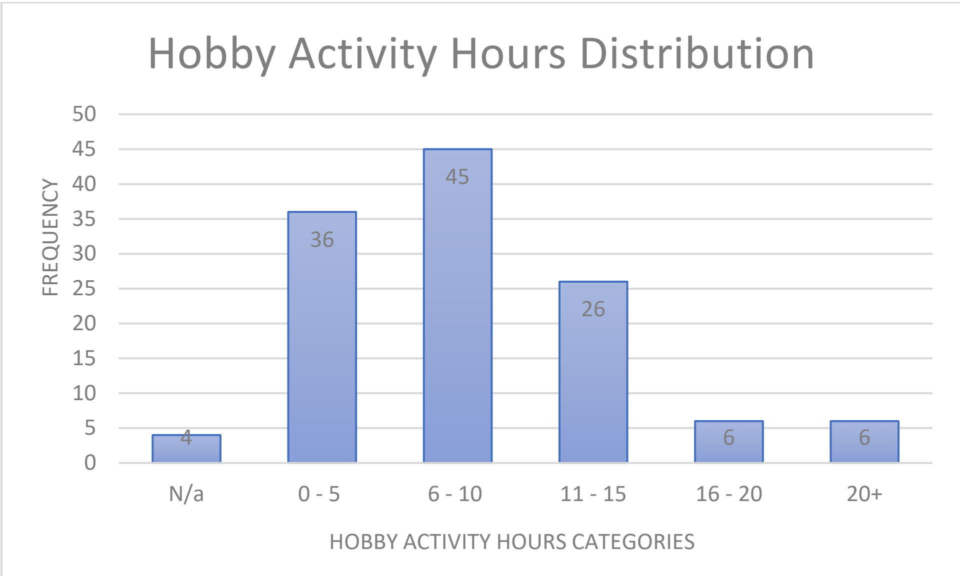

Figure 8: Hobby Activity Hour Distribution

Figure 8 shows the hobby activity hour distribution obtained from the survey. The highest number of responses were provided for 6-10 hours. Participants spent more time on hobbies than compared to extracurriculars. Almost 5% spent more than 20 hours on hobbies versus less than 2% on extracurricular activities.

GPA Distribution Results

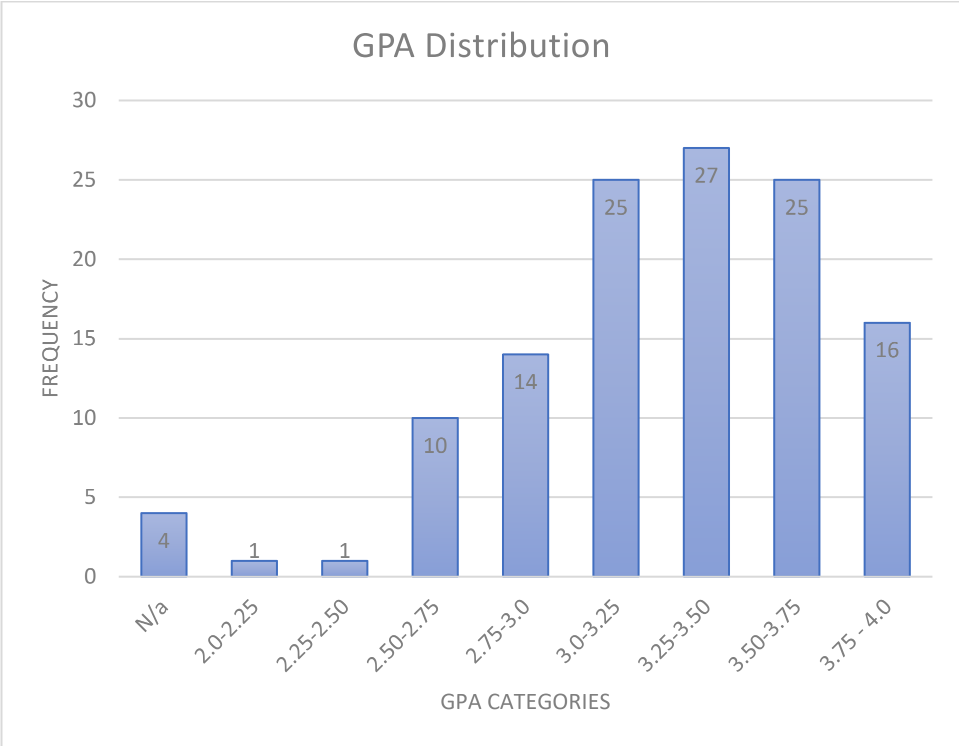

Figure 9: GPA Distribution

Figure 9 shows the GPA distribution obtained from the survey. The highest number of responses were provided for 3.25-3.5. More than 75% of respondents reported a GPA of greater than 3.0. Four participants decided not to disclose their GPA in the survey.

Creativity Score Results

The complete creativity score data set was evaluated for normality to validate the statistical model, as seen in table 2 and figure 10. Creativity scores showed a strong indication of normality within the test score data set. Selecting a confidence interval of 95%, alpha 0.05, in conjunction with the application of the Shapiro-Wilk test for normality, the significance value is shown to be greater than that of alpha, indicating a strong presence of a normal distribution as seen in table 3. In addition, the visual Q-Q plot (figure 11) also indicates a robust normal distribution amongst the test scores as the data points generally follow the trend line.

Table 2 Creativity score Statistical Analysis

			Statistic	Std. Error
Avg Test Score	Mean		29.3252	0.91688
	95% Confidence Interval for Mean	Lower Bound	27.5102	
		Upper Bound	31.1403	
	5% Trimmed Mean		29.2683	
	Median		30.0000	
	Variance		103.4020	
	Std. Deviation		10.16866	
	Minimum		4.00	
	Maximum		52.00	
	Range		48.00	
	Interquartile Range		14.00	
	Skewness		0.017	0.218
	Kurtosis		-0.319	0.433

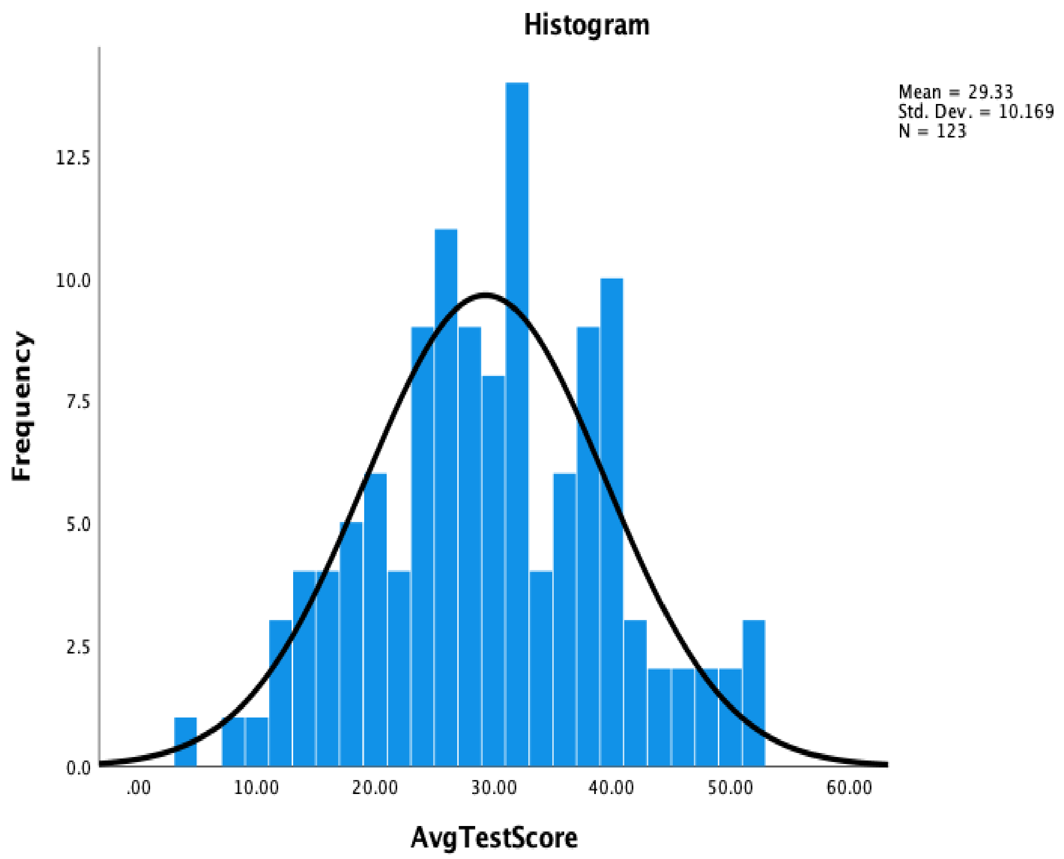

Figure 10: Normality Histogram for Average TCT-DP Test Scores

Table 3
Test of Normality

	Kolmogorov-Smiron			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
AvgTestScore	0.047	123	0.200*	0.992	123	0.749

*. This is the lower bound of the true significance.
a. Lilliefors Significance Correlation

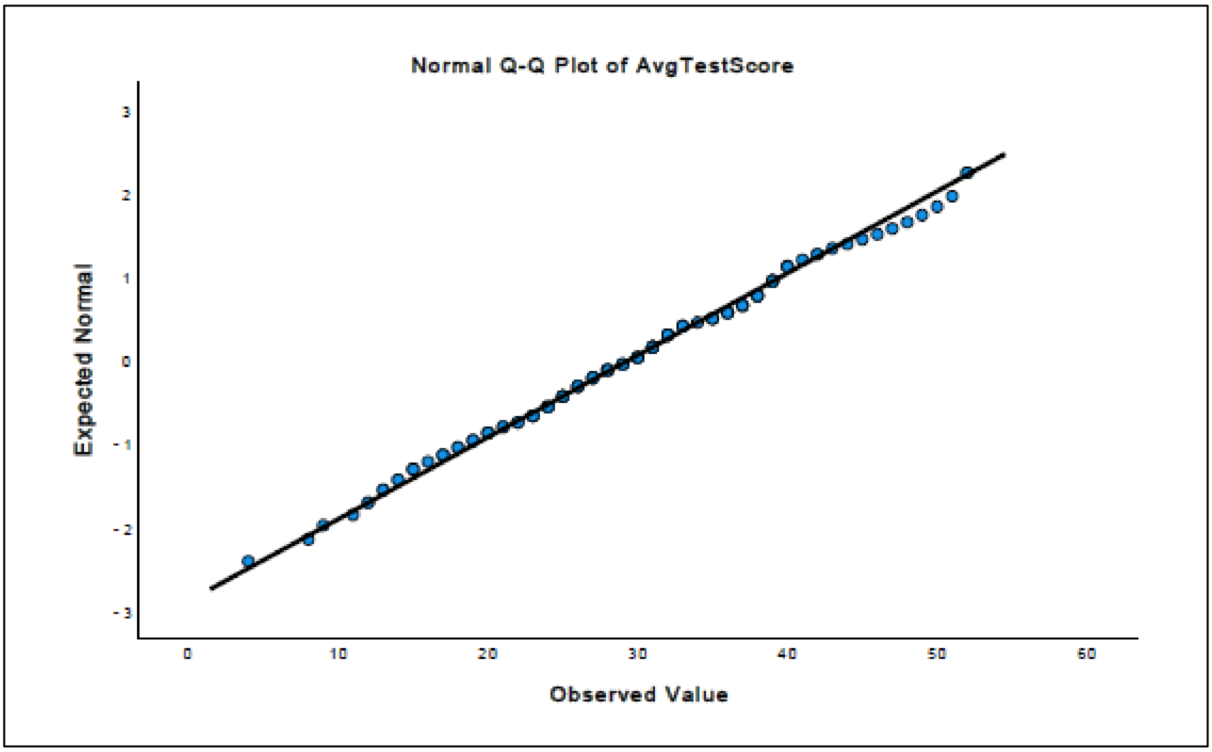

Figure 11: Q-Q Plots for Normality of Average TCT-DP Test Scores

By combining the data above with linear regression and curve-fitting models, the study will examine the independent variables of Hobby Activity, Extracurricular activity, Hours Spent on each, and GPA to predict the relationship on the dependent variable TCT-DP score.

Extracurricular and Hobby Activity Regression Results

The significant coefficients addressed for this study is B. This coefficient is critical in identifying the individual categorical predictors on the outcome of the dependent variable. Coefficients B represent the intercept of the predicted outcome for cases that fall within this categorical variable; another way to analyze this coefficient would be the average creativity score value for a selected category, given that no other category was selected. From the table below, the category of Arts is responsible for the highest coefficient value of 33.4, followed by Volunteer (32.923), and then Athletics (32.211). The lowest coefficient value is given by Other (26.273). All coefficients within this table are statistically significant in relation to alpha (0.05).

Table 4 Extracurricular Activity Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	N/A	27.387	1.822	0.443	15.035	0.000	23.779	30.995
	Athletics	32.211	2.327	0.408	13.844	0.000	27.602	36.819
	Academic/Pro Org	29.143	1.714	0.501	17.000	0.000	25.747	32.538
	Volunteer	32.923	2.813	0.345	11.704	0.000	27.352	38.494
	Arts	33.400	4.536	0.217	7.364	0.000	24.417	42.383
	Greek Org	26.889	3.381	0.234	7.954	0.000	20.193	33.585
	Other	26.273	3.058	0.253	8.592	0.000	20.216	32.329

Similarly, the Hobby Activity Coefficients are also presented to show the coefficient B response to the creativity score. From the table below, the category of Arts is responsible for the highest coefficient value of 33.111, followed by Play (30.152) and then Making (30.059). The lowest coefficient value is given by N/A (20.0). In the context of these results, N/A would represent students that are not involved in any hobby activity.

In comparison with the results presented for Extracurricular Activity, the common leading category for both was Arts, in which the highest coefficient presented among all categorical activities was Extracurricular Arts. The lowest coefficient among all categories was Hobby N/A. This would imply that not participating in any hobby has the largest negative impact on creativity score outcome. The results also show a larger delta between the leading categories in Extracurricular Activity compared to Hobby Activity. The difference between the leading Hobby category of Arts and the next closest coefficient of Play was 2.959.

In comparison, the difference between the leading Extracurricular category of Arts and the next closest coefficient of Volunteer was 0.477. Finally, the range of the hobby categories was also greater than the extracurricular categories when looking at non-activity; hobbies ranged from Arts (33.111) to N/A (20.000), a delta of 13.111, while extracurricular ranged from Arts (33.400) to N/A (27.387) a delta of 6.013. All coefficients except for the N/A coefficient within this table are statistically significant in relation to alpha (0.05). The N/A coefficient is marginally greater than alpha at 0.051.

Table 5 Hobby Activity Coefficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B	
		B	Std. Error	Beta			Lower Bound	Upper Bound
1	N/A	20.000	10.138	0.058	1.973	0.051	-0.079	40.079
	Collecting	25.800	4.534	0.168	5.691	0.000	16.820	34.780
	Making	30.059	2.459	0.360	12.225	0.000	25.189	34.929
	Activity	26.606	1.765	0.444	15.076	0.000	23.111	30.101
	Play	30.152	1.495	0.594	20.172	0.000	27.192	33.113
	Arts	33.111	2.390	0.408	13.857	0.000	28.378	37.844
	Other	28.667	5.853	0.144	4.898	0.000	17.074	40.259

Extracurricular Activity Hour Regression Results

Table 6 shows the resulting Extracurricular Activity Hours Coefficients (B) and the linear model best fit curve shown in figure 12. The Extracurricular activity hours linear regression was modeled using a modification of the previous method to analyze Extracurricular and Hobby activity. The previous regression was modeled against the separate categorical variables; the linear regression will be modeled against a single predictor variable (hours or GPA) for the remaining variable analyses. This approach will allow for a comprehensive model across all categorical predictors. There are several options in selecting regression curves available through SPSS. The resulting best fit curve for extracurricular activity hours produced a quadratic equation in the form of $y = \beta_o + \beta_1 x + \beta_2 x^2$; the quadratic form was chosen via statistical significance through the B_o and B_2 coefficients. The B_1 coefficient was only marginally greater than alpha at 0.053. No other models within the regression analysis produced any more significant variance for this variable. In applying the calculated coefficient, the regression equation of creativity score (CS) on the value of extracurricular hours (ECH) takes the form shown in equation 1:

$$CS = 27.813 + 0.878(ECH) - 0.056(ECH)^2 \qquad (1)$$

The fitting of the resulting quadratic formula would indicate a slight increase and peak among the hourly categories of 5-10 hours before beginning to decline as more hours are represented. The highest creativity scores obtained in the study were found within this extracurricular hour range; creative people appear to spend some time but not an excessive amount of time on extracurricular activities. The cause of this creative “sweet spot” is currently unknown but has merit for additional investigation.

Table 6

Extracurricular Activity Hours Coefficient

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
ExtraCirActHrsAvg	0.878	0.449	0.467	1.956	0.053
ExtraCirActHrsAvg ** 2	-0.056	0.025	-0.525	-2.201	0.030
(Constant)	27.813	1.509		18.432	0.000

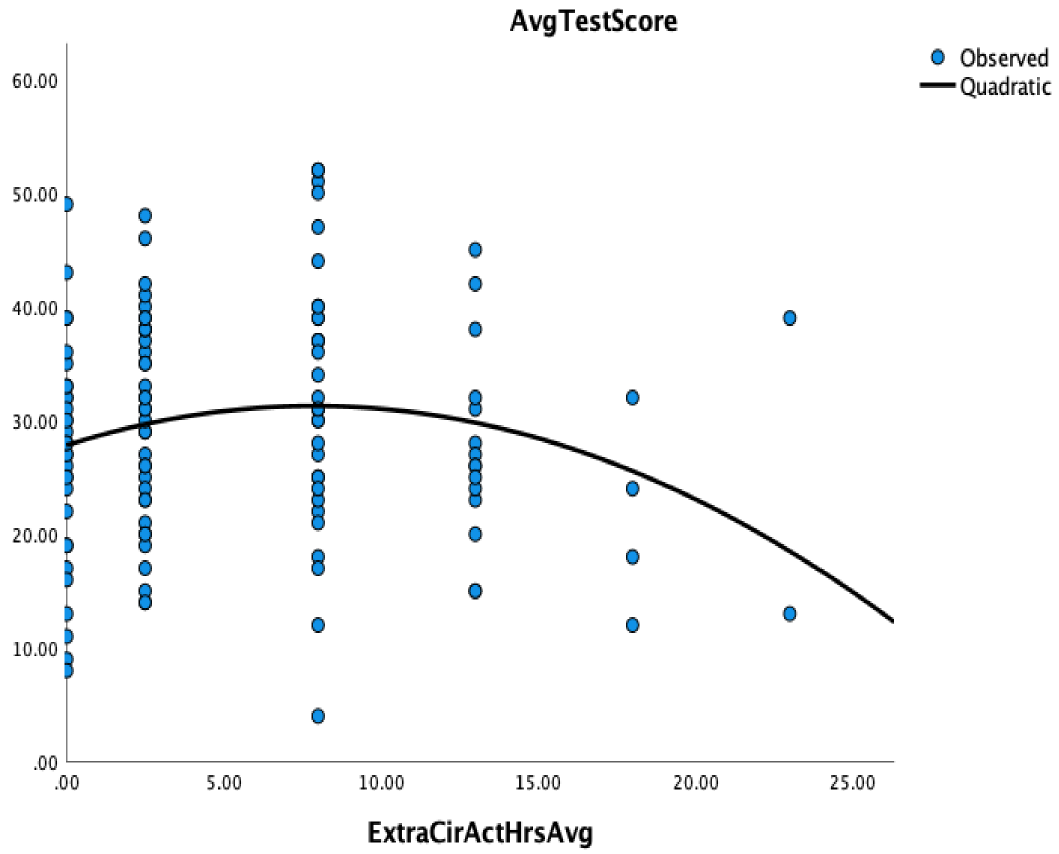

Figure 12 Extracurricular Activity Hour Curve Fitting

Hobby Activity Hour Regression Results

Table 7 shows the resulting Hobby Activity Hours Coefficients (B) and the linear model best fit curve shown in figure 13. The resulting best fit curve produced a linear equation in the form of $y = \beta_o + \beta_1 x$; the linear form was chosen to achieve statistical significance through the B_o constant coefficient and other models not producing any more significant variance for this variable. In applying the calculated coefficient, the regression equation of creativity score (CS) on the value of hobby hours (HH) takes the form shown in equation 2:

$$CS = 30.359 - 0.112(HH) \quad (2)$$

All coefficients in the resulting curve fit were not significant and therefore this analysis does not provide sufficient evidence for a conclusion to be drawn. The fitting of the resulting linear formula would indicate a minor, almost negligible decline across all the hourly categories. As a result, although students who participate in any hobby seem to improve creativity, the overall time spent on these hobbies appears unrelated to the creativity scores.

Table 7
Hobby Activity Hour Coefficients

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
HobbyHrsAvg	-0.112	0.167	-0.061	-0.673	0.502
(Constant)	30.359	1.696		17.900	0.000

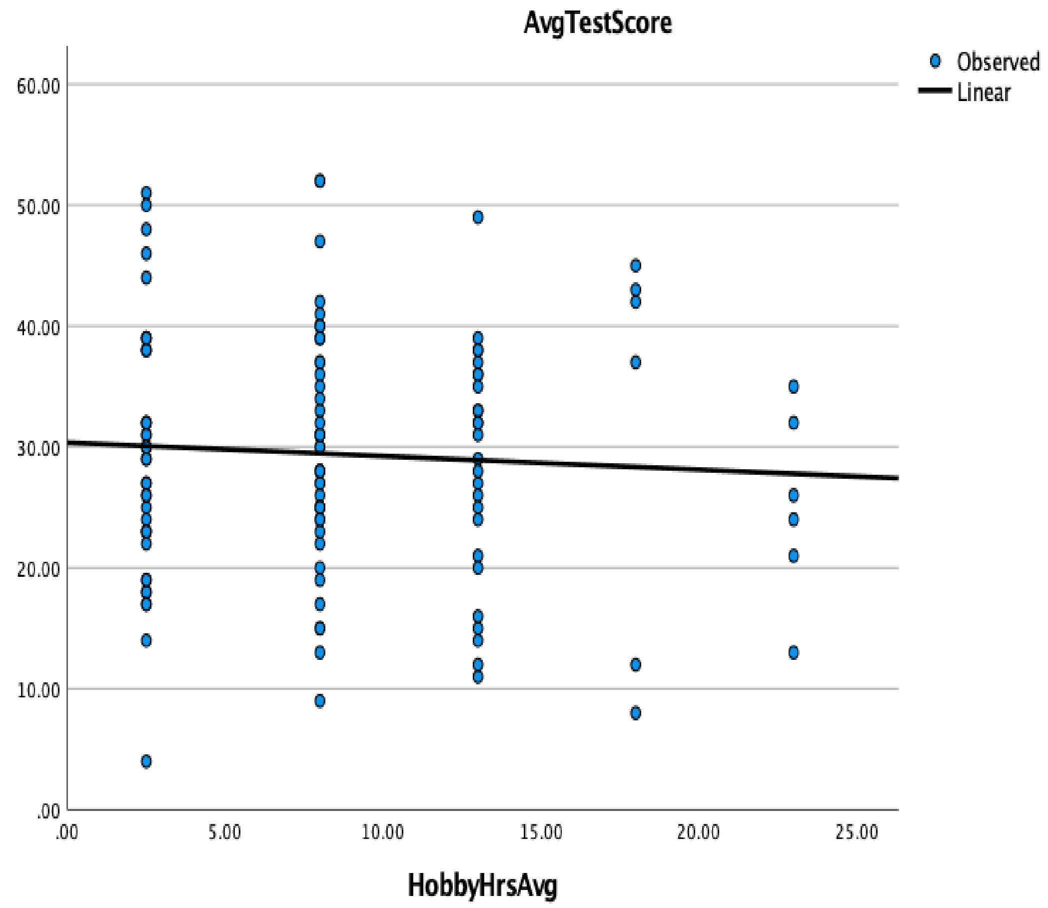

Figure 13 Hobby Activity Hour Curve Fitting

GPA Regression Results

Table 8 shows the resulting GPA Coefficients (B) and the linear model best fit curve shown in figure 14. The resulting best fit curve produced a linear equation in the form of $y = \beta_o + \beta_1 x$; the linear form was chosen for its significance of the B_1 rate of change coefficient, and due to other models not being able to produce any more significant variance for this variable. In applying the calculated coefficient, the regression equation of creativity score (CS) on the value of GPA takes the form shown in equation 3:

$$CS = 13.757 + 4.630\ (GPA) \tag{3}$$

The fitting of the resulting linear formula would indicate a positive linear relationship across the GPA categories. This curve was the only curve fit of the three that resulted in a positive relationship across all categories. The extracurricular curve fit resulted in a quadratic form that achieves its vertex around 5-10 hours before declining. The hobby curve fit resulted in a non-significant numerical trend towards fewer hobby hours being associated with higher creativity, appearing to show hobby hours and creativity to be unrelated. However, this positive GPA to creativity relationship shows that students obtain higher creativity scores with higher GPAs.

Table 8 GPA Coefficients

	Unstandardized Coefficients		Standardized Coefficients		
	B	Std. Error	Beta	t	Sig.
GPAAvg	4.630	2.308	0.182	2.006	0.047
(Constant)	13.757	7.674		1.793	0.076

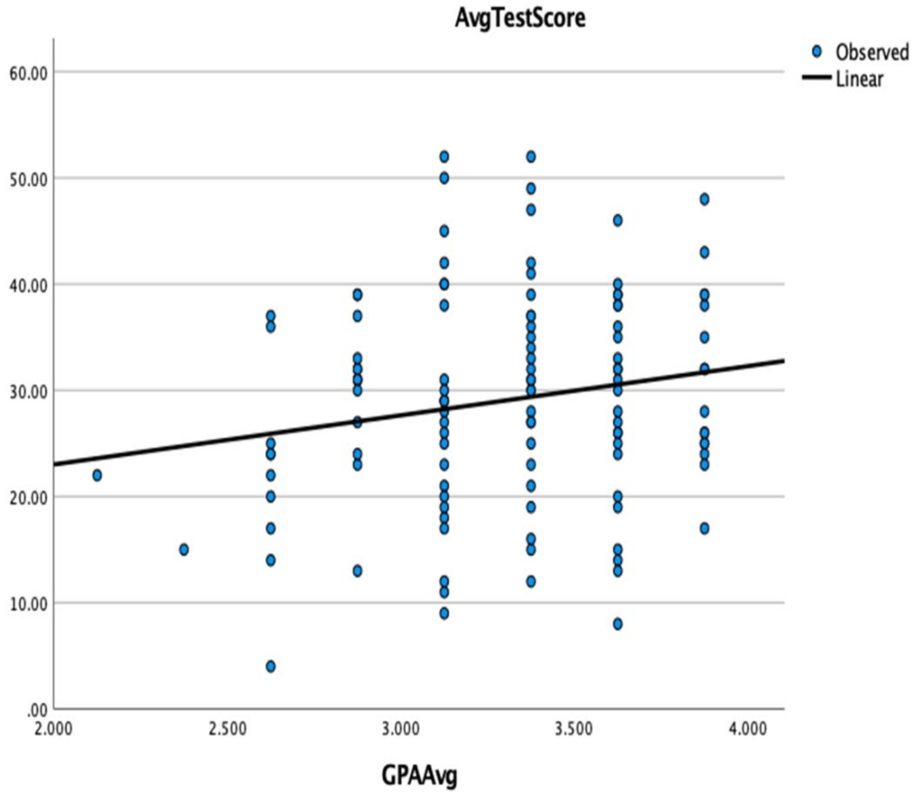

Figure 14 GPA Curve Fitting

Multiple Variable Regression Results

The previous resulting linear regression analyses showed three models of significance, the Extracurricular Activity, Hobby Activity, and GPA. Table 9, Table 10, and Table 11 show the resulting model summary, ANOVA analysis, and Coefficients (B) when all three variables are provided within a single linear regression model. The resulting model summary shows a high R and R Square value of 0.954 and 0.910, respectively; these values show that the model can represent a large portion of the data variance for a dependent variable given the independent inputs. The ANOVA table shows an F scope of 75.722 and a significance of < .001 compared to an alpha of 0.05. In applying the calculated coefficients, the regression equation of creativity score (CS) against the values of all the variables considered takes the form shown in equation 4:

$$CS = 11.691\ (EC_{N/A}) + 17.06\ (EC_{Athletics}) + 13.626\ (EC_{Academic}) + 16.981\ (EC_{Vol}) + 15.604\ (EC_{Arts}) + 11.665\ (EC_{Greek}) + 10.118\ (EC_{Other}) - 8.052\ (Hobby_{N/A}) - 1.336\ (Hobby_{Collect}) + 0.737\ (Hobby_{Making}) - 2.499\ (Hobby_{Activity}) + 0.89\ (Hobby_{Play}) + 4.2\ (Hobby_{Arts}) + 4.616\ (GPA) \tag{4}$$

This resulting equation assumes that only one type of Extracurricular and one type of Hobby activity may be selected as an input into the equation. For example, if a subject participates in an Athletics Extracurricular and Arts Hobby, only those two variable categories would be assigned a value of 1, and all other activities would be 0. The GPA variable input is assumed to be any continuous value on the standard GPA scale from 0 through 4. Although the significance of the ANOVA model indicates a strong predictive model, additional evaluation of this predictive model can be obtained through a residual analysis.

Table 9 Multiple Variable Regression Model Summary

R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
.954	0.910	0.898	9.80830	2.326

Table 10 Multiple Variable Regression Model ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	101984.716	14	7284.623	75.722	<.001
	Residual	10101.284	105	96.203		
	Total	112086.000[d]	119			

Table 11 Multiple Variable Regression Model Coefficients

		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	ExtraCirAct=N/A	11.691	10.224	0.194	1.143	0.255
	ExtraCirAct=Athletics	17.060	9.873	0.216	1.728	0.087
	ExtraCirAct=Academic / Pro Org	13.626	10.580	0.230	1.288	0.201
	ExtraCirAct=Volunteer	16.981	10.940	0.183	1.552	0.124
	ExtraCirAct=Arts	15.604	12.022	0.104	1.298	0.197
	ExtraCirAct=Greek Org	11.665	10.584	0.105	1.102	0.273
	ExtraCirAct=Other	10.118	11.031	0.100	0.917	0.361
	HobbyCat=N/A	-8.052	11.594	-0.024	-0.694	0.489
	HobbyCat=Collecting	-1.336	7.698	-0.009	-0.174	0.863
	HobbyCat=Making	0.737	6.324	0.009	0.116	0.907
	HobbyCat=Activity	-2.499	6.063	-0.043	-0.412	0.681
	HobbyCat=Play	0.890	5.957	0.018	0.149	0.882
	HobbyCat=Arts	4.200	6.403	0.050	0.656	0.513
	GPAAvg	4.616	2.506	0.500	1.842	0.068

Multiple Variable Regression Residual Results

An additional statistical calculation was performed to determine the residuals analysis between the predicted and actual values of the resulting linear regression equation shown in equation (4). Without this secondary analysis, the resulting regression equation cannot statistically indicate whether the variables tested are indeed predictors of creativity or simply a correlation measure against the creativity score. Figure 15 and figure 16 show the resulting residual analysis. Figure 15 shows the normal P-P plot of regression standardized residuals. This P-P plot confirms the normality of the residuals by closely following the trend line. Figure 16 shows the scatterplot of standardized residuals vs. standardized predicted values. The resulting scatterplot appears to be equally distributed and does not veer outside of the -3 to 3 boundaries in either axis of the regression standardized residual (Y-axis) or the regression standardized precited value (X-axis); these figures in unison confirm the statistical predictive strength of the model, along with the independence and constant variance of the residuals.

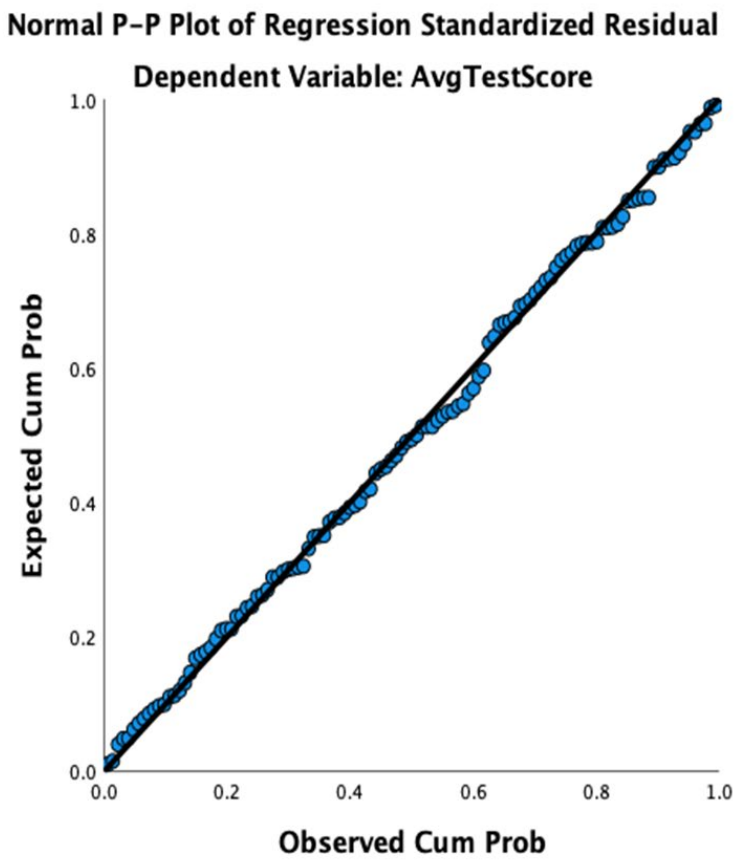

Figure 15 Normal P-P Plot of Regression Standardized Residuals

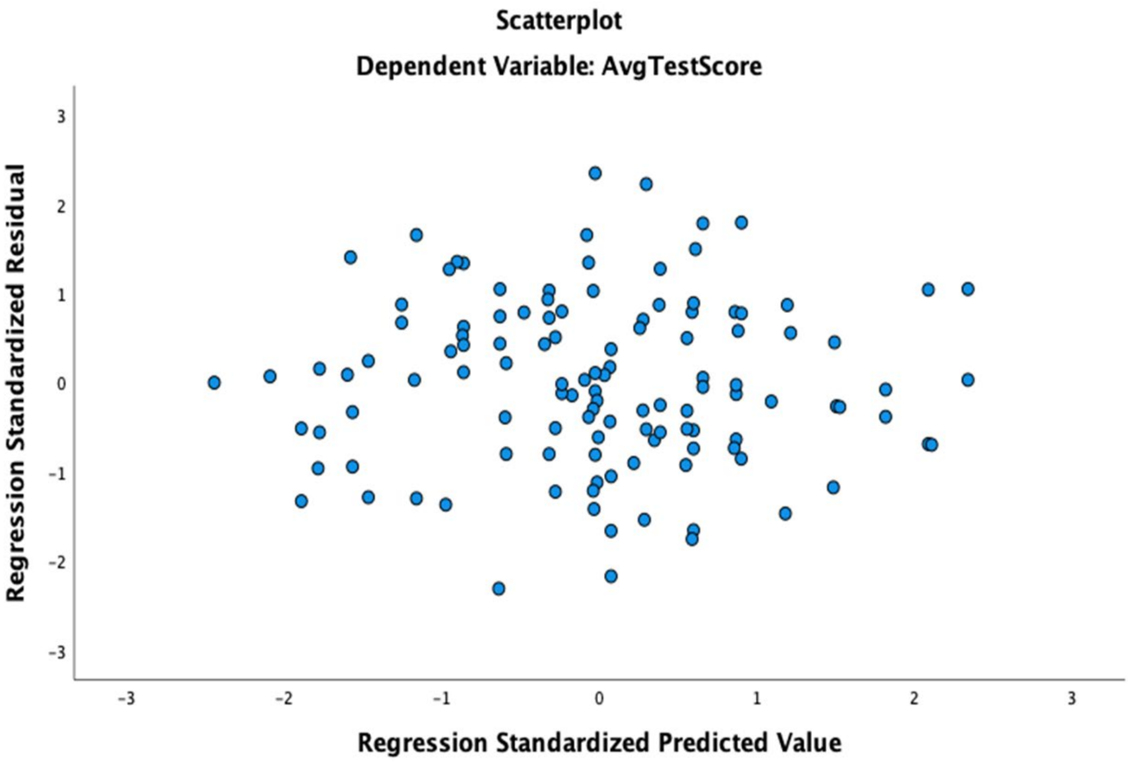

Figure 16 Standardized Residual vs. Standardized Predicted Value Scatterplot

CHAPTER FIVE: CONCLUSIONS

This study displayed both predicted and unpredicted insights in creativity within an engineering undergraduate sample population. The study's main experiment asked whether predictors existed to suggest higher levels of creative output with engineering students. It specifically investigated external factors outside the typical curriculum, including hobbies, extracurriculars, and time spent on activities. Another aspect the study explored was the relationship between GPA and creativity. Is GPA a reliable predictor in identifying creative output? The study results highlighted some known and unknown limitations within students and their engineering curriculum. This section presents the various conclusions with additional input into the limitations of this study and future directions to improve on the findings.

Statistical evidence shows that there are, in fact, possible predictors for creativity. As measured by the TCT-DP and observed through the survey, students who engaged in extracurricular or hobbies exhibited a higher creativity output score. A larger impact on creativity score was seen with hobbies over extracurricular, but this statistical evidence suggests that engineers who engage in any extracurricular or hobby activities outside of the classroom and on their own time may be more creative than their peers. As previously mentioned, ongoing research stresses the importance of creativity and innovation. Enhancing the creativity output potential of forthcoming engineers will be vital to their future workplace and careers (Bojulaia & Pleasants 2021). Businesses that lack to evolve at a quick pace will be in danger of being consumed by their competitors (Kouzes & Posner 2012 pg. 110). There is also statistical evidence that this creative output score is not consistently increased or strengthened due to the number of hours spent on an activity. Moderation appears to be a trend in the relationship between the time spent on extracurriculars and creativity. The data shows a decline in average scoring as more time is spent on extracurricular activities. As for time spent on hobby activities, the data suggest that this is largely unrelated to creativity score.

Furthermore, there seems to be a common theme in the type of activity leading to higher creativity scores among this population. For both Extracurricular and Hobby activities, the Arts category resulted in the highest B coefficient representing the average creativity score value for a selected category. Although the Arts category was the leading category, other categories of interest among Extracurricular and Hobbies included Volunteering, Athletics, Play, and Making. These results suggest that engineers involved in these activities may see the most benefit of creative potential; this further reinforces the ability to produce more creative engineers to enter the workplace. With the results of this study suggesting that a potential path to increasing overall creativity in engineers may exist through the active participation in extracurricular and hobby activities, Universities should be actively pursuing the integration of these activities into the curriculum. These inclusions would further allow future graduate engineers to better meet the challenges of an industry driven by innovation and creativity.

This experiment has further confirmed findings in the existing literature and has contributed additional understandings of creativity in engineering students. The potential of creative skills is apparent in engineering undergraduates but fostering that creativity within the entire student body is where stagnation occurs. Furthermore, it confirms that creativity is an acquired skill, with increased creativity output associated with several influencing factors. This finding is significant, as the problem-solving creativity output of engineers can be improved. Real-world engineers are not typically faced with perfectly crafted problems resembling textbook examples but rather deal with open-ended concepts that need a multitude of problem-solving techniques. The best way of obtaining these much-needed skills include creative decision-making, diverse thought processes, real-world applications, play, and interdisciplinary studies. The intersection of activities and academics show these skills on display. In thinking about the students' future needs and the industries they are inevitably heading into, universities must provide their graduates with those real-world skills.

Although the current engineering curricula may not encourage creative thinking or behavior, the creative potential appears to be present. Unlike the predictors of Extracurricular and Hobby hours that appear to decline or remain constant across the categorical ranges, creativity output appears to increase with GPA. The GPA predictor may imply that the most creative engineering students also possess higher GPAs, but this is not the only predictor that should be considered, as the data has shown influence from extracurricular and hobby activities on creativity. Employers hoping to gain this creativity asset may focus on GPA but also on diversification of skills and interests in their assessments.

Furthermore, the engineering curriculum may benefit from students who are engaged in extracurricular and/or hobbies, primarily through interdisciplinary categories such as the Arts. As it can be seen, the need for creative engineers is paramount. Luckily there are answers and solutions to this concerning lack of creativity. By having universities encourage students to have extracurricular activities and hobbies, these students will display higher creativity skills to grow and strengthen. Thus, providing the workforce with more diverse and creative engineers to include in their resources to compete in this ever-growing economy (Atwood & Pretz, 206; Cotter, Pretz, & Kaufman, 2016; Freund & Holling, 2008; Gajda, 2016; Grey et al., 2018; Xiao-Jiang & Xue-Ting, 2012)

CHAPTER SIX: FUTURE WORK

As discussed throughout this study, creativity in engineering is receiving more attention due to its significant implications on industrial innovation and problem-solving. While the study provides important insights into engineering creativity and the current engineering curriculum, several new discussion topics for future exploration are presented. This section will address both the limitations imposed by the study and suggest areas of future research.

Limitations

Due to the limited number of students available in a single class within the college of engineering, only 123 students participated in this study. While able to produce statistically significant results in the context of the mathematical methods used to perform this study, this sample size may not be extrapolated to generalize all engineering students and disciplines within the College of Engineering. It must be noted that a particular population was studied within the scope of the work. This study only identified mostly senior students from the industrial engineering discipline. This study is also limited in the types of activities identified as responses to the survey; not all activity types could be accounted for, so some generalization needed to be recognized for leisure-based activities. Additional work may investigate a single activity type for more in-depth contributing factors when the activity type is normalized. Finally, there were limitations on how the procedure for this experiment should have been conducted due to the pandemic. Not being able to provide the research material in person for a more controlled study environment to ensure the material was understood and submitted correctly might have hindered more accurate data collection.

Future Work

The ability to further research the following discussion topics would significantly contribute to the overall literature on the subject. A longitudinal study could be conducted to follow freshman students and record their extracurricular and hobbies to see how creativity changes over time, and during this study, offer other possible predictors to be identified. Another aspect to explore are other disciplines under the same study parameters, especially different engineering disciplines and students from other colleges, to expand the research. With a larger subset of students, an opportunity to study possible compounding effects of extracurriculars and hobbies instead of individual activities may also be available. Finally, by observing creativity scores over a period when the student is active in an extracurricular or hobby and after when they are no longer active, record the effects on creativity score. This can also be performed for the opposite effect, observing the possible changes in creativity when a student does not participate in an extracurricular or hobby and then deciding to do so.

Causation vs. Correlation

Veličković (2015) provides additional awareness of the causation vs. correlation argument. While every attempt has been made to conduct a well-designed experiment for the correlation results presented in this study to confirm the existence of causality with creativity, the underlying implication that correlation does not necessarily equal causation must still be stated. While correlation does indeed describe the strength of the linear relationship between two observed phenomena, the simplicity of a calculated correlation coefficient may conceal the considerable complexity in interpreting its meaning. While a correlation approach has been used in this study, it is essential to note that although the statistical evidence does point to the existence of causality, it is not sufficient to prove it. Researchers have considered possible assumptions behind a statistical analysis, methodologies, and resulting data to address this concern.

APPENDIX A

UCF IRB APPROVAL

UCF

UNIVERSITY OF CENTRAL FLORIDA

Institutional Review Board
FWA00000351
IRB00001138, IRB00012110
Office of Research
12201 Research Parkway
Orlando, FL 32826-3246

APPROVAL

January 8, 2021

Dear Maria Gonzalez:

On 1/8/2021, the IRB reviewed the following submission:

Type of Review:	Modification / Update-increased extra credit, changed course for recruitment
Title:	An Experimental Investigation of the State of Creativity in Relation to Extra-Curricular Activity and GPA in Undergraduate Engineering Students
Investigator:	Maria Gonzalez
IRB ID:	MOD00001515
Funding:	None
Grant ID:	None
IND, IDE, or HDE:	None
Documents Reviewed:	• HRP-502 - TEMPLATE CONSENT DOCUMENT Maria Gonzalez JAN2021 Rev3.pdf, Category: Consent Form; • HRP-503-TEMPLATE-Protocol-Maria Gonzalez JAN2021 - Rev4.docx, Category: IRB Protocol;

The IRB approved the protocol modification on 1/8/2021.

In conducting this protocol, you are required to follow the requirements listed in the Investigator Manual (HRP-103), which can be found by navigating to the IRB Library within the IRB system. Guidance on submitting Modifications and a Continuing Review or Administrative Check-in are detailed in the manual. When you have completed your research, please submit a Study Closure request so that IRB records will be accurate.

If you have any questions, please contact the UCF IRB at 407-823-2901 or irb@ucf.edu. Please include your project title and IRB number in all correspondence with this office.

Sincerely,

Renea Carver
Designated Reviewer

APPENDIX B

STUDY SURVEY

Survey

1. **Gender**

   Man Woman Other

2. **Are you of Hispanic, Latino, or of Spanish origin?**

   Yes No

3. **How would you describe yourself?**

   American Indian or Alaska Native Asian Black or African American

   Native Hawaiian or Other Pacific Islander White

4. **What is your age? ______________**

5. **What is your class status?**

   Freshman Sophomore Junior

   Senior Graduate

6. **Have you ever heard or ever been administered this examination before?**

   YES NO

7. **Do you participate in any extracurricular activities, (activities that are outside the field of the normal curriculum of University education)**

   YES NO

   a. **Which Category would best describe the extracurricular activity where the most time is spent**

   Student Government
   Athletics
   Academic and Professional Organizations
   Volunteer and Service Related Activities
   Multicultural Activities
   The Arts
   Greek Organizations
   Other __________

   b. **On average how many hours per week are spent on this category of extracurricular activity**

   0-5 6-10 11-15 16-20 20+

8. **Do you participate in any hobbies (activities done in your leisure time for pleasure)**

YES NO

a. **Which Category would best describe the hobbies where the most time is spent (See Appendix 1 for more detail)**

Collecting
Making
Activity
Play
Arts
Other ______

b. **On average how many hours per week are spent on this category of extracurricular activity**

0-5 6-10 11-15 16-20 20+

9. **Are you currently employed**

YES NO

a. **What is your current employment status**

Full Time
Part Time
Internship / Externship
Other ______

b. **Which Category would best describe your current field of work**

Science / Technology / Engineering
Healthcare
Social Service
Media / Arts / Design
Finance
Retail / Service
Office / Admin Support
Other ______

c. **On average how many hours per week are spent in this field of work**

0-5 6-10 11-15 16-20 20+

10. Have you ever enrolled in any course that deals with creativity or training in creativity?

YES NO

11. On average how many hours per week are spent studying for your classes (responses will not be shared outside of this research study)

0-5 6-10 11-15 16-20 20+

12. How would you describe your leisure to study workload not including lecture time? (Leisure – Study)

0-100 25-75 50-50 75-25 100-0

13. In your opinion does the engineering curriculum encourage creativity? Please elaborate.

14. To the best of your knowledge what is your GPA?

2 – 2.25 2.25 – 2.5 2.5 – 2.75 2.75 – 3

3 – 3.25 3.25 – 3.5 3.5 – 3.75 3.75 – 4

Thank you for your participation

Category	Sub-Category	Hobbies
Collecting	**Physical**	Action figures, Antiquities, Art, Books, Cards, Coins, Comic books, Deltiology (postcards), Elements, Flags, Flowers (pressed), Insects, Mineral, Movie and movie memorabilia, Stamps (Philately), Sea glass, Seashells, Stones, Toys, Video games, Vintage cars
	Record	Genealogy, Scrapbooking, Movie and movie memorabilia, Music/Audio Records, Video games
	Spotting	Aircraft spotting, Amateur astronomy, Bird watching, Bus spotting, Dowsing (ground water), Foraging, Geocaching (GPS), Ghost hunting, Gongoozling (canals), Herping (reptiles), Metal detecting, Microscopy, Mushroom hunting/mycology, Satellite watching, Shortwave listening, Train spotting
Making	**Clothing**	Crocheting, Cross-stitch, Embroidery, Fashion, Jewelry making, Knitting, Lacemaking, Leather crafting, Macrame, Quilling, Quilting, Sewing, Tatting
	Cooking	Baking, Coffee roasting, Cooking, Home brewing, Kombucha brewing, Wine making
	Garden	Gardening, Hydroponics, Topiary
	Model	3D printing, Blacksmithing, Candle making, Carving, Do It Yourself, Glassblowing, Lapidary (stones and gems), Lego building, Machining, Metalworking, Model building, Origami, Pottery, Rock balancing, Taxidermy, Whittling, Woodworking
	Utility	Amateur radio, Auto audiophilia, Book restoration, Computer programming, Electronics, Gunsmithing, High-power rocketry, Home building, Knife making, Soapmaking, Vehicle restoration
Activity	**Animal**	Animal fancy, Beekeeping, Fishing, Fishkeeping, Herp keeping, Horseback riding, Hunting, Pet, Whale watching
	Outdoor	Backpacking, BASE jumping, Camping, Canyoning, Climbing, Driving, Flying, Hiking, Kayaking, Mountain biking, Mountaineering, Rafting, Rappelling, Rock climbing, Sailing, Scouting, Scuba diving, Skydiving, Slacklining, Tour skating, Zipline
	Travel	Cruise, Excursion, Exploration, Holidaying, Pilgrimage, Road Trip, Traveling, Touring, Sightseeing, Vacation
Play	**Fitness**	Aerobics, Bodybuilding, Brazilian jiu-jitsu, Gymnastics, Jogging, Judo, Martial arts, Powerlifting, Running, Taekwondo, Tai chi, Walking, Weightlifting, Yoga, Zumba
	Games	Board/tabletop games, Bridge, Card games, Cheerleading, Chess, Color guard,

		Cosplaying, Crossword, Cryptography, Debate, Exhibition drill, Fantasy sports, Gaming (tabletop games and role-playing games), Go, Hunting, Kite flying, LARPing, Laser tag, Letterboxing, Mahjong, Marbles, Model aircraft, Poker, Puzzles, Radio-controlled car, Slot car racing, Spinning top, Speedcubing, Stone skipping, Treasure hunt, Video gaming, Yo-yo
	Sports	Air sports, Airsoft, Archery, Auto racing, Badminton, Baseball, Basketball, Billiards, Board sports, Bowling, Boxing, Cricket, Curling, Cycling, Darts, Disc golf, Dog sport, Equestrianism, Fencing, Flying disc, Footbag, Football, Golfing, Handball, Hockey, Hooping, Horseback riding, Ice hockey, Jukskei, Kabaddi, Kart racing, Lacrosse, Motor sports, Netball, Orienteering, Paintball, Parkour, Polo, Pool, Racquetball, Road biking, Roller derby, Rowing, Rugby, Shooting, Skating, Skiing, Soccer, Sport stacking, Squash, Surfing, Swimming, Table tennis, Tennis, Triathlon, Ultimate frisbee, Volleyball, Water polo, Water sports
Arts	**Dance**	Ballet, Ballroom, Baton twirling, Belly, Break dancing, Bharatanatyam, Bollywood, Cabaret, Cha cha, Contemporary, Folk, Free style, Fusion, Hip hop, Jazz, Jive, Kathak, Kathakali, Kuchipudi, Mohiniyattam, Latin, Odissi, Poi, Salsa, Troupe, Rock n Roll, Rhumba, Waltz
	Music	Alternative, Bands, Bass, Blues, Bollywood, Carnatic, Classical, Country, Drums, Electro, Flute, Fusion, Jazz, Kanjira, Ghatam, Guitar, Hindustani, Metal, Morsing, Mridangam, Latin, Nadaswaram, Pop, R&B, Rock, Singing, Saxophone, Soul, Tabla, Vocal, Veena, Violin
	Theatre	Acting, Drama, Juggling, Knife throwing, Magic, Marching band, Puppetry, Stage shows, Stand-up comedy
	Visual	Calligraphy, Coloring, Digital arts, Drawing, Flower arranging, Graffiti, Painting, Movie making, Photography, Sand art, Sculpting, Sketching
	Literary	Astrology, Creative writing, Language learning, Meteorology, Reading, Videophilia, Watching television, Web surfing, Worldbuilding, Writing

APPENDIX C

FIGURE 1 COPYRIGHT PERMISSION

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