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The Research Annual of the UTA Honors College

UNIVERSITY OF TEXAS ARLINGTON

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Volume I • Issue I

The Research Annual of the UTA Honors College

2018

The Honors College of the University of Texas at Arlington is a purposefully diverse community of student scholars in all majors dedicated to student success. The mission of the College is simple: to offer high achieving students an extraordinary undergraduate education through special academic programs and opportunities for research, study abroad, and leadership. The Honors curriculum fits with all majors, and complements and advances the goals of students' academic disciplines.

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Establishment of ATAC-Seq Library for Epigenomic Profiling During Myogenesis

Valerie Rose Bilton, B.S. Nursing

Faculty Mentors: Zui Pan and Sang Yong Choi

Understanding the whole-genome gene's transcription profiling that determines myogenesis may help us to find a potential cure for muscular dystrophy and cardiomyopathies. ATAC-sequencing (ATAC-seq) is a fairly new non-bias genomic approach that we used to study the gene's transcriptional activity involved in myogenesis of the C2C 12 mouse muscle cell line. Our goal was to evaluate and optimize the ATAC-seq method to construct high-quality libraries of muscle cells in different stages of myogenesis in order for further sequencing and analysis to be performed. In the original ATAC-seq protocol (Protocol A), the end product is mixed with unusable mitochondrial DNA information. After comparing a few mitochondrial exclusion methods, we adopted one with the shortest isolation time and least harshness and better mitochondrial DNA elimination efficiency. In this method (Protocol B), we used a special 20-G needle to homogenize broken cells by pipetting and used Extraction Buffer A to help further separate everything not of nuclear DNA material. The modifications did result in significantly reduced concentrations of mitochondrial DNA contamination, but did not lead to higher quality sequencing and analysis. Based on these results, Protocol A was used to construct the C2C l 2 muscle cell libraries for final ATAC-seq and analysis.

Does Short-Term Whole Body Vibration Plate Training Have an Effect on Balance in College-Aged Females?

Alyssa Bragg, B.S. Exercise Science

Faculty Mentor: Cynthia Trowbridge

The risk of an anterior cruciate ligament (ACL) tear in the knee is two to ten times higher in women than in men. Biomechanical differences, including the stability of the knee, have been identified as potential causes. The purpose of this study was to determine if five days of whole body vibration-based training would result in improvements in the balance of healthy females. Subjects were randomized into treatment and control groups and were pre- and post-tested using the Y-Balance test. The treatment group performed six core and lower extremity exercises using a whole body vibration plate over five treatment sessions.

Explicit Representations of the Lorentz Group

Darshan Chalise, B.S. Mathematics

Faculty Mentor: Dimitar Grantcharov

Lorentz group is the Lie Group of the symmetries of Minkowski spacetime. Because of this reason, representations of the Lorentz group and its Lie algebra attract considerable attention both in theoretical physics and mathematics. In this thesis we will investigate and relate to each other several different types of representations of the Lie algebras su (2) and so (3) that lead to representations of the

Lorentz group. Our explicit formulas allow finding necessary and sufficient conditions on which of these representations are isomorphic to each other.

Search for Invisible Decay of Heavy Higgs Bosons Produced through Vector Boson Fusion

Darshan Chalise, B.S. Physics

Faculty Mentor: Andrew White

Higgs Bosons mediate the interaction of Dark Matter with ordinary matter in Higgs-portal models of Dark Matter. Limits deriving from the search for invisible decays of Higgs Bosons can be used to set limits on the interaction of Dark Matter with ordinary matter. ATLAS and CMS have reported an upper limit on the invisible decay of Higgs Bosons (mass of 125 GeV/c2) to invisible branching ratio. This analysis involves the search for invisible decay of Higgs Bosons of mass 1000 GeV/c2 and 3000 GeV/c2. Monte-Carlo samples with Higgs mass of 125 GeV/c2, 1000 GeV/c2 and 3000 GeV/c2 are analyzed through EventLoop algorithm using ROOTCore. Event selection cuts are applied and comparisons of kinematic distributions for the three Higgs masses are made. Monte-Carlo files with Higgs mass of 125 GeV/c2, 1000 GeV/c2, and 3000 GeV/c2 are found to have event selection efficiencies of 2.1%, 3.7% and 3.9%, respectively. The kinematics distributions from heavy Higgs Bosons are distinct compared to the distributions from 125 GeV/c2 Higgs Boson. The results from this analysis, followed by estimation of background processes, can be used to place an upper limit on Higgs to invisible branching ratio for the 1000 GeV/c2 and 3000 GeV/c2 Higgs Bosons.

Conjugate Heat Transfer Analysis of Thermal Management of a Li-Ion Battery Pack

Divya Chalise, B.S. Mechanical Engineering

Faculty Mentor: Ankur Jain

Thermal management of Li-ion battery packs is a critical technological challenge that directly impacts safety and performance. Removal of heat generated in individual Li-ion cells into the ambient is a considerably complicated problem involving multiple heat transfer modes. This work develops an iterative analytical technique to model conjugate heat transfer in coolant-based thermal management of a Li-ion battery pack. Solutions for the governing energy conservation equations for thermal conduction and convection are derived and coupled with each other in an iterative fashion to determine the final temperature distribution. The analytical model is used to investigate the dependence of the temperature field on various geometrical and material parameters. This work shows that the coolant flowrate required for effective cooling can be reduced significantly by improving the thermal conductivity of individual Li-ion cells. Further, this work helps in understanding key thermal-electrochemical trade-offs in the design of thermal management for Li-ion battery packs, such as the trade-off between temperature rise and energy storage density in the battery pack.

Explaining the Connection between the Returns on Fixed-Income Mutual Funds and Underlying Securities' Yields

Sanjari Chelawat, B.B.A. Finance

Faculty Mentor: David Rakowski

One of the most attractive sources of income for both individual and institutional investors is fixed-income securities. However, due to the undesirable risk that arises when investing in a single security, investment in fixed-income securities is often made indirectly through fixed-income mutual funds, or funds that pool contributions of individual investors and further invest them in securities such as bonds. This study attempts to determine how returns on fixed-income securities are related to corresponding returns on fixed-income mutual funds. By using algebraic equations to ascertain bond prices and yields, the study models the return of a typical mutual fund based on the prices and yields of the underlying bonds. The study shows that bond returns are related to, but distinct from, both past and current bond yields and fund returns.

Obesity, Dyspnea on Exertion and Health Related Quality of Life in Obese Males

Lauren Crane, B.S. Nursing

Faculty Mentor: Deborah Behan

Both dyspnea on exertion (DOE) and obesity can have a negative influence on a person's health related quality of life (HRQOL). However, it is unclear if these relationships can be found in otherwise healthy mild-to-moderately obese men. In this study, we examined the relationship between 1) obesity and HRQOL, and 2) DOE and HRQOL. A secondary analysis was conducted from the baseline data of an interventional 12-week weight loss study. Volunteers filled out the Medical Outcomes Short Form-36 (SF-36) as the measurement for HRQOL. Obesity was determined from measurement percent body fat and BMI. Lastly, during a six-minute submaximal constant load exercise cycling test at 105 watts, participants provided ratings of perceived breathlessness. Forty-one men participated. We found that there is a reduced physical functioning when an individual has an increase in BMI and DOE. In addition, social functioning is reduced when an individual has an increase in percent body fat. Therefore, reduced physical and social functioning may lead to reduced physical activity levels, which ultimately may increase weight gain and continue worsening HRQOL.

Measurements and Modeling to Determine the Critical Temperature for Preventing Thermal Runaway in Lithium-Ion Cells

Iretomiwa Esho, B.S. Mechanical Engineering

Faculty Mentor: Ankur Jain

Understanding the nature of thermal runaway in Li-ion cells is critical for the safety of electrochemical energy storage and conversion systems. Specifically, it is important to understand and predict the critical temperature beyond which the cell enters thermal runaway. This paper presents an experimentally validated, analytical method to predict the critical temperature based on the thermal balance between temperature dependent heat generation, thermal conduction in the cell, and heat dissipation on the cell surface. It is shown that the critical temperature can be determined from the root of a nonlinear, transcendental equation involving characteristic parameters from Arrhenius heat generation, thermal conduction, and convection on the cell surface. The predicted critical temperature is found to be in good agreement with experimental measurements on a thermal test cell in a wide range of thermal parameters. The effect of cell thermal conductivity and convective heat transfer coefficient on the critical temperature is examined. The

trade-off between these two key parameters is shown to dramatically influence the critical temperature. Results presented here develop the capability of accurately predicting the critical temperature of a Li-ion cell in a given thermal environment, and therefore, may contribute toward effective thermal management design and the prevention of thermal runaway.

Effects of Exercise Environments on Stress with Premedical and Predental College Students

Islam Hammad, B.S. Biology

Faculty Mentor: Daniel Levine

The purpose of this study is to measure effects of exercise environments on stress in premedical and predental students, thus contributing to the development of a method to reduce stress levels in college students. To further understand the different ways stress levels can be reduced, a method was performed to see if exercise environments have an effect on stress in premedical and predental students. Participants took the Perceived Stress Survey Inventory (PSSI) and were then instructed to walk one mile every day for one week at the University of Texas Arlington (UTA) or a park. It was hypothesized by the researcher that walking at the park for one mile, every day for one week, would reduce the stress levels in students more than walking the same distance and schedule at UTA. This research then analyzed the data obtained from the exercise and calculated results. The results were concluded with no significant decrease in stress levels based on the environment. However, evidence showed a significant decrease in stress levels in both groups, demonstrating that exercise did reduce stress.

Tools of the Trade: Improving Nurses' Ability to Access and Evaluate Research

Phyllis Mae Helms, B.S. Nursing

Faculty Mentor: Deborah Behan

The purpose of this longitudinal quasi-experimental descriptive study was to measure the effect of an educational project on nurses' knowledge and frequency of using library database resources to acquire and appraise evidence-based practice (EBP). A secondary purpose was to examine the effects of nurse characteristics (educational background, professional certification, and years of experience) on nurses' library resource knowledge and usage. Twenty-eight nurses participated in the project by attending the one-hour training class (covering how to find resources for EBP data and how to critique research articles), and by completing a short Likert-type questionnaire at three intervals: before the class, after the class, and five months later. The questionnaire was designed for this project. Mean scores for the knowledge and ability section of the questionnaire had statistically significant improvements for four of the five questions, and the mean scores for the frequency section had statistically significant improvements for four of the five questions. Only one question in the knowledge and ability section showed slight decline five months after the intervention. Nurses' educational characteristics had no effect on mean scores. Overall, the brief training influenced the nurses' ability to search for, find, and appraise evidence-based information.

Campaigning to Millennials: How Social Media Affects Voter Turnout

Alyssa Hernandez, B.S. Political Science

Faculty Mentor: Herschel Thomas

Social media establishes an instant connection between people online and has become an outlet for young adults to express their ideas, opinions, and beliefs with others. Previous scholars have broadly studied voter turnout and social media, but little is known about the impact of candidates' presence on social media in relation to young voters. In this paper, I extend the research on social media and voter turnout by focusing exclusively on millennials. To test the hypothesis, I administered an original survey in the spring of 2017 to 362 millennials who attend the University of Texas at Arlington. The results show that when controlling for political interest, there is a positive relationship between a millennial following a candidate on Twitter and the probability of them voting. For example, for millennials who are "usually not interested" in politics, there is a 25% increase in probability of voting if they are following a candidate on Twitter. This suggests that candidates' use of social media may influence whether millennials are likely to vote on election day.

Mathematics of Medical Imaging

Mostofa Hisham, B.S. Mathematics

Faculty Mentor: Gaik Ambartsoumian

Imaging techniques have a wide array of applications in various fields of technology. One such application is medical imaging, such as the use of Computerized Axial Tomography (CAT) or Magnetic Resonance Imaging (MRI). The mathematical techniques behind such imaging technologies will be discussed, such as the transformation of a given set of data representing an object into a mathematical function. This data will be transformed through as Radon transform that shows certain characteristics of a set of data in terms of two variables that completely describe the data set. However, the Radon transform only transfers the data into a sinusoidal form, which must then be transformed into the image of the object by Fourier and inverse Fourier transform of the Radon Transform. The Back projection will be applied on this transformed set of data. This final data set should reflect the original object provided by the data set.

Engineering Low-Loss Plasmonic Materials

Mostofa Hisham, B.S. Physics

Faculty Mentor: Joseph Ngai

Plasmonics, the study of the interaction of an electromagnetic field with free electrons in conductors, allow devices that would combine the speed of photonic devices with the scalability of electronics. Efficient plasmonic devices should exhibit a low scattering of electrons, and a tunable carrier density. Undoped semiconductors exhibit very low carrier scattering; however, achieving tunable carrier density is challenging. This project will involve the growth of crystalline oxides on undoped semiconductors to achieve tunable carrier densities in the semiconductor via charge transfer. A LABVIEW program will be made that will measure the traditional and Hall voltage of the sample. The Hall voltage is measured perpendicular to the applied current and enables the carrier density to be quantified when measured in the presence of a magnetic field. The LABVIEW program will be interfaced with a commercial cryomagnetic system to perform the measurements.

Partner Cuing in Relation to the Middle Range Theory of Flight Nursing

Valery Lofton, B.S. Nursing

Faculty Mentor: Mary Mancini

Flight nursing involves the care and transport of critically ill patients in uncontrolled environments. Because of the critical nature of this role, it is crucial to understand what flight nursing expertise entails to properly guide education and training for these highly specialized nurses. The Middle Range Theory of Flight Nursing has been introduced; however, only one study besides this one has tested its validity in real-world applications. This study examined the concept of partner cuing in relation to the theory and identified its impact on expertise in flight nursing. The study utilized a two-part investigation of the theory that involved both the administration of individual surveys, as well as in-flight observations of flight crews. The survey, covering all nine concepts of the theory, was administered to a total of nine flight nurses who voluntarily participated in the study. After administration of the surveys, the flight nurses were observed interacting with their partner in the field. Survey responses aided in identifying the role that partner cuing has in the care of patients. Direct observation confirmed that partner cuing played a significant role in flight nursing practice. Identification of this phenomenon can be influential in future training and education.

Reconstructing the Past: Rebuilding Churches and Reconstructing Identity in Postwar Germany

Virginia Morris, B.A. History

Faculty Mentor: Joyce Goldberg

When the Second World War ended in 1945, Germany lay in ruins. Divided East and West, under Western and Soviet occupation, their country devastated, Germans began to rebuild their lives, homes, and country while searching for a way to process their role in the war, their defeat, and its meaning for themselves as a people. One way they began to reconstruct a sense of identity was to highlight historic German cultural creations. Germans, amidst the physical and political turmoil that surrounded them under military occupation, expended extraordinary efforts to preserve and rebuild two churches nearly obliterated by Allied bombing—the Frauenkirche of Dresden in East Germany and the Kaiser-Wilhelm-Gedächtniskirche of Berlin in West Germany. The struggle to preserve as much as possible the pre-war appearance of these universally recognized architectural landmarks demonstrates how Germans, even in defeat, used links to past glory to help forge a new, postwar German identity.

Preliminary Performance Tests of a Wireless Body Balance Measurement Device

Jonathan Nufable, B.S. Electrical Engineering

Faculty Mentor: George V. Kondraske

A thorough preliminary performance on the validity of a wireless Postural Stability Sensing Unit (PSSU) was performed. The tests were performed with the device attached to myself, and the following scenarios were conducted for standing on both legs and standing on dominant/right leg: eyes open, eyes closed, eyes open with moderate instability in the medial-lateral plane, eyes open with moderate instability in the anterior-posterior plane, eyes open with severe instability in the medial-lateral plane, and finally eyes open with severe instability in the anterior-posterior plane. In most trials, the PSSU was able to provide information

on how unstable my body was in a variety of scenarios. The result of the tests did not provide a percentage score of how stably my body performed; other indicators, however, such as absolute mean values, were substituted for each of the trials. These findings provide insight into not only how the human body system maintains stability, but also how PSSU and similar devices can be developed to aid in human performance research and to provide direction for further projects.

SPRING 2018 ABSTRACTS

Improvement of the Form and Function of the AL5D Robotic Arm

Cristian Almendariz, B.S. Mechanical Engineering

Faculty Mentor: Raul Fernandez

The University of Texas at Arlington Research Institute's Automation and Intelligent Systems Lab assigned the task of developing a multi-robotic framework to autonomously identify, sort, and deliver various objects to desired locations in a workspace. One main component of the framework is the AL5D Robotic Arm, which serves as the sorting machine. In an attempt to mitigate the limitations of the hobby grade motors that the AL5D uses, modifications were made to implement a position feedback to its controller. The AL5D's servo motor showed negligible change in the system response with the application of a digital compensator to the electronic controller. Other alterations made to the AL5D include the implementation of position teaching program and a 3D printed cover for the joints and links. The suggested alterations and the additional functionality implemented onto the AL5D robotic arm serve as a proof of concept for future improvements.

Study of Aluminum Using Coincidence Doppler Broadening Spectroscopy

Nicholas Byrnes, B.S. Physics

Faculty Mentor: Ali Koymen

Aluminum is an easily oxidized metal that can provide some valuable insight to the nature of positron-electron annihilation. In order to circumvent accidental analysis of the aluminum-oxide surface layer, our aluminum sample was first biased to 20 kilovolts, allowing the positrons to penetrate the surface layer and annihilate within the bulk of the aluminum, then later biased to 200 volts to display the broadened spectrum in the presence of Al_2O_3. The results we gathered will allow us to compare preexisting data to that collected by R. S. Brusa, who used aluminum as a standard in all of his Doppler-Broadened measurements. By comparing our results with Brusa's, we can confirm that our recently completed positron beam apparatus is functioning properly. This also allows us to better compare Copper and Graphene data previously collected with measurements available in the literature. This information will allow for further research into the topic of positron-electron annihilation in aluminum, such as possible correlations between plasmons and positronium formation.

True Marketing Leadership Explained: Characteristics of the Ideal Marketing Leader That Will Conquer the 21st Century

Daniela Chavez Garcia, B.B.A. Marketing

Faculty Mentor: Lawrence Chonko

Marketing and leadership have plenty of exclusive data, but not much blended data have been developed. There is also existing research into predicted marketing of the future and leadership of the future. Research on marketing leadership is limited, and an in-depth description of such is necessary to guide future marketers who aim for a bigger impact. In this project, data are gathered of each individual concept and, by identifying the overlaps, intertwined to reach an ideal Marketing Leadership definition. Since this project

focuses on what is necessary to succeed in the 21st century, surveys are conducted on students at the University of Texas at Arlington with the purpose of gathering leadership styles that represent anticipated preferences of the future. Furthermore, interviews are conducted with successful marketers and leaders. Their responses are analyzed thoroughly and compared to highlight similarities. All data are analyzed critically and grouped by characteristics of what is considered the ideal marketer of the future. Key factors to success in marketing leadership in the 21st century are identified and represented in a simple and attractive visual model.

Airline Responses to Mandated Non-Financial Performance Disclosures

Sanjari Chelawat, B.B.A. Accounting

Faculty Mentor: Nandu Nagarajan

Although the effect of improvements in non-financial measures (NFMs) of performance on the financial performance of companies is still not fully understood, research has indicated that there is a positive relationship between NFMs and the financial performance of airlines. The Department of Transportation (DOT) mandates that some non-financial measures of airline performance, like the percentage of on-time arrivals of flights, be disclosed. Collecting and disseminating this information is not costless. Therefore, it is important to determine whether airlines respond to these disclosures. In this research paper, we investigate this issue, by examining whether airlines ranked lower by the DOT in one period report improved results in the subsequent period and whether such changes have any value implications. Airlines that are considered "poor" performing initially improve their subsequent performance in response to lower rankings as disclosed by mandated DOT disclosures. However, the rate of improvement decreases over time. In general, all airlines report deteriorating performance on all NFMs with the passage of time.

The Effect of Lumbosacral Transitional Vertebrae on the Fifth Lumbar Vertebra and First Sacral Body and Its Prevalence in the Osteological Collection of the University of Texas at Arlington

Stephanie Dolenz, B.A. Anthropology

Faculty Mentor: Shelley Smith

Lumbosacral transitional vertebrae, or LSTV, is generally considered to be a congenital anomaly affecting the fifth lumbar vertebra and first sacral body. It is presented as sacralization, characterized by a caudal shift of fifth lumbar vertebra, and lumbarization, characterized by a cranial shift of the first sacral body. This research focused on the prevalence of LSTV in the osteological collection (overall and by sex), on nonmetric observations to describe the anomaly, and on metric observations to observe the effect of LSTV on bone. It was found that LSTV occurs in 20% of the sample. In addition, LSTV is more common in females and sacralization is more common than lumbarization. The areas affected by LSTV on the fifth lumbar vertebra and first sacral bodies showed metric differences when compared to the control sample; however, there is not a distinguishable pattern. Overall, it appears that LSTV is highly variable in its expression on bone.

Deviance and the Divine Madness

Jeremy Dubhrós, B.A. Sociology

Faculty Mentor: Robert Young

Society is governed by a set of social norms and schemas. Deviance, or transgressing these values, usually results in a loss of social status or even possible stigma. However, there are situations where the transgression does not negatively impact social status and may at times actually increase prestige and social power. Plato describes several examples in which an individual had abandoned rationality and should be considered insane, but where that madness was ultimately beneficial. He distinguished these forms of madness from "common" madness caused by disease and argued that they were divinely inspired. Though often viewed in a classical context, careful examination reveals that Plato was describing traits that were not bound to Greek culture and in fact occur across many cultures and time periods.

GloveLet

Arnav Garg, B.S. Computer Science

Faculty Mentor: Christopher Conly

The traditional computer mouse is unable to provide as high a level of productivity and efficiency in workflow for three-dimensional virtual objects as it provides for two-dimensional virtual objects. With the rise in three-dimensional virtual objects in augmented and virtual reality technologies, the need for a more user-friendly and convenient user interface device is now an inescapable necessity. GloveLet is a wearable glove that is designed to be used as a user interface device for three-dimensional as well as two-dimensional object movements. It is conceptualized to be lightweight, comfortable, and able to be used in work for long periods of time. It has a minimalistic yet robust design. To achieve maximum reliability and simplicity, it will normalize the data to best suit the user and apply multiple filters to catch false negatives and false positives. This will allow fewer possible points of failure in the design.

GloveLet: A Wearable 3D and 2D Tracking Glove

Prasoon Gautam, B.S. Computer Science

Faculty Mentor: Christopher Conly

The traditional mouse as a user-interactive device has been around for quite some time but can be a hindrance when used to control three-dimensional devices. Through GloveLet, my team and I seek to develop a wearable glove that can replace the traditional mouse with a more user-interactive and easy-to-use device. This would greatly enhance the user experience and would allow users to employ their hands to move objects, both two-dimensional and three-dimensional, on the computer screen, thereby making the experience more intuitive for younger and older adults. GloveLet will be designed from the beginning to be light-weight, comfortable, and able to be worn for long periods of time without any discomfort. Users will be able to freely switch between GloveLet and typing on a keyboard or even switching back to a mouse if they wish.

Arranging the Music of Billy Strayhorn

Wade Girton, B.A. Music

Faculty Mentor: Dan Cavanagh

Billy Strayhorn was Duke Ellington's arranger for decades and wrote much of his most popular music. Because he started his career as Ellington's protégé, his distinct compositional style was often assumed to have come from Ellington. After his death, his music experienced a critical reappraisal, and he was canonized as one of jazz's great composers. Because of this relatively recent change in his perceived stature as a composer, most of his works have not been reinterpreted or re-arranged as much as those of other prominent jazz composers. The goal of this project is to reinterpret Strayhorn's music in a modern jazz idiom while retaining the essence of his music. The selections ("Chelsea Bridge," "Isfahan," "Johnny Come Lately," and "Take the 'A' Train") represent the span of Strayhorn's career and some of his most important work. Recordings of both Strayhorn and other musicians will be used to inform the arrangements.

Improving Automatic Summarization for Low and Moderate Resource, Morphologically Complex Languages

Kalen Goss Manshack, B.A. Linguistics

Faculty Mentor: Pete Smith

Resource-poor, morphologically complex languages are at a disadvantage in natural language processing tasks, such as automatic text summarization or machine translation, because of the shortage of quality linguistic data available in these languages. Recently, researchers have introduced a language-independent, centroid-based method for automatic text summarization which garnered international attention for its success. This thesis explores methods for improving Rossiello et al.'s summarization approach on resource-poor, morphologically complex languages by implementing additional preprocessing steps on the data. Thereafter, stemming is shown to marginally improve research benchmark ROUGE scores for summarizations in German, a relative morphologically complex language, as well as in Turkish, an agglutinative language. In addition, a manual semantic analysis of the associated Word2Vec models in this approach showed improved accuracy when models were constructed on stemmed corpora. This result has implications for research on word embeddings in low-resource and morphologically complex languages.

Experiences of Dual-Minority Men within Shared Decision-Making Models: A Descriptive Comparison of Common Themes

Jared Hanes, B.S. Nursing

Faculty Mentor: Donelle Barnes

Healthcare providers can utilize the Shared Decision Making (SDM) model to help facilitate trustful communication and mutual decision making with their patients, especially with those who identify as a racial/ethnic minority and lesbian, gay, bisexual, or transgender (LGBT). A qualitative, phenomenological interview was conducted with six different patients, and participants were recruited from a local primary care clinic. Participants placed value on the quality of trustful communication with their provider. In order to have effective communication, these respondents felt that their provider should incorporate an objective and nonjudgmental approach toward their lifestyle practices. SDM can help develop trust and effective communication between a provider and their patient. Interview participants were comfortable discussing their

lifestyle practices with their provider, and felt that they were more likely to trust a provider who was personable and open-minded about their lifestyle practices.

A Flexible Distribution in Modeling Survival Data

Ian Harris, B.S. Mathematics

Faculty Mentor: Suvra Pal

Analyzing survival data involves such parameters as lifetime, censoring rate, and any number of covariates. The problem with using such distributions as the exponential, gamma, lognormal, and Weibull distributions, to fit the study into a model is that their parameter requirements are inflexible. The generalized gamma distribution is malleable and it can be used as a blanket distribution of sorts to catch datasets that fall outside the commonly used distributions. Using R software, we performed a simulation study in which we generated datasets under the generalized gamma distribution and compared different iterations of the simulated data to models of the different distributions in a likelihood ratio test to show the rejection rates of models whose parameters differ. As the number of generated generalized gamma datasets increased (50 to 300 to 500), the rejection rates among different parameters grew larger while the fixed vs. fitted model comparisons of the same parameter grew closer to a 5% rejection rate. With this as a background, we applied the generalized gamma distribution to a real dataset, whose parameters were unknown, to estimate its parameters. Although it did not fall into any of the special cases, it still could fit in the generalized gamma distribution.

The Relationship between Body Composition and Cardiorespiratory Fitness of Female Collegiate Students with Similar Activity Levels

Nawal Joulani, B.S. Kinesiology

Faculty Mentor: Judy Wilson

Body image is a huge topic in our society, and while people are being encouraged to "love their bodies," it would also be reassuring if they were able to understand the science of their body and just how much body composition affects their health. One way to measure fitness level, more accurately known as cardiorespiratory fitness, is by calculating maximal oxygen consumption (VO_2 max). To further understand the extent to which body composition affects fitness levels, 10 collegiate students were placed in a Bodpod to measure their body composition in terms of body fat percentage and fat-free mass percentage. Following that, a maximal exercise test was conducted to calculate their VO_2 max values, which are an indication of cardiovascular fitness levels. The values of body composition and VO_2 max values were analyzed to find any correlation between the two components. The ANOVA between groups was done to find no significant difference in the VO_2 max values of those with a body mass index lower and higher than 25.

The Relationship between Body Composition Measures and Aerobic Cardiorespiratory Fitness in Female Softball Outfielders and Infielders

Niveen Joulani, B.S. Exercise Science

Faculty Mentor: Judy R. Wilson

Researchers have found that the different positions in a sport can play a significant role in the internal proportions of the body. This work focused on comparing the body composition and cardiorespiratory fitness

between softball infielders and outfielders. Six female collegiate softball players (20.0 ± 0.89 yrs, 64.9 ± 1.7 in, 65.2 ± 8.1 kg), were split into two groups, infielders and outfielders, in order to compare the differences between the two groups. Participants were asked to report to the University of Texas at Arlington MAC 153 on one occasion for 30 minutes. Body composition was taken using the BodPod, a machine that measures the body's fat and fat-free mass, and cardiorespiratory fitness was measured as maximal oxygen consumption (VO_2 max) using the Bruce Protocol. Results found that infielders had lower cardiorespiratory fitness (42.63 ± 8.14 VO_2 max) and higher fat mass (21.5 ± 10.04 percent body fat). Overall, the position within this sport appears to have an impact on the players' fitness levels and body composition.

Altair Hyperworks Optimization Design Guide: Topology, Free-Sizing, Free-Shape, and Topography Optimization

Alexandra E. Kessler, B.S. Mechanical Engineering

Faculty Mentor: Robert Taylor

This guide is a companion paper to 2018's "Optimization of the Internal Topology and Sizing for Thin-Walled Aircraft Structures—A Design and Production Guideline for Fused Deposition Modeling" and covers the methodology behind optimization in HyperWorks, specifically: topology, free-sizing, free-shape, and topography optimization. The guide includes a comprehensive summary of anything that someone attempting an optimization within HyperWorks for the first time would want to know, such as guidance, meaning, and uses for different tools mentioned throughout the guide. In addition, the benefits and drawbacks of structural optimization are covered. This guide is not meant to replace a basic understanding of navigation within HyperWorks and requires a respectable amount of computer and engineering acumen. The guide seeks to define exactly how to initiate an optimization and why. Lastly, the guide will reveal in depth the justifications of beam member placement during topology optimization of the fuselage and a supplementary free-sizing optimization for possible future use by the next senior design team.

Statistical Analysis of Household Labor Supply: Education, College and Earning Power

Hrishabh Khakurel, B.S. Mathematics

Faculty Mentor: Christy Spivey

The general trend, historically, is that when husbands start earning more, their wives reduce their household labor supply. In the last few decades, the number of wives who have attained higher education has increased, and with this, the number of wives earning a higher income than their husbands has also increased. Research till now suggests that husbands' labor supply is not significantly affected by wives' wage increase. This paper studies the labor supply of husbands and wives relative to their educational attainment, using educational attainment to measure earning power. A statistical analysis on 2014–2016 American Community Surveys data was used to study the dynamic relationship between the labor supply decisions of husbands and wives. This study looked for evidence to see whether husbands' labor supply is affected by an increase in wives' earning power. Using college majors to calculate earning potential, we find that husbands' labor supply response is more significant than when simple educational attainment is used. The preliminary results of this research show that husbands' wage increase has a negative effect on labor supply of wives, whereas increase in wives' salary does not show any significant effects on husbands' labor supply.

Service Learning Education Intervention: Survey of Knowledge on Parasitic Worms and Hand Hygiene in Northern Belize Adolescents Ages 10–18

Tiffany Kim, B.S. Nursing

Faculty Mentor: Denise Cauble

The purpose of this project is to assess if there is a knowledge barrier concerning hand hygiene and the contraction of parasitic worms in the northern districts of Belize. In countries around the world, hygiene maintenance is an issue. This issue is complicated by factors such as deficient knowledge, poor implementation of hand hygiene, and minimal access to clean water or soap. This lack of consistent hand hygiene practice often leads to higher infection rates. The most prominent infection observed in communities of Belize is of parasitic worms. Hand hygiene and its effect upon infection rates by parasitic worms requires further investigation. In this service learning project, an educational intervention was implemented in an international population that is highly impacted by poor hygiene practices and high infection rates by parasitic worms. I applied the nursing principles of patient education and applied it to four communities in northern Belize.

The Modeling, Optimization, Printing, and Testing of Thin-Walled Fused Depositioned Aircraft

Nicholas Lira, B.S. Mechanical Engineering

Faculty Mentor: Robert Taylor

The production of a 3D printed aircraft requires a procedural design and testing process to guarantee reliable manufacturing. To begin, an aircraft model is created in Computer Aided Design (CAD) software or selected from available sources. In this study, a DG-1 Version 2 model was chosen from OpenVSP, then the responsibility of production for the fuselage and wing sections were divided up into two teams. AeroSpac3D took on the fuselage, and DS Wingsquad worked on the wings. After model selection, the next step is to optimize a stiffening structure for each section in Altair HyperWorks to resist forces defined by bending, torsion, tension, and pressure. The stiffening structure generated is then exported and projected on the original fuselage or wing model in CAD software. The new CAD model, with a stiffening structure, is printed, and the mechanical testing begins to validate the design procedure. In the testing phase, loads simulated in optimization are reproduced to better understand the quality of the print and the deflections generated from loading. If failure occurs, iteration of the design must take place before printing may continue. At the time of writing this paper the wings had been printed but the fuselage had not.

Health Literacy in Social Work

Marissa Lopez, B.S.W.

Faculty Mentor: Regina T. Praetorius

Health literacy is defined as the cognitive and social skills that determine the motivation and ability of individuals to gain access to, understand, and use information in ways that promote and maintain good health. Many studies have identified that there is a problem with health literacy among Hispanics in the United States. This research thesis explores why health literacy is a problem, the history of social work's role in health literacy, the Hispanic health literacy problem, social work's role in addressing it, and what health literacy looks like in a Hispanic country.

The Significance of Making Accessible User Interfaces in Digital Applications

Vaishanavi Mirapurkar, B.S. Software Engineering

Faculty Mentor: Christopher McMurrough

With digital applications, one parameter which influences user experience (UX) is accessibility. In the design context, accessibility means that a product or service should be able to be used by everyone, regardless of a person's physical, economic, or cultural status. Because people with disabilities form one of the largest user groups in the world, UX designers must investigate some key areas of disabilities and follow certain principles and guidelines in order to make accessible designs for such users. For example, individuals with autism spectrum disorder, specifically sensory disintegration disorder, have trouble adjusting to certain environments. As a result, certain environmental conditions are not conducive to relaxation for such individuals. Vcare is a mobile (Android) application that can be used by people with autism or their family members to find suitable and "autism-friendly" recreational places to enjoy. The intended audience for the application are individuals without disabilities, and individuals with disabilities, including individuals with autism. Amid a smorgasbord of mobile and web applications, Vcare is an innovative and disruptive technology that will make a major difference in the lives of individuals suffering from autism spectrum disorder. Because Vcare is a digital application, user experience UX is critical to its success.

Biomechanical Characterization of the Neonatal Porcine Ventricular Septum

Chidalu Mozie, B.S Biomedical Engineering

Faculty Mentor: Jun Liao

Defects in the interventricular septum are the most common congenital cardiac defect in infants. The pressure difference between the two ventricles causes increased blood flow to the right ventricle, which leads to septal deformation. Given the difficulty of imaging the interior of the intact heart, the mechanics of this interventricular septal deformation has not been determined in situ. My project entails the creation a motor-controlled pressurization system to deform the neonatal porcine left ventricle for the characterization of the interventricular septal mechanical properties. The pressurization system uses a motor controlled piston pump, run by a personalized LabVIEW program, that deforms the left ventricle at varying pressures. The corresponding displacement of the septum was characterized by tracking septal marker movement, calculating the equivalent biaxial strains (εX And εY) and areal strain ($\varepsilon areal$) using MATLAB, and plotting data curves of pressure vs. $\varepsilon areal$, pressure vs. εX, and pressure vs. εY.

Analyzing Gene Conversion in Parthenogens

Murtaza Mucklai, B.S. Biology & Chemistry

Faculty Mentor: Matthew Fujita

Parthenogenesis is a type of asexual reproduction in which an unfertilized, typically female, gamete develops into a genetically identical clone of the mother. Gene conversion is the unidirectional transfer of genetic material from one DNA strand to another, that is, from a donor strand to an acceptor strand; this mechanism is not expected to occur in parthenogens. This project determines whether gene conversion occurs in a few species of parthenogens. The 18S gene was first amplified via PCR, and the resulting amplicons were run on a gel to confirm successful amplification before sequencing. We found that 18S was genetically identical in Aspidoscelis; however, sequences of Heteronotia were seen to be not heterozygous, indicating that gene conversion was taking place. Further study on this species is ongoing.

Advanced Chemical Technologies: An Innovative Problem-Based Approach to Teaching Chemistry

Ariel O'Brien, B.A. Chemistry

Faculty Mentor: Frank W. Foss Jr.

The Advanced Chemical Technologies (ACT) Program led by Dr. Kevin A. Schug and Dr. Frank W. Foss Jr. proposes an innovative approach to achieving a bachelor of science in Chemistry and Biochemistry for students at the University of Texas at Arlington. This study quantified the effects of the inclusion of research methods and problem/inquiry-based learning in the programs first semester general chemistry laboratory. This included analysis of student test scores and survey responses. It can be concluded that the ACT program can be projected to achieve the goal of increased retention of students who major in Chemistry and Biochemistry by increasing comprehension and evolving student views on the nature of science through a community-based learning approach.

New Graduate Nurses in Early Solo Flight: Nurse Manager Perspectives

Leonee Onyekwere, B.S. Nursing

Faculty Mentor: Regina Urban

Nurse managers play an integral role in the transition of new graduate nurses (NGN) to competent nurses. Their roles include ensuring that NGNs are integrated properly into the workplace and having monthly check-ins to identify progress and setbacks with their transition to professional practice. This study explores the perspectives of nurse managers on the strengths and weaknesses of NGNs during their fourth to eighth month of experience working as a nurse. Five nurse managers were interviewed for this study at a location of their choice, and the interviews were transcribed for analysis. They were asked about the strengths and weaknesses that they have observed in NGNs during the first few months of independent practice. The results indicated that nurse managers see strengths in NGNs' ability to be connected to the unit and the environment. Moreover, nurse managers share a viewpoint that NGN weaknesses were a reflection of the fact that they were not yet finished with the transition to practice presented.

Training Darknet Yolo for Use in an Industrial Setting

Ashley Quimod, B.S. Computer Science

Faculty Mentor: Christopher D. McMurrough

Darknet YOLO is an object detection software that is based on the usage of a neural network to perform its real-time predictions. YOLO stands out from other object detectors with its speed and method of prediction; as illustrated by its name (You Only Look Once) analyzes an image once for its predictions. Our team was tasked in training YOLO to detect objects common to an industrial warehouse setting with training efforts to soon be followed by testing phases. Creation of the datasets involved the tracing and annotation of hundreds of images per class to be fed into YOLO's network, which would then learn from the given input. We would utilize TinyYOLO, a lightweight version of YOLO, due to a priority in speed in training, predictions, and video feed when running YOLO. Our results were satisfactory though we encountered some issues along the road to the final model. Work with Darknet YOLO does not stop with this single instance of training and is open to a wide range of future work ideas.

Functional Study of Two Testis-Specific Nuclear-Encoded Mitochondrial Gene Duplicates in Drosophila Melanogaster

Mohammad Rashik, B.S. Biology

Faculty Mentor: Esther Betrán

This project involved the study of the fertility effects of lowering the amount of transcript (i.e., knocking down) two testis-specific duplicated genes in Drosophila melanogaster to understand their function. The Betrán lab discovered that many genes duplicated from parental genes with mitochondria related function. The lab also found that these duplicated genes acquired testis-specific expression. The study of two specific genes can help elucidate the reason for the duplication. The first gene was cytochrome c distal (CG13263). The second gene was cytochrome c1-like (CG14508). RNA interference (RNAi) technology was used to knock down the genes at two different temperatures (25°C and 27°C). Males from the CG14508 and CG13263 knockdowns showed significantly reduced fertility at 25°C and complete sterility at 27°C for the gene libraries that were tested. The results revealed that these genes are important for male reproduction. Furthermore, the study helped the understanding of the selective pressures that lead to the duplication of those genes. For CG13263, the RNAi served to confirm that the observed effects recapitulate the phenotype of a P-element insertion confirming RNAi usefulness as an approach to study gene function in spermatogenesis (i.e., serving as a positive control of the approach for the lab).

The Economic Outcomes of Breastfeeding

Raegan P. Rust, B.S. Economics

Faculty Mentor: Christy Spivey

Breastfeeding is related to numerous benefits for newborns and mothers. Juxtaposed with formula-fed newborns, breastfed newborns encounter less severe and lasting illnesses. Children who are breastfed experience more benefits, such as a higher IQ, than individuals who are formula-fed. Also, fewer breastfeeding mothers experience illnesses tied to breastfeeding than women who do not breastfeed their newborns. Because the identification and management of these illnesses lead to higher medical usage, health expenses would be expected to decrease with effective breastfeeding advertisement. For these reasons, studies that correctly estimate the expenses and savings connected to breastfeeding would be useful for decision makers as they study breastfeeding-friendly programs. This thesis evaluates ideas central to understanding the medical economics of breastfeeding. Costs are summarized from the viewpoints of newborn and mother/father, healthcare payer and company. Increased breastfeeding is anticipated to lead to a substantial cost savings for the United States economy.

Determining Hardware Setup for Training and Testing an Object Detection Model for Use in an Industrial Setting

Tanmay Sardesai, B.S. Computer Science

Faculty Mentor: Christopher McMurrough

As part of the senior design project, our team has trained a seven-class object detection model. The classes that can be detected by this model are people, forklifts, trucks, boxes, pallets, pallet jacks, and industrial carts. The goal of this honors thesis was to run this object detection model on different hardware systems to decide the best option. Darknet YOLO (you only look once) is a real-time object detection system used in this project. YOLO uses a single convolutional neural network to detect objects in an image. For the purpose

of this project we will be using Tiny YOLOv2, which is a version of YOLO that is lightweight and performs fewer calculations, giving us a lower accuracy but higher frame rate. Tiny YOLOv2 applies a single neural network to the full image and divides the image into regions and predicts bounding boxes and probabilities for each region. Our model was tested on five different systems: Raspberry Pi 3, Asus Intel i5 4th Gen CPU, Nvidia Jetson TX1, Nvidia Jetson TX2, and Nvidia GeForce GTX 980 Ti. After taking into account the frame rate, accuracy, and cost of each of these systems, our recommendation is to use Nvidia Jetson TX2.

Comparing News Coverage of Richard Nixon and Donald Trump in Their First Hundred Days

Chanel Sassoon, B.A. Journalism

Faculty Mentor: Erika Pribanic-Smith

News values have remained the same since the inception of journalism; however, the ways we consume news and write stories have changed with the times. Print media, which used to be the main avenue of receiving news, has since been replaced with digital formats. Tumultuous times bring an influx of news stories, especially when they involve politics. Two of the most controversial US presidents, Richard Nixon and Donald Trump, were the subjects of many news stories during their times in office. To further understand the way political news coverage has changed over the years, the author studied articles published within the first hundred days of each administration in the *Dallas Morning News* and *The New York Times*. A content analysis of 200 articles revealed not only several similarities in the way the newspapers covered each president, but also some striking differences. The differences could be attributed to the changing political and technological environments.

Training a Neural Network to Recognize a Fish and a Coin and Performing a Comparative Analysis to Deduce the Length of a Fish

Swangya Saurav, B.S. Computer Science

Faculty Mentor: Christopher Conly

Recognizing objects in an image is a complicated task and combines a plethora of variables, which deviates substantially with a small deviation in the environmental conditions. Taking into account all of those variables and programming an object detector to work in multiple conditions is a difficult task. However, using neural networks makes accounting for these variables a lot easier, as it eliminates the requirement of human involvement in setting up those variables. Further, developments in new neural network architectures like Faster RCNN and Mobilenet have made the prediction using neural networks more efficient and accurate than ever. These advancements have enabled us to create applications that require less computational power, yet can produce an accurate result. This technology was used to create a measuring tool that can be used by anyone to easily determine the length of a fish. The neural network for this project was trained to recognize a fish and a US quarter coin in an image, and upon detection of those two objects, the code compared the length of fish to the length of a coin to approximately deduce the length of the fish in imperial units.

An Examination of JNK Signaling During Caenorhabditis Elegans Mitohormesis

Romeeka Arfeen Siddiqui, B.S. Biology

Faculty Mentor: Mark Pellegrino

Mitohormesis is the biological concept that a mild dose of mitochondrial stress has beneficial effects on an organism, leading to increased longevity. While mitohormesis has been demonstrated to result in a conserved increase in lifespan across multiple species, the molecular players involved in this phenomenon still need to be fully identified. We investigated the role of KGB-1, the Caenorhabditis elegans homolog of mammalian c-Jun N-terminal kinase (JNK) in the regulation of mitohormesis. Specifically, what substrate(s) interact downstream of the stress-activated kinase KGB-1 to mediate mitohormesis? Primary methodology was lifespan analysis using C. elegans in which each predicted KGB-1 interactor gene's function was reduced by RNA interference (RNAi). For each RNAi strain, lifespan of C. elegans was monitored and used to construct survival graphs. Results indicated that the effect of KGB-1 on mitohormesis longevity was dependent on the specific substrate that was knocked down. Of the KGB-1 substrates that were reduced following RNAi, the GTPase NOG-1 that is required for ribosome assembly showed the greatest effect. Our preliminary results suggest a novel mechanism of mitohormesis by the regulation of ribosome assembly through the interaction of KGB-1 and NOG-1. Biochemical assays will be carried out to further study this in mammalian cells.

Storm Water Quality Analysis of Holland Road Expansion and Extension

Trevor Stull, B.S. Civil Engineering

Faculty Mentor: Andrew Kruzic

Before many construction projects, there is no human influence on the land. There is more vegetation in pre-developed land that acts like a filter, absorbing many chemicals in stormwater runoffs. Vegetation cover also leads to lower flows for stormwater runoff. The development of land decreases the vegetation cover by introducing impervious layers, such as concrete. The increase in impervious layers decreases the amount of runoff that can be absorbed naturally by the ecosystem, leading to more stormwater runoff. Furthermore, development leads to an increase in exposure to humanmade chemicals. Thus, development leads to more intense exposure to harmful chemicals that the ecosystem cannot handle. My honors project will address the problem of contaminated stormwater runoff by analyzing the effectiveness of different water quality management techniques and practices. This project will also include a discussion of the governing design criteria for water quality management. Furthermore, my honors project will include a discussion of several hydraulic structures and systems that aid in improving the water quality of stormwater runoff. Finally, recommendations for a water quality management system will be made for the site of my senior project.

The Trump Effect: Are Politicians Tweeting Like President Trump?

Jaycee Weber, B.A. Public Relations

Faculty Mentor: Mark Tremayne

The social media platform Twitter has become President Donald Trump's communication channel of choice, possibly contributing to his unexpected win in the 2016 US presidential election. This research examines the impact of Trump's distinctive tweeting style on the discourse of other US politicians.

Specifically, this study examines ten senators' tweets from the Obama era and the Trump era to see if other politicians are currently adopting President Trump's tweeting style. A simple random sample of tweets from the senators were taken from the two eras. The results showed some changes in the types of posts senators made. The results also revealed that Democrats' posts were more likely to mimic the Trump style. This suggests that President Trump has had an effect on political communication through Twitter. Additional findings are presented and implications for political communication discussed.

IMPLEMENTING PROJECT-BASED LEARNING: THE EFFECTS OF STANDARDIZATION IN A TEXAS MIDDLE SCHOOL

MISBAH AHMED | B.S. EDUCATION

Faculty Mentor: Kathryn Pole

ABSTRACT

This study examined project-based learning (PBL), a teaching methodology that requires students to work collaboratively in order to solve an authentic, real-world problem that is driven by inquiry. Of particular interest was the relationship between the implementation of PBL and standardization. Due to the student-driven nature of PBL, the methodology contains many instructional components and requires a great a deal of planning from teachers. This can pose a challenge to teachers in an era in which standardized testing is a primary focus in schools and teachers must manage benchmark testing and test preparation, in addition to day-to-day instructional activities. A project-based learning questionnaire was obtained from a previous study and was coded into the Qualtrics Survey System. The questionnaire was sent out to all fifty-six faculty members at a Texas project-based learning middle school, and the responses were coded for themes. The results showed that teachers had a generally negative perception of PBL. Lack of time, meeting all state accountability requirements, and fitting all state standards were found to be among the biggest challenges when implementing PBL. There seemed to be a relationship between teaching core subjects and having a negative perception of PBL. This may indicate that standardized testing in the core subjects may play role in teachers' perceptions of PBL. A positive relationship was found between the perceived most challenging components of PBL and their association with standardization. This may have led to the possibility that, due to the instructional schedules created around standardization, it was more difficult to implement PBL while making sure all standards were met.

"Tell me and I forget. Teach me and I remember. Involve me and I learn."

— Benjamin Franklin

When I began discussing the subject of this study with the middle-level program director, I was immediately drawn toward conducting a case study involving project-based learning (PBL). I always visualized my classroom to be student-centered, where my students were directly involved in their learning. Researching more about PBL, motivated by pure curiosity, led me to realize the instructional method I had envisioned being used in my future classroom was exactly what PBL encompassed. As an aspiring middle school teacher who wished to teach through PBL, I wanted to know more about any challenges teachers have faced when implementing PBL in their classrooms. In many schools across America, end-of-course examinations have become a focal point of education, and there is great stress on making sure students pass these assessments. The emphasis on standardization led me to focus on standardized testing and its impact on teachers who, like me, envision their classroom instruction involving PBL.

1.1 Background of the Study

Project-based learning is an instructional model that requires not only students, but also teachers, to work collaboratively in order to solve an authentic, real-world problem, guided by a driving question (Harris, 2014). This teaching method also encourages technology

to be utilized by students in order to cultivate inquiry, research, and creativity (Tamim & Grant, 2013). As the world entered the 21st century and technology became easier to access in many American schools, teachers began shifting their instructional methods to address the needs of the learner (Harris, 2014). The turn of the century brought forth a generation of students who became adept at technology and learning through doing. Traditional teaching methods, in which teachers stood in front of the class and gave lectures about the day's lesson, soon became outdated because students needed to learn through involvement and not through listening only. From that stemmed the concept of connecting students' learning to the real-world and allowing students to use technology in the classroom to learn more, which later evolved into the more complex methodology of PBL.

1.2 Statement of the Problem

As mentioned earlier, project-based learning is considered to be a more complex instructional method because the projects are based on challenging questions that require students to use problem-solving and decision-making skills in order to design a solution to the driving question at hand (Thomas, 2000). Because PBL is more student-driven and less teacher-led, it often contains many instructional components and requires quite a bit of planning from the teacher. This can be challenging especially in an era in which standardized testing is the primary focus in schools and teachers have to juggle benchmark testing and test preparation days in addition to the end-of-course examinations. Furthermore, teachers may have varying opinions about PBL and its purpose, which may influence their decision as to whether they would like to implement it in their classroom. This case study explored teachers' perceptions on PBL and the challenges standardized testing placed on teachers implementing it in a Texas suburban middle school.

1.3 Potential Outcomes

This case study investigated the relationship between standardization and its impact on teachers' ability to apply 21st century pedagogy in order to teach the competencies of standardized tests. The survey responses added insight on teachers' confidence levels when they were asked to start using PBL in the classroom. The responses also brought to light how well teachers at this particular school understood the full scope of PBL. This study provided feedback to school administration on how teachers felt about PBL and how they could help the teachers overcome the challenges they faced. It allowed the teachers at a school that had been promoting PBL for the past three years to contribute their perspective to the world of education.

1.4 Definition of Terms

The following is a list of definitions of the terminology used in this study to provide clarity.

Project-based learning is defined as a teaching method in which teachers help students learn about different subjects simultaneously by "guiding students to identify, through research, a real-world problem, developing its solution using evidence to support the claim, and presenting the solution through a multimedia approach based in a set of 21st-century tools" (Wolpert-Gawron, 2015).

Data instruction is a systematic approach to improving student learning and achievement throughout the school year. This includes assessment, analysis, and action; it is considered "a key framework for school-wide support of all student success" (New York State Education Department, n.d.).

Inquiry is a learning approach in which students question, examine credible sources for information, propose hypotheses, analyze data, make conclusions, and communicate results (Vasconcelos et al., 2012).

Race to the Top is a competitive federal grant that awards states that advance reforms around adopting standards and assessments, build data systems that measure student growth and success, recruit and retain teachers and principals, and turn around the lowest-achieving schools (United States Department of Education, 2016).

Scaffolding is a variety of assistive instructional techniques that provide successive levels of temporary support that help students move toward stronger understanding and, ultimately, independence in the learning process (Hidden Curriculum, 2014).

Team project-based learning is a variation of PBL in which a team of four or five teachers who teach different subject areas collaborate with one another to create and implement a cross-curricular project-based learning model in their classrooms during the same grading period (Chang & Lee, 2010).

TEKS is an abbreviation for Texas Essential Knowledge and Skills. These are the state standards for what the students should know and be able to do (Texas Education Agency, n.d.).

LITERATURE REVIEW

2.1 Defining Features of Project-Based Learning

Instructional methodologies all have very specific features that characterize the approach and delivery of the lesson. These ways of teaching can be very simple and have minimal steps to the lesson; or they can be very complex and have multiple steps in a lesson that span over the course of days or weeks. PBL seeks to incorporate 21st century skills into students' learning, and because of this it contains a plethora of components that differentiate it from other, similar types of teaching methods. PBL has three primary components: student learning goals, the essential project design elements, and project-based teaching practices (Larmer, Mergendoller, & Boss, 2015). Each of these components work together to create the concept of the Gold Standard PBL, or the highest quality PBL. Without some of these components, a PBL-intended project may not be defined completely as a PBL, so it is important for teachers, especially those who teach in PBL-based schools, to know the parts that create a Gold Standard PBL.

2.1.1 *Student Learning Goals.*

The foundation of a well-designed project typically revolves around the academic content students will learn about and the skills students will develop from the project (Harris, 2014). A Gold Standard PBL should be guided by the grade-level specific content standards and should teach students concepts and understandings that are key to school subjects and academic disciplines (Larmer et al., 2015). Teachers are responsible for creating and connecting a PBL to content area standards so that students are learning new knowledge, similar to an ordinary lesson plan, but, in contrast, are applying the new knowledge to a real-world problem. However, content area knowledge alone is not sufficient for survival in the 21st century. Knowledge regarding subject area concepts is closely associated with developmental skills. Generally speaking, in the real world people must have the skills to use critical thinking in order to solve problems, work well with others, and manage their time effectively (Smith, 2016). These skills are also known as "21st century skills" because they are necessary for career readiness in this era (Smith, 2016). It is important to remember that students cannot learn problem-solving skills apart from subject matter, but rather gain these skills by thinking critically about the subject matter. This is why a Gold Standard PBL makes sure to incorporate critical thinking, problem solving, collaboration, and self-management (Larmer et al., 2015). These skills are considered to be fundamental to a student's future success.

2.1.2 *Essential Project Design Elements.*

In addition to the inclusion of student learning goals and knowledge, the Gold Standard PBL contains many design elements that are necessary for a successful project. These elements include: a challenging problem or question, sustained inquiry, authenticity, student voice and choice, reflection, critique and revision, and a public product (Larmer et al., 2015). An example of a Gold Standard PBL might involve students working with community members in order to address an issue in their city, such as hunger, clean water, or homelessness. Students may need to research what actions the city has taken to address this need and the success rate of those actions. Students could speak to community leaders and visit city hall to understand how local government functions. Based on their research students would need to develop a possible solution to solve the need they identified. This solution would need to include the logistics of carrying it out in their community such as funding, obtaining supplies, or even government legislation that may need to be passed. This particular PBL incorporates all subject areas: mathematics, science, social studies, and language arts/reading. Students might use mathematics to calculate funding for their solution and use science concepts to understand the cause and effect of their need, especially if the need is clean water, for example. Students will understand the branches of government and how local communities function while researching which community departments are in charge of addressing the identified need. Lastly, students will incorporate reading and writing skills throughout the project while researching and writing letters. The next few paragraphs discuss the definitions and scope of each essential project design element in PBL.

2.1.2.1 *Challenging Problem or Question.*

A PBL must have a guiding problem or question that encourages students to use higher-level thinking skills so they can investigate the issue and create a solution (Tamim & Grant, 2013). Driving a PBL with a problem or question makes students' learning much more meaningful in that they know they are learning this new knowledge to apply it to solve a problem or answer a question (Larmer et al., 2015). Students are thus motivated to stay on task in class so they can really learn and understand the material being taught.

2.1.2.2 *Sustained Inquiry.*

Sustained inquiry indicates two things that should be happening in a PBL: First, students should be asking questions, investigating answers to their questions, and subsequently asking more in-depth questions; and second, the investigation portion should last more than a few days (Larmer et al., 2015). Students are typically given the freedom to

investigate in whatever way they choose—for example, researching through the web or conducting field-based interviews. This process usually spans a few days because students are expected to continue to investigate and ask questions until they develop a solution.

2.1.2.3 Authenticity.   Authenticity in the world of education refers to how relatable the given task is to the real world. The real-world connection in a PBL is considered to be fundamental to the project because it allows students to understand future applications of the concepts and skills they are learning in the classroom (Larmer et al., 2015). A PBL can identify with the real world in many ways. It can have a real-world context, involve real-world processes or tasks, involve a real impact on the community, or relate to the students' interests and identities.

2.1.2.4 Student Voice and Choice   When students are given the opportunity to contribute their input to a project, they have a sense of ownership. Students feel as though their voice is being heard when their opinions and ideas are being shared with their teacher and peers. A Gold Standard PBL gives students the freedom to have their input and control, to a degree, over their project (Larmer et al., 2015). Students can express their thoughts in a PBL during many aspects of the project such as creating questions, deciding which team members will take over which roles, or even during the product creation stage.

2.1.2.5 Reflection   During the PBL process of investigating and developing a solution, students should reflect upon what and how they have learned (Larmer et al., 2015). The reflection element helps students gain a solidified understanding of the concepts they have learned and how they may use this knowledge when they are employed professionals in the future (Smith, 2016). Because PBL promotes the use of creativity and open-endedness, students are encouraged to reflect on the project in whatever way they choose, such as in the form of a reflective journal or a discussion among peers.

2.1.2.6 Critique and Revision   In the real world, people often provide each other with constructive criticism, especially when large-scale projects and work assignments are involved. As a result, it is important for students to know how to give and receive constructive criticism. Project-based learning seeks to instill critique and revision skills in students by incorporating these skills into the PBL process. After students have developed a solution, using their research and ideas, they must meet with their peers and give each other feedback on items in their solution they may want to adjust or improve on (Larmer et al.,

2015). After students have been given feedback, they are expected to make the necessary adjustments and/or changes to their solution (Larmer et al., 2015).

2.1.2.7 Public Product   The last and final step in a PBL is for students to create a public product that represents their solution or answer to the problem or question (Larmer et al., 2015). This product can be in the form of something tangible and physical, or it can be a presentation of the solution or answer. There are three major reasons as to why a Gold Standard PBL should have students create a product. First, students gain motivation when they understand that they must create a visual that represents their accomplishments in their work (Larmer et al., 2015). Second, when students are required to create a product that is to be shown to their peers, teachers, and community members, students build a learning community around them, where discussions are welcome and perceptions are shared (Larmer et al., 2015). Last, making students' work public generates a path for communication between parents, teachers, and community members (Larmer et al., 2015). It is a physical indication to the community of how much their students are learning and how they are applying that knowledge.

2.1.3 *Project-Based Teaching Practices*   The last defining feature and component of project-based learning is project-based teaching practices. From a teacher's perspective PBL is very different from traditional classroom methods because teachers give the students more control over their learning and thus trust in their students to take the responsibility of adhering to deadlines and staying on task (Harris, 2014). Teachers must follow seven practices when implementing PBL: design and plan, align to standards, build the culture, manage activities, scaffold student learning, assess student learning, and engage and coach (Larmer, 2015).

To begin with a PBL, teachers must first design or adapt a project to fit the context of students and their learning abilities (Larmer, 2015). Teachers must also plan the implementation and guidance of a PBL from beginning to end, while keeping in mind to leave room for student voice and choice (Larmer, 2015). Once a PBL has been designed, teachers need to make sure the subject area content it incorporates, aligns to state or national standards and learning goals.

While implementing PBL, teachers should build a culture of independence and growth in their classrooms. In order to build the culture, teachers should encourage their students to take part in inquiry, practice team building, and pay attention to detail in their work as it is representative of their learning (Tamim & Grant, 2013). When students are working through the PBL process, teachers should also be actively engaged in their students'

work (Larmer, 2015). This is important because often not all students in a classroom are at the same learning level, and some may need additional help getting their project started. Teachers often work with their students to organize project goals, schedule deadlines, and find resources that are pertinent to the problem or question at hand. Keeping in mind students' backgrounds, teachers may also be responsible for providing materials and ways in which students can create their public product at the end of the PBL process (Larmer, 2015).

In regards to student learning and content knowledge, teachers are responsible for maintaining traditional instructional methods, such as scaffolding, in order to accommodate students' learning styles and abilities (Smith, 2016). Teachers should also use formative and summative assessments through the PBL process to assess how well students are understanding the content, developing 21st-century skills, and working with their peers in teams (Larmer, 2015). Lastly, teachers learn and create alongside their students in order to identify students' needs such as skill-building, redirection, encouragement, or praise (Larmer, 2015).

2.2 Rationale behind Project-Based Learning

Currently, in a typical class the teacher lectures, the students take notes and absorb information, and the lesson ends with the students demonstrating their knowledge and skills on a worksheet or exam. While this traditional teaching method has been implemented for many years and students have benefitted from it in the past, it is missing the student engagement needed for 21st century learners. Studies have revealed that students are not engaging in their learning when they are taking notes and working on worksheets; and this causes disinterest in learning and school curriculum (Fredericks et al., 2011). In fact, in 2011 student disengagement was at an all-time high, with sixty percent of all students being disengaged in their learning by the time they reach high school (Fredericks et al., 2011). Student disengagement in the classroom has been found to lead to disinterest in school and overall lower exam scores (Fredericks et al., 2011). However, recent studies have found that PBL increases student engagement and overall classroom performance and leads to improved student-teacher relationships and intrinsic motivation in students.

PBL was found to improve student-teacher relationships in the classroom and enhance students' enjoyment in the lesson (Hugerat, 2016). One particular study examined students' perceptions of the classroom climate when working in a PBL environment and teachers' achievements in instruction. The study found that the implementation of PBL was able to create a positive classroom climate due to better student-teacher relationships, and this enabled the teacher meet all

standards and objectives in a lesson plan (Hugerat, 2016). The students responded that they felt their teacher was more supportive and they were able to build a stronger relationship with their teacher because their teacher acted as a mentor through the duration of the PBL (Hugerat, 2016). Because the classroom climate became less tense and more enjoyable through PBL, the students were able to focus more and the teacher was able to meet all required learning standards (Hugerat, 2016).

Another study examined the impact PBL had on a group of at-risk, minority students in comparison with a group of white-majority, middle-class students. The at-risk, minority students were placed in a PBL environment and the white-majority, middle class students were placed in a traditional instruction environment. Both groups of students' monthly content exam scores and end-of-course surveys were assessed. The study found that both groups mastered at least fifty percent of the exam. However, the academic performance gap diminished between the white-majority, middle-class group and the at-risk, minority group (Holmes & Hwang, 2016). Through the assessment of surveys from the PBL students, the study found there was a 42% increase in intrinsic motivation and a 34% increase in an appreciation for peer learning (Holmes & Hwang, 2016). Furthermore, the survey responses indicated that the students were better able to learn how to regulate study time, and the majority of students indicated they enjoyed having more control of their own learning (Holmes & Hwang, 2016). Interestingly, the control group of white-majority, middle-class students showed a decrease in self-efficacy, from 99% to 88%, and a very large increase in test anxiety, from 20% to 60%, during the course of this one-year study (Holmes & Hwang, 2016). This study provided evidence that traditional teaching methods can cause negative impacts on students, while PBL can cause significantly positive impacts.

Similar to Holmes and Hwang (2016), a separate study examined the impact of PBL and traditional instruction on self-regulated learning. In this study, students were separated into two groups, in which one learned via PBL and the other learned via traditional instruction. At the end of the instruction, students were given a reflection-based questionnaire that explored the cognitive effects of both methods of instruction among students (Sungar & Takkaya, 2006). The results indicated that PBL students had higher levels of intrinsic goal orientation, critical thinking, and peer learning compared to the control group of students who learned via traditional instruction (Sungar & Takkaya, 2006). This study revealed that PBL enhances self-regulatory skills among students and allows them to practice responsibility and independence from their peers and teachers. This in turn cultivates a generation

of students who are intrinsically motivated to participate in school and may lead to more students pursuing higher education in college (Sungar & Takkaya, 2006).

2.3 Project-Based Learning and Standardization

Standardization is just one measure of student achievement out of many, and each state has its own standard measure of competencies (Bell, 2010). Standardized testing is typically organized so that each core subject has its own test and students are tested on certain or all subjects, depending on the grade level. The concept of standardization in the educational setting came to be when education met political ideals, and federal reforms led to the No Child Left Behind Act of 2001 (Smith, 2016). The No Child Left Behind Act was created in an effort to make sure primary and secondary schools were held accountable for their instructional performance by imposing higher standards that all students were expected to meet (No Child Left Behind, 2001). This act inaugurated the era of standardized testing, and although it was repealed in 2015, it left a lasting impact on the education system (Smith, 2016).

The No Child Left Behind Act led to states testing students as young as six years of age and all students being tested an unprecedented number of times throughout their K-12 education (Kohn, 2000). In fact, the average American student takes about 112 standardized tests between pre-kindergarten and the end of grade twelve (Layton, 2015). That number does not include the number of times students take practice exams, such as benchmarks and curriculum-based assessments, that are used to prepare students for the standardized tests at the end of the school year (Layton, 2015). All this testing leads to challenges in the classroom for teachers, and in particular PBL teachers, due to differing ideologies. Another difference between PBL and standardization is that standardized testing does not measure the 21st century skills that are integral for student success.

PBL and the standardized educational setting are two very different methods of instruction. PBL was created on the foundations of student creativity and choice, whereas standardization was formed with the assumption that "one set of standards fits all" (Smith, 2016). This becomes an issue when students in the classroom all have very different needs and many times cannot fit into the standardized framework (Bell, 2010). Because of federal education reforms, teachers are having to satisfy the needs of their 21st century learners as well as the requirements of their state's standards (Smith, 2016). While standardization does not seem to affect traditional instruction very much, it does clash with the pedagogy of PBL (Smith, 2016). PBL teachers are having to find a balance between data-driven instruction and teaching real-world, 21st century skills. An important issue in the clash between standardization and PBL is that accountability legislation, such as Race to the Top and the No Child Left Behind Act, was found to conflict with learner-centered and authentic instruction, which are both part of the foundation upon which PBL was created (Urban & Wagoner, 2008). This becomes a problem for teachers who teach in a PBL educational setting and often brings about varying perceptions of PBL and many challenges for teachers to face in the classroom.

The current study attempts to understand further the relationship between implementing PBL and standardization. As the literature demonstrates, the two ideologies are very different and there is merit in understanding the successes and shortcomings of implementing PBL in today's society of standardization. In particular, this study will examine middle-school teachers' perceptions of PBL and the challenges these teachers face when developing and implementing PBL in their classrooms as well as teaching 21st century skills in an era in which they are not being measured by standardization.

METHODOLOGY

3.1 Participants

This study involved five teachers at a North Texas project-based learning middle school. The participants' years of teaching experience ranged from one to twenty years, and they all taught in either seventh or eighth grade. The subjects they taught also varied from pre-advanced placement and standard math, language arts, and life skills. The teachers who participated were not selected based on certain requirements, but rather a survey was sent out to the entire faculty and those who agreed to participate completed the survey. All of the participants were familiar with the concept of PBL and its scope prior to this study. They were not required, but were highly encouraged, by school administration to incorporate PBL into their lesson plans.

3.1.1 *Project-Based Learning Middle School* This particular North Texas middle school was chosen to be the site of this research because the school was in the process of transitioning all teachers to fully implementing PBL in their classrooms and had been attempting to fully implement it for three years. General observations from school administration showed that teachers were leveled at four different stages of implementing PBL. The first stage consisted of early adopters who immediately and fully understood PBL and were ready to implement it in their classrooms. The second stage consisted of early adopters who thought

they understood PBL but were not quite implementing PBL and all of its components. The third stage consisted of those who were interested in PBL but were not implementing it in their classrooms. The fourth stage consisted of those were not interested in PBL and had no intentions of implementing it in their classrooms.

In terms of school demographics, in 2017 the school had a total enrollment of 886 students between seventh and eighth grade. The student to teacher ratio was 15:1 and the average teacher experience level was eleven years. The rate of students who qualified for free and reduced lunch was thirty-four percent. The school met standard in the state's academic accountability system, which was the highest accountability rating a school could earn.

3.2 Procedure

The project-based learning questionnaire was obtained from a previous and related study and coded into the surveying software, Qualtrics (Harris, 2014). The link to the survey was sent to all faculty by the principal, via the school district's email server. Upon opening the link, faculty were redirected to an informed consent document that discussed the purpose of the research and confidentiality of the participants. Faculty who agreed to the informed consent document became participants in this study and were directed to the anonymous, ten-question survey. After each participant completed the survey, their answers were anonymously recorded into Qualtrics. The multiple-choice survey questions were analyzed through Qualtrics and the open-ended questions were coded for recurring themes.

3.3 Project-Based Learning Survey

The survey used in this study consisted of ten questions and contained questions from surveys used in previous and related studies to maintain credibility and effectiveness. The survey in this study consisted of questions that addressed the following research sub-questions:
1. What are teachers' perceptions of project-based learning?
2. What makes a teacher want to implement or not want to implement project-based learning in the classroom?
3. What are the challenges and successes of implementing project-based learning?

Type of PBL	0 times	1 time	2 times	3 times	4 times	5 or more times
Classroom PBL	1	1	2	0	0	1
Team PBL	4	0	0	0	0	1
Grade-level PBL	3	1	0	0	0	1
Whole-school PBL	4	1	0	0	0	0

Table 4.1: Frequency of Type of Project-Based Learning Experience

RESULTS

Out of the fifty-six teachers who were given the opportunity to respond to the survey, seven chose to do so. Two responses were excluded from the results of this study because they were incomplete. Results indicated that all five participants taught seventh grade, and two out of the five participants taught both seventh and eighth grade. When asked to indicate the years of teaching experience, three participants indicated they had been teaching six to ten years, one indicated they had been teaching one to five years, and one responded they had been teaching sixteen to twenty years. The subjects the participants taught were also collected, and all core subjects (language arts/reading, math, history/social studies, science) were included as an option. Three out of the five participants responded they taught math, one responded they taught language arts/reading, and one chose the option of "other" and indicated in the provided text field they taught an elective named life skills. No participants indicated they taught history/social studies or science.

In order to understand more about teachers' perceptions of PBL as an approach to teaching and learning, data was collected on the participants' general opinion of the teaching methodology. The results indicated three out of five participants had a generally negative opinion of PBL, one out of the five participants had a generally positive opinion of PBL, and one participant had a neutral, or mixed, opinion that was equally positive and negative. There were no participants who indicated a very positive or very negative opinion of PBL.

Teachers were asked to identify the number of times they participated in each type of PBL, as shown in Table 4.1. Results indicated that classroom PBL was most frequently used among the five participants. In contrast, team PBL and whole-school PBL were found to be the least frequently used. Three out of five participants indicated they did not use grade-level PBL, one indicated they used it one time, and one indicated they used it five or more times.

Common challenges associated with implementing PBL were ranked by participants from least to most difficult in Table 4.2. A rank of one is considered least difficult and a rank of five is considered most difficult. The challenges perceived to be most difficult

Challenges	1	2	3	4	5
Collaborating with other teachers	2	3	0	0	0
Co-teaching with other teachers	2	0	1	0	0
Shifting from directing the instruction to facilitating more group work	1	2	0	1	1
Time to plan and implement	0	1	2	0	2
Creating the project	0	2	2	1	0
Designing the project	0	1	3	1	0
Managing the student groups	2	0	2	1	0
Managing the entire project	1	0	3	1	0
Helping parents understand the project	1	2	0	1	1
Fitting all of the standards	0	1	2	1	1
Meeting all of the state accountability requirements	0	1	2	0	2
Implementing the project within the school's schedule	0	2	2	0	1
Assessing the project to determine a grade	1	0	3	0	1

Table 4.2: Perceived Challenges When Implementing Project-Based Learning

21st Century Skills	Completely Agree	Generally Agree	About the Same	Generally Disagree	Completely Disagree
Creativity and Innovation	0	3	1	1	0
Critical Thinking and Problem Solving	0	3	1	1	0
Communication and Collaboration	0	3	0	2	0
Information, Communications, and Technology Literacy	0	3	2	0	0
Flexibility and Adaptability	0	3	1	1	0
Leadership and Responsibility	0	3	1	1	0
Initiative and Self-Direction	0	4	1	0	0
Social and Cross Cultural Skills	0	3	1	1	0
Productivity and Accountability	0	3	1	1	0

Table 4.3: Perceived Role of 21st Century Skills

when implementing PBL were "time to plan and implement," "meeting all of the state accountability requirements," and "fitting all of the standards." The challenges perceived to be least difficult were "collaborating with other teachers," "co-teaching with other teachers," and "managing student groups."

Participants were given an open-ended opportunity to describe other challenges they have encountered when implementing PBL. One participant responded, "We can't do PBL all the time and still teach all the TEKS we need to. It takes 2–4 times as long to teach the same TEK in a PBL." Another participant responded, "As teachers we always have to go back and re-teach the concepts due to majority of the students not passing the exam after a PBL." Table 4.3 shows the responses when participants were asked to identify the extent to which they agreed that PBL did a better job teaching certain 21st century skills. The category of "Generally Agree" was the most frequent response among all 21st century skills. Four out of five participants responded they "Generally Agree" to the skill of "Initiative and Self-Direction," while three out of five participants responded they "Generally Agree" to all other skills.

DISCUSSION

This study examined teachers' feelings toward project-based learning and the impact standardized testing has on the implementation of PBL in a middle school. Faculty at a Texas middle school indicated their perceptions of PBL, the challenges they encountered when implementing PBL, and how well PBL prepared students for 21st century skills. The results showed that the majority of the group of teachers who responded to the questionnaire had a generally negative view of PBL. Out of all the attributes of PBL, the ones that were indicated to be most challenging were all associated with standardization. In terms of PBL's role of teaching certain 21st century skills, the majority of the respondents generally agreed that PBL was effective in teaching most 21st century skills.

There seemed be a relationship between teaching core classes for which there was a standardized test and a negative perception of PBL. The teachers who responded to having a generally negative perception of PBL all taught one of the four core classes. In contrast, there was one teacher who responded to having a generally positive perception, and they taught a life skills elective class, in which no standardized tests were given. This may lead to the possibility that teachers' perceptions of PBL are heavily affected by standardization and that standardization may play a role in having a negative view of PBL. Previous research found that the majority of teachers at a project-based learning middle-school experienced a level of negative anxiety while implementing PBL due to standardized

testing (Smith, 2016). The research also found that the anxiety was based upon fear and worry about students' performance on the standardized assessment (Smith, 2016). Interestingly, an additional study found that teachers felt testing and limitations on time in the school's schedule created a negative mindset toward PBL (Harris, 2014). While the current case study did not further investigate the reasoning behind the negative view of PBL, it may be possible the group of teachers in this case study felt similarly. Teachers may also have had a negative perception of PBL because of certain challenges they met while implementing PBL.

While most of the participants seemed to have a negative perception of PBL, most participants also felt that PBL did a better job than traditional instruction in teaching 21st century skills to students. It could be possible that the participants were aware of the benefits of PBL and may have previously had a positive opinion of the teaching methodology, but the challenges standardized testing placed on them led them to have a negative outlook on PBL.

The results showed a relationship between the perceived most challenging components of PBL and their association with standardization. Lack of time seemed to be a common challenge for most of the participants. Some of the participants mentioned that there was not enough time to cover all of the necessary standards when implementing PBL. Similar responses were seen in another study, with participants responding that they felt being bound by time and the pacing of the department instructional calendar (Smith, 2016). Another study found that when teachers were given professional development for PBL and more planning time, the teachers were able to develop wholesome PBL plans. Although no participants mentioned the reason why they felt low on time, it may be possible that time constraints created by standardized pacing and/or instructional calendars led to this perceived challenge. Interestingly, a study found that when teachers were given professional development for PBL and more planning time, they were able to develop wholesome PBL plans (Blumenfeld et al., 1991). A possible solution to this issue of time constraints may be to ensure teachers have enough planning time and professional development to create and develop PBL plans that contain the essential design elements.

One of the participants responded to question seven by stating that teachers often had to re-teach concepts because of students not passing exams after completing a PBL. This was interesting because a similar study found that PBL was just as effective as traditional instruction at increasing student achievement scores on standardized tests (Markham et al., 2003). However, the same study also noted that at times during a PBL, it may be necessary for the teacher to provide traditional instruction in order

for students to better understand the material taught (Markham et al., 2003). This may reveal a relationship between the challenge of creating an effective PBL and student achievement scores on standardized tests.

Teachers also felt meeting and fitting all state standards was a common difficulty. The results from this study revealed that there was a relationship between lack of time and meeting state standards. A couple of the participants indicated in the open-ended questions that it took more time to complete one standard, or TEKS, in PBL than in traditional instruction. This may indicate that due to the instructional schedules created around standardization, it was more difficult to implement PBL while making sure all standards were met.

5.1 Limitations and Future Directions

While this study revealed quite a bit of information, there were limitations. The sample size was very small, in comparison to what was anticipated. While the survey was sent out a total of three times to faculty at this middle school, only seven out of fifty-six teachers chose to respond over the span of one month. Out of those seven, only five responses were used, since the other two were incomplete. This led to the results of this study revealing relationships rather than implications and causality. Additionally, not all core subjects were represented in the sample size. The majority of the respondents indicated they taught math, and one indicated they taught language arts/ reading. The core subjects of history and science were not represented. If there was representation across these subjects, in addition to math and language arts/ reading, the study may have revealed more about the relationships between the subject a respondent taught and their perceptions of PBL. Both of these limitations could have been improved by offering incentives to

participants or allowing more time for data collection in order to increase the number of participants.

Among all five participants, responses provided to question eight in the survey did not address what the question was asking. The answers provided additional criticisms of PBL instead of addressing how the participants overcame the challenges. However, their answers gave additional input into the teachers' experience with PBL. For example, one participant selected the challenge of "Time to plan and implement" and said, "We aren't given a lot of time on our timeline to complete the project piece of the PBL." Another participant selected the challenge of "Meeting all of the state testing accountability requirements" and responded, "We don't have the time to teach everything with PBL." From these responses, it seemed that lack of time was a common theme among all five responses for this question. While the responses led to more insight on teachers' feelings toward PBL, the question was ultimately excluded from the results. This could be improved by rewording to make the question clearer.

The results of this case study may be extended to areas of further research. A follow-up study could be conducted to understand why teachers had a negative view of PBL. This could be done in a case study style, with the main focus being on the three participants who indicated they had a negative perception of PBL. A variation of this study could be conducted at multiple project-based learning schools in different areas within Texas. This would allow for a larger scope within the study. This study took place in a middle school setting. It would be interesting to replicate this study in an elementary or high school setting to examine and compare how the results vary. It may also be interesting to replicate this study in a STEAM (Science, Technology, Engineering, Art, and Math) school where the curriculum is already structured to fit a project-based learning model.

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CULTURAL TRANSLATION AND THE ICONOGRAPHY OF THE MASTER AND MISTRESS OF THE ANIMALS

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ABSTRACT

The image of a figure holding two wild animals, often called the "Mistress/Master of Animals", has appeared across many ancient periods and regions, on artifacts from proto-literate Mesopotamia in the Near East to the Aegean Iron Age. This motif has a demonstrable chain of cultural custody that is closely tied to concepts of both divinity and royalty. Rather than following a linear progression of diffusion with consistent interpretation, the Master/Mistress motif is culturally translated by adopting populations to suit the understandings of the individuals within those populations. Though some concepts such as healing remained constant from culture to culture, the symbol was reinterpreted or modified based on the role it played in adopting populations' cultural schemas. This resulted in the two seemingly separate motifs of the "Master" and "Mistress". This translation demonstrates the close relationship these early cultures had to one another in spite of their perceived distinctness.

Some of the earliest depictions of Artemis, the Greek goddess of the hunt, is in an arrangement often called the "Mistress of Animals" (Nilsson 1923). However, this motif predates the classical Greeks by thousands of years and can be found across many cultures in the Near East and the Aegean. Similar imagery has also been found on Canaanite artifacts from ca.1400 BCE, (Day 1992), on Aegean seals as early as the 21st century BCE (Crowley 2010), on terracottas from the Indus Valley of the mid-third millennium BCE, and even on some of the very earliest seals from the proto-literate Near East, dating to about 5000 BCE.

It was not until the late 1800s that the female image was dubbed Potnia Therōn (*Πότνια Θηρῶν*) by Franz Studniczka (1890), who appropriated this name from an epithet of Artemis in Homer's Iliad (Book 21, line 470). This was perhaps the first time that the term "Mistress of Animals" was linked to Potnia Therōn and, by association, the archaic symbol to the Hellenic goddess.

The Master and Mistress of Animals motif has a demonstrable history of cultural transference in the Near East and Aegean. The story of this arrangement illustrates not only the interconnectedness among the early populations in those regions, but also the consistency and continuity of human cognition and desires.

Many of the social and psychological processes that were at work as the motif was passed among those ancient populations are still very much in effect today, just as ideas are transferred among groups in modern populations.

1.1 Description of Iconographic Arrangement

Before embarking on an analysis of Mistress / Master of Animals motif, it is necessary to establish the scope of the investigation. The title Potnia Therōn has been attached to almost any female that can be associated with animals. The connection between animals and some of the folkloric characters on whom the title has been bestowed is sometimes questionable at best. The appropriateness of the modern title often rests on a tenuous association based on the folkloric ability to control animals, or even a a single story involving an animal, as is the case in Matossian's discussion of Baba Yaga (1973). Such arguments are usually political in nature and completely divorced from the iconographic arrangement.

Throughout history the Master / Mistress arrangement has always had a central humanoid figure with animals grasped in both hands or at either side, in a composition that demonstrates some degree of bilateral symmetry (see Figure 1.1).

Since this study involves cultural transference and interpretations of iconography, the composition inevitably undergoes modifications. Styles change not only among cultures; they also evolve over time within individual cultures. Because of this the main figure in some examples might not be grasping the animals in a closed grip (Figure 1.3), or the composition might not be perfectly symmetrical (Figure 1.2). Special attention must be paid to these alterations because they can be indicative of cultural changes.

Though variations do occur, they never stray far from the aforementioned canon. For instance, Figures 1.1 and 1.2 are both from the François Vase, and are known depictions of Artemis even though the animals she is holding differ. Examples such as those in Figures 1.1 – 1.3 have been included in this study if an argument could be made that they were directly influenced by, or related to, the basic form of Potnia Therōn.

Whereas many prior researchers have presented almost any depiction of a person interacting with animals as a "Master" or "Mistress" image, the term is reserved by museums exclusively to describe those motifs that specifically conform to the aforementioned criterion. Perhaps most importantly, a great many unrelated cultures have scenes depicting animals and people together, but in spite of humanity's well documented penchant for symmetry, Mistress of Animals compositions only seem to appear in cultures that are known to have had contact or trade networks with one another. This, along with the complexity of the imagery, greatly decreases the likelihood of completely independent innovation.

1.2 Terminology

In the hard sciences the legitimacy of a conclusion can most clearly be established when it is supported by several sources. I would argue that due to the nature of human perception this is even more relevant to the social sciences. For this reason, I will be taking an interdisciplinary approach to this topic. This will involve applying concepts normally found in cultural anthropology, sociology, and psychology to a subject that is very thoroughly rooted in archaeology. Unfortunately, some of these disciplines use terms that are not defined consistently across disciplines. Similarly, some concepts may be familiar in one field but much less so in the others. For this reason, I have found it necessary to define several terms for the purpose of this study.

1.2.1 Iconography In current parlance, the term "iconography" is often assumed to be related to divinity, since most persons today encounter the word in the realm of religion. Iconography is derived from the Greek words *εἰκών* ("image") and *γράφειν* ("to write"). It is used in this paper in its historical and academic context simply to refer to the study of the composition, identification of parts, and possible significances of an image or

Figure. 1.1: François Vase, Detail
Chiusi, Circa 570 BCE
Florence, Museo Archeologico Etrusco 4209

Figure. 1.2: François Vase, Detail
Chiusi, Circa 570 BCE
Florence, Museo Archeologico Etrusco 4209

Figure 1.3: Boeotian amphora, Potnia Therōn, detail
Thebes, 680 – 670 BCE
National Archaeological Museum, NM 220, AT 119

artifact. No insinuation of divinity should be construed from its use, and any suggestion of possible religious concepts will be stated directly rather than implied.

1.2.2 Diffusion   For the purposes of this paper the term "diffusion" is used to describe the movement of ideas, beliefs, and material culture among peoples. In what follows, I have given attention to both the possibility of diffusion and the mechanism of transference. This is not to suggest that all similarities imply diffusion. Special vigilance was also paid to the historical context, cultural particulars, and situational variables in order to avoid labeling parallel innovations as diffusion.

Diffusion should not be taken as indicative of a unidirectional path or an unerring linear progression. As ideas and practices spread and adapt to new cultures, it becomes highly likely that these new phenomena will at some point come into contact with different cultural interpretations of the original concept. It is natural that these new interpretations would then also be compared, adapted, adopted, or dismissed depending on the sensibilities and needs of the culture encountering them. In the process these new concepts themselves would become an additional point of transference if they can find cultural purchase in the population.

1.2.3 Translation   It is sometimes easy to forget that all populations are composed of individuals, each providing the possibility of altering the significance of a symbol or concept through the scope of their own perception. This is especially true when someone is trying to integrate foreign concepts into their own understanding. The new idea must not only be reconciled with the personal perception of the individual, but also with the cultural context of the population as a whole.

We have a tendency to want to seek meaning from what we encounter in the world around us. It is much easier to integrate new ideas and aesthetics if they easily relate to existing concepts and preferences. So new information is adjusted to meet personal perceptions, or fit within cultural norms, while being integrated into personal schemas. This can cause the personal meaning or interpretation of a symbol or idea to be slightly different, or even quite distinct, from those of the original concept. These personal concepts can become cultural ideas if the belief or symbol is presented by a member of the population with sufficient social status, authority, or persuasiveness necessary to legitimize the interpretation. The chances of integration increase if the social environment is predisposed to be receptive to the concept. This alteration of form or meaning while being incorporated into an understanding is called translation.

This often accounts for the alterations in both the meaning and morphology of a symbol during adoption. It should be noted that these translations are usually a slight tailoring of significances rather than wholesale reinterpretations. Over time, however, these variances can compound into a seemingly distinct concept or symbol.

1.3 Master or Mistress?

In many of the earliest examples, such as the stone seal from Tepe Giyan in Iran (Figure 1.4), the sex of the engraved image of the humanoid figure cannot be established. In fact, many of these images are so lacking in distinguishing details that one might question whether the figure was even intended to represent humans a human at all (Oates 1978). In the absence of defining anatomical traits or cultural costuming, it often falls to the researcher to bestow an identity upon the image.

In doing so, even the most objective researchers must draw on personal understandings and experience regarding the nature of society for their interpretations. These understandings are strongly influenced by cultural norms and other concepts that may be familiar to the researcher but were unknown in the culture studied. Variations in gender roles, cultural costuming, and social norms have led highly skilled archaeologists and other academic professionals to misidentify the gender of burials due to the accouterments of the deceased (Rubinson 2008).

Most scholarly papers have focused on the "Master of the Animals" or the "Mistress of the Animals" exclusively. Some images have been either included or excluded by gender, such as the clearly male image on the Lorestān bronze pin in Figure 1.5, but others were not so easily categorized. This results in the classification of 'Master' or 'Mistress' becoming subjective and/or arbitrary at times.

The examples in Figure 1.6 and 1.7 are also Lorestān bronze pins. Their motifs, like prior example,

have consistently been described as the "Master of Animals". Do the horns make them male? Though both images feature horns, the example in Figure 1.7 clearly features prominent breasts, and what may be interpreted as a vulva. If 1.7 is female, does this suggest that 1.6 is well? Though it demonstrates many of the same features and layout, it lacks the distinctive female characteristics the other seems to possess.

The problem is even more complicated when the image displays traits that are indicators of both genders in contemporary culture, as in Figure 1.8. For many modern viewers this image may be confusing, but the Lorestān population that created it could undoubtedly discern the sex of the image, as well as its cultural importance.

The problem is that we do not have a cultural context for the imagery, and so we must rely on our own knowledge, expectations, and culture to fill in the missing information. This directly affects whether we categorize the image as a "Master" or a "Mistress". Yet, in spite of the disagreement over the gender of the image, the iconographic similarities between the images remain apparent.

There is no reason to assume that these early cultures did not engage in the same processes when interpreting images from other cultures. When viewing images, they too were likely to interpret them based on their own histories, both personal and cultural. A single personal interpretation at the point of contact could become a whole new cultural interpretation. Even assuming some communication between two cultures, and an individual in one culture being able to

Figure 1.4: Tepe Giyan Stone Seal
Iran, 5000 – 4000 BCE
British Museum – BM 128660 (AN00109870_001_l)

Figure 1.5: Lorestān Bronze Pin
Iran, 1000 – 600 BCE
Los Angeles County Museum of Art – M.76.97.135

Figure 1.6: Lorestān Bronze Pins
Iran, 1000 – 600 BCE
Los Angeles County Museum of Art – M.76.97.183

Figure 1.7: Lorestān Bronze Pins
Iran, 1000 – 600 BCE
Los Angeles County Museum of Art – M.76.97.187

Figure 1.8: Lorestān Bronze Pin
Iran, 1000 – 600 BCE
Los Angeles County Museum of Art – M.76.97.142

directly query someone from the other culture, issues of language, cultural norms, and religion could influence interpretation of what was said at the point of possible adoption. Because of these issues with classification, both modern and historical, it becomes absolutely necessary to examine all forms of the iconographic compositions regardless of their classification as "Master" or "Mistress". It would be myopic to attempt an analysis of either one to the exclusion of the other.

MASTER OF THE SERPENTS

Human figures begin appearing on seal imagery about 5000 BCE (Figures 2.1 – 2.3). Those early figures were always accompanied by serpents, and neither the serpent nor the figure would be depicted separately for at least half a millennium. This suggests that both the humanoid figure and the snake had already developed a cultural significance by this point. These seals constitute some of the earliest examples of the Master/Mistress motif. This version of the motif is often described as the "Master of Serpents".

Clay sealings on bullae show that the Master of Serpents motif was in use in Susa by the time of its first appearance on seals from Tepe Giyan (Figure 2.4) and would be used similarly for the next two millennia (Figure 2.5 and 2.6). During this time clay bullae with Master of the Serpent seals begin to appear also at Chogha Mish.

The use of the Master of Serpents motif in sealings, and the number of seals themselves, suggests that the

motif had some administrative purpose, in addition to possible religious or cultural significances, and may have represented some form of political or socioeconomic authority. Preliterate Mesopotamia offers us no written accounts of religious or cultural beliefs for this period outside the material culture itself. We do not know if the figure represents a shaman (Costello 2011), a monster, or demon as described by Henri Frankfort (1955), or was merely a crude way to depict a human.

There have been suggestions that the snake may have actually been a symbol of healing (Van Buren 1935). This concept is echoed by later writers who theorize that the Master of Serpents may have been the predecessor to the staff of Asclepius in classical Greek iconography (McDonald 1994 and Nayernouri 2010). It is known that for the Sumerians the serpent was not a feared symbol of evil; instead, it represented the snake god of healing Ningizzida (Van Buren 1934). The context and consistency suggest that the Master of Snakes might have also been religious in nature.

This may be a very early example of priest kings merging political authority with concepts of healing and life. Attributing divine aspects or healing powers to rulers has occurred in a great many cultures, for instance

Figure 2.1: Master of Snakes Seal
Tepe Giyan, 5000 – 4000 BCE
British Museum – 128660

Figure 2.2: Master of Snakes Seal
Tepe Giyan, 5000 – 4000 BCE
British Museum – 128659

Figure 2.3: Master of Snakes Seal
Tepe Giyan, 5000 – 4000 BCE
British Museum – 128664

Figure 2.4: Drawing of Sealing
Susa, 5000 BCE
Shush Museum (Harper 1992)

Figure 2.5: Clay Sealing
Susa 1, 4000 BCE
South Acropole – SB 2050 (Harper 1992)

Figure 2.6: Clay Bulla
Susa, 3800 – 3100 BCE
Louvre - SB1932

Figure 2.7: Clay Bulla
Chogha Mish, 4000 BCE
(Delougaz 1996)

the King's Touch in 16th century Europe (Toynbee 1950). Such an association often reinforces the legitimacy of ruling elites, and was not unknown in the Near East.

2.1 Cultural Impact of Early Trade Routes

One of the most remarkable examples of the Master motif can be found on a steatite seal from Tel Ahmar (Figure 2.8). What makes this artifact unique is that it is the earliest known example of the motif to feature the human figure without snakes. In their stead, the figure is grasping two goats or rams with curved horns. This suggests both a change in the cultural significance of the motif, and that the meaning bestowed on the animals may have varied by region and/or culture.

Horned animals of this type were curiously rare during the early 4th millennium BCE at Tell Ahmar and equally unknown in most of the region that would become Mesopotamia. However, the curved-horn animals are abundantly depicted in the pottery of the same period from Tepe Hissar in Iran (Schmidt 1937).

Though the aforementioned Tepe Hissar and Tel Ahmar are seemingly distant from each other, they were known to be a part of a trade route that had become well established by the Early Dynastic period (Majidzadeh 1982). The earliest Master of Serpents seals were carved from soapstone (steatite) or a related mineral in the chlorite family. Though a common material, its sources are regionally limited (Beale 1973).

The closest source of steatite or chlorite is just north of Tepe Giyan (see Figure 2.9, no. #2) (Kohl 1974, David 2002). This would take the populations of Susa and Chogha Mish directly into the trade route proposed by Yousef Majidzadeh at the point it crosses Tepe Giyan. This trade route goes directly through Tepe Hissar (modern Damghan) on the way east. The same route passes close to Tell Ahmar on its way west into Anatolia.

Yousef Majidzadeh was able to establish that the trade routes had become well used by the end of the 4th millennium BCE or the beginning of the 3rd. There is evidence that the trade along this route may have been active as early as the end of the 5th millennium BCE (Pitskhelauri 2012).

This trade activity coincides with the creation of the Tel Ahmar seal and provides us with a possible explanation for its unorthodox imagery. Both the Master of the Serpents and the horned animals were foreign symbols to Tel Ahmar and may well have been encountered through trade or by travelers along this route. The images on the seal could have been combined while being integrated into a cultural context for the population at Tel Ahmar.

In addition to the overall composition, , the Tel Ahmar example also incorporates the asterisks from

Figure 2.8: Stone Stamp Seal
Tell Ahmar, 4500 – 3500 BCE
British Museum – 135249

Figure 2.9: Sites of Early Seals on Map of Trade Routes Proposed by Majidzadeh

1 - Tel Ahmar   2 - Tepe Giyan   3 - Chogha Mish   4 - Susa   5 - Tepe Hissar

the earlier Master of Serpents seals (Figures 2.8, 2.2 and 2.3), these are an important symbol that is often associated with the Master and Mistress iconography and indicates that the image is very likely divine in nature. This marking often appears with the Master/Mistress motif over the centuries and across many cultures. Its significance will become clearer below.

This would not be the last time trade influenced the fate of this icon. The route purposed by Majidzadeh would eventually become the Great Khorasan Road (Abdi 1999). It would greatly expand the range of the Near Eastern peoples and prompt several alterations the Master of the Animals motif as competing ideas were traded along with the trade goods transiting the Great Khorasan Road.

THE URUK EXPANSION: 4000 to 3000 BCE

Around 4000 BCE a significant period of exploration and migration of the Near Eastern populations began that would eventually be defined as the Uruk Expansion (Algaze et al. 1989). By 3500 BCE Middle Eastern trade routes had reached as far north as Transcaucasia (Pitskhelauri 2012), west as Egypt (Joffe 2000), and as far east as Badakhshan (Herrmann 1968).

3.1 Predynastic Egypt

It is in Predynastic Egypt that the symbol gets its first major cultural overhaul. Trade with Mesopotamia is evidenced by the appearance of the motif on two separate artifacts form this region. The more famous of these is in a wall painting from Hierakonpolis, Tomb 100, also called the Painted Tomb (Figure 3.1).

As in Mesopotamia the mural is associated with social elites: in this case it was the tomb of either a magistrate or a proto-pharaoh. Unfortunately, the image is indistinct, and the figure appears to be grasping cows with unusually long tails.

The other example provides us with a much clearer picture. The Gebel el-Arak Dagger is a masterpiece for its time. This flint knife has an elaborately carved handle made from hippopotamus ivory and features a detailed early example of the Master of Animals motif amid a hunting scene on one side (Figure 3.2); the other side depicts a battle in several registers (Figure 3.3). The handle was sold to the Louvre by an Egyptian antiquities dealer in Cairo who claimed that it came from Gebel el-Arak, in Upper Egypt. However, the dealer also unknowingly had the flint blade in his possession; he sold it to the Louvre as part of a collection said to be from the site of Abydos (Delange 2009).

The motif is very clear in this example: not only can we tell that the central figure is male, but his attire is very clearly Middle Eastern rather that Egyptian (Pittman 1996). This strongly suggests that the motif is a direct Mesopotamian import rather than simply independent innovation, in spite of the distance between the two cultures.

However, this image is not fully Middle Eastern. On this specimen the snakes and the horned rams have been replaced by a pair of rampant lions. The Master motif's inclusion on an artifact with such otherwise distinctly Egyptian imagery and the additional appearance of the Master motif in

Figure 3.1: Hierakonpolis Tomb 100 (Painted Tomb) Hk loc. 33, Detail
Naqada IIC, circa 3500 - 3200 BCE
Cairo Egyptian Museum

Figure 3.2: Hippo Ivory Dagger Handle
Abydos or Gebel el-Arak, circa 3300 - 3200 BCE
Louvre - E11517
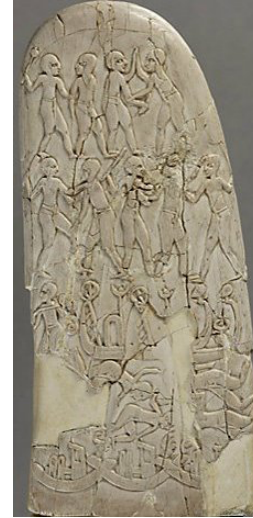
Figure 3.3: Hippo Ivory Dagger Handle
Abydos or Gebel el-Arak, circa 3300 - 3200 BCE
Louvre - E11517

Tomb 100 around the same period suggests that the image likely embodied a cultural significance for the Predynastic Egyptians to adopt it for use on such luxury goods. But there was something about the Master of Snakes that caused them to change the format.

It could well be that the snake had a different role in Predynastic Egypt than it did for the Mesopotamian populations, and so was replaced with lions. Later Egyptians would associate the snake with Apep, god of lies, darkness, and chaos (Kippenberg 1986). He was the enemy of Ma'at, goddess of justice and social order. The concept of ma'at was a key aspect of pharaonic ideology and represented unchanging social order (Bard 2015). Alexander Joffe argues that this "concern for the containment of unrule" caused the social elites to translate the image into something more relatable to their own ideology, so they replaced the snakes with lions and the symbol came to represent power over chaos (Joffe 2000).

But why lions? Though these examples predate dynastic Egypt, they also foreshadow the future theology of the region. It is interesting to note that later Egyptians would have a lion-headed goddess named Sekhmet who, like Ningizzida, was thought to hold power over healing and disease (Norrie 2016). It may be that we are seeing one of the earliest expressions of that belief through the Master of Animals motif. It is a pattern that will be repeated in many cultures that adopt the composition.

3.2 Sumer

As technology evolved and culture became more stratified in the Near East, the cylinder seal was invented as a new tool of administration. Cylinder seals are cylindrical stones drilled longitudinally; on the circumference they bear images carved in relief. The owner would insert a stick and roll the seal onto a soft material such as wax or wet clay, leaving the imprint of a continuous scene such as a procession. The seal in Figure 3.4 is made from marble and was found at Tepe Gawra in Iran. In addition to being the one of the first examples of the Master of Animals motif on a cylinder seal, it is the earliest instance of a "contest scene" on a seal. A contest scene is a type of seal image depicting battles or contests between humans and animals that would later become one of the most popular motifs on Middle Eastern seals.

These early scenes were important because they routinely depicted a version of the Master motif called the "Nude Hero". In this version of the composition the central figure is a bearded male with six locks of hair, and nude save for a belt. The Nude Hero would come to be directly connected to concepts of kingship in Ur several centuries later. Though this seems an immense expanse of time between the two symbols, the calcite seal in Figure 3.5 is from Abu Habba in Iran and shows that the composition was still in use, relativity unaltered, at around 2700 BCE. By that time the Nude Hero had acquired not only his trademark beard but also his friend, the "Bull Man".

The variegated animals he is grasping in Figure 3.4 are difficult to make out, but the similarity suggests the possibility that the animal may have been some form of large feline such as the ones on the calcite seal. If this is the case then it recalls the Master motif on the handle of the Gebel el-Arak dagger, and could be further indication of cultural transference between the two regions.

Figure 3.4: Marble Cylinder Seal
Tepe Gawra, 3500 - 2900 BCE
Penn Museum, 31-52-54

Figure 3.5: Calcite Cylinder Seal
Abu Habba, circa 2700 BCE
British Museum – 89538

Figure 3.6: Stone Cup
Uruk (Warka), 3300 - 3000 BCE
British Museum - 118465

Figure 3.7: Gypsum Cup
Tell Agrab, 3100 - 2900 BCE
Oriental Institute of Chicago - (D. 015848_A17948)
Courtesy of the Oriental Institute of the University
of Chicago

As with the lions on the Gebel el-Arak dagger, the addition of the of the bulls on the calcite seal also correspond with future regional divinity. Although the seal in Figure 3.5 is a later specimen, we do have earlier examples of bulls in Master of Animals motifs. The two ritual cups below are from Uruk (Figure 3.6) and Tell Agrab (Figure 3.6), two sites in Iran separated by over two hundred miles.

Both vessels date from the period between the marble and calcite seals. They display very similar imagery to that of the seals except here they are three-dimensional artifacts. Each cup features a bearded male with curled locks and a belt, holding mirrored animals in his grasp. In the example from Uruk (Figure 3.6) the figure is almost embracing the shoulders of a bull while his Doppelgänger grabs the bull's tail in

a mirrored scene on the reverse of the cup. On the Tell Agrab vessel lions attack the bull while the lone bearded figure grabs two of the great cats (Figure 3.7).

The figures on the cups resemble the central figure on a seal from Tell Asmar (Figure 3.8). In it a bearded man with flowing locks of hair is seen grasping snakes in the classic Master of Serpents motif. This unique seal seems to show an intermediate synchronization of the earlier motif with the later Nude Hero. Over the next millennia similar characters without snakes would continue to make appearances on cylinder seals in almost the exact same poses, suggesting that we may be seeing a translation of a significant cultural myth.

Such a merging of iconography suggests that the concepts behind the images may have also begun

Figure 3.8: Seal Impression
Tell Asmar, 2750 - 2600 BCE
Oriental Institute Chicago - As. 34 91
(Frankfort 1955 Plate 51, 535) (Stolen)
Courtesy of the Oriental Institute of the University of Chicago
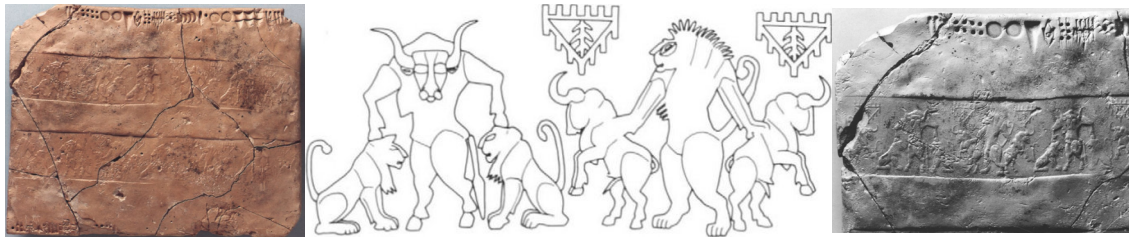
Figure 3.9: Clay Tablet – Drawing - Detail
Susa, 3100 – 2850 BCE
Louvre - SB2801

to blend together in the minds of the populations. It could be that rather than dying out, the Master of Snakes iconography was transformed into later Master of Animals motifs such as the Nude Hero. The use of this motif and its variants over such a long period of time indicates that it likely represented a significant cultural concept. This belief must have been well known enough to be recognizable in spite of an alteration of context between the two-dimensional seals and the three-dimensional ritual vessels.

The importance of bulls and lions is attested to by their widespread appearance on early seals and sealings. On a clay tablet from Susa, an area in Iran that was once a neighboring country of Sumer, bulls and lions appear

again in the Master motif (Figure 3.9). This time they are in a slightly different format. One half of the seal depicts a anthropomorphic bull subduing two lions, and the other shows a anthropomorphic lion is grasping two bulls. The composition is almost heraldic and their appearance together on the same cylinder seal suggests that the lion and bull may have been emblems of distinct kingdoms or individuals rather than amorphous concepts.

Though very different from Master images we have examined previously, the tablet above in Figure 3.9 demonstrates that there was already strong cultural significance attached to both the bull and the lion by the end of the 3rd millennium BCE. It also provides us with the earliest example of the Nude Hero's counterpart,

Figure 3.10: Seal Impression
Khafajah, 2750 - 2600 BCE
Kh. IV 388 - (oip72_0246l)
(Frankfort 1955, Plate 25, 254) (stolen)

Figure 3.11: Lexical List of God Names
Sumer, 2400 - 2200 BCE
The Schøyen Collection - MS 2272_f, Oslo and London

Figure 3.12: Hematite Seal
Mesopotamian, 1720 - 1650 BCE
Morgan Library - (seal_0979)

the "Bull Man", who would be featured on cylinder seals for the next several centuries almost exactly as he is depicted on the Susa tablet. This replication indicates that the Bull Man must have already been part of an existing myth or other cultural belief at this time.

A more primitive version of the Bull Man can be seen on a seal from Khafajah (Figure 3.10). This may be the first instance of his being paired with a "Nude Hero" prototype. The right side of the seal depicts a bearded figure grasping the snakelike tails of two lions over which he stands. This figure has many similarities to the earlier ritual vessels and later Nude Hero iconography. He is bearded with six locks of hair and is depicted in the Master of Animals composition. The figure in the center is a Bull Man in a very similar pose as on the Susa tablet, but here he is in profile and armed with a dagger in his fight against the lions. Asterisk-like symbols similar to those seen on the preliterate seals also appear on the seal next to crescent moons; these would later become a symbol of kingship.

The asterisk is a cuneiform character called a dingir, and it is the symbol of divinity in Sumer (Whiting 1977). The dingir is placed before the name of a god in cuneiform writing such as on the tablet of divine names in Figure 3.11. It also used to designate images as deities, as is the case with the water god Enki pictured on the seal in Figure 3.12.

The similar symbols that appeared on the preliterate seals in Figures 2.2, 2.3 and 2.8 may be early examples of the cuneiform symbol that would come to represent

Figure 4.1: Lyre of the King
Royal Cemetery at Ur, 2600 BCE
Penn Museum - B17694A

the essence of divinity in Mesopotamia. This symbol has extensive use on Near Eastern seals in following millennia, and would continue to appear the Master of Animals motif both here and in other cultures.

One of the most striking things about the Master of Animals motif is that it is always associated with elites. The cylinder seals themselves were implements of authority. The Gebel el-Arak Dagger was a luxury item well out of reach of the average person. And the ritual vessels were not the sort of drinking cups that would be used by a carpenter.

Nor is it of small significance that the image appeared in the tomb of a proto-pharaoh. Predynastic Egyptian elites of this period often utilized several Mesopotamian symbols in an attempt to legitimize their own power (Wilkinson 2000). Much like the interchange of symbols between Middle Eastern populations, this iconographic transference was likely made possible by trade. Both Abydos and Hierakonpolis were on major trade routes (Bard 2015) that would have provided access to both raw materials and new ideas. The Nude Hero with his distinctive curled locks and belt would continue to be depicted on the most regal of goods, but this time the written word and better archaeological context gives us more insight into his story.

EARLY ORIGINS

4.1 The Nude Hero

In the 1920s Leonard Woolley discovered the first traces of the Royal Cemetery of Ur and made the University Museum at the University of Pennsylvania home to one of the most stunning examples of the Master of Animals motif. The Lyre of the King (Figure 4.1) dates to about 2600 BCE. It features a gilded bull's head with a flowing beard carved from lapis lazuli.

Underneath the lapis beard four shell-inlaid registers decorate the front of the instrument's sound box. The image in the top register is a bearded male with three locks of hair on either side of his face who is wearing only a belt and is embracing two human-faced bulls. The figure in this panel is called the Nude Hero. He closely resembles the figures on the early ritual vessels (Figure 3.6 and 3.7), and dates to just after the prototype Nude Hero seals (Figures 3.8 and 3.10). This imagery will be repeated on a great many cylinder seals of this millennium and will often be seen in contest scenes (Costello 2010), similar to the ones seen in the seals in Figures 3.4 and 3.5.

The Master of Animals often appears to embrace the animals with which he is pictured (compare the Lyre of the King). In many scenes the animals are being attacked by lions, much like the carving on the Tell Agrab cup (Figure 3.7). If the images of the Master of Animals grappling lions were intended to reinforce the belief that the ruling parties could quell chaos or fend off an attack, then perhaps the motifs depicting him embracing bulls could represent a protective benevolence akin to later concepts such as that of the "good shepherd".

The Sumerians believed that the bull represented Nanna, the god of the moon. Early texts describe him as the Lapis Bull (Ornan 2001), which is parallel to the imagery on the Lyre of the King. In addition to being the "decider of fate" and associated with healing rituals, he was a protector of livestock (Hall 1986). Images of Nanna on the Lyre would be prominent due to his position as the patron god and

guardian of Ur (Klein 2001), but Nanna was closely associated with kingship as a whole (Ferrara 1972).

It has been suggested that the Nude Hero is none other than the warrior king Gilgamesh (Ward 1982). There may be some validity to that claim inasmuch as Nanna had ties to both Gilgamesh and the Nude Hero. Gilgamesh was a Sumerian king of Uruk who was thought to have lived 2800 to 2500 BCE (Dalley 2000). This puts him just before the image of the Nude Hero on the Lyre of the King (Figure 4.1) but several centuries after both the ritual vessels (Figures 3.6 and 3.7) and the early cylinder seals (Figures 3.8 and 3.10). Thus, it is very likely that the Nude Hero was not originally Gilgamesh, but an earlier symbol that he appropriated to reinforce his political power. In mythology Gilgamesh was the grandson of Utu, the Sumerian sun god, and was the great grandson of Nanna. The association with divinity would also have helped legitimize Gilgamesh's authority, and it seems to have been a common practice among later rulers.

Individuals identified as kings on cylinder seals would often be pictured facing a crescent, the symbol of Nanna (Figures 4.2 - 4.4). This depiction always seems to have designated kingship on Near Eastern seals. Though this relationship is repeated across many seals, this seems to have escaped the notice of modern scholars. The seals in Figures 4.2 and 4.3 also depict an asterisk like dingir, as on the earlier seal from Khafajah (Figure 3.10). In the first two seals gods are meeting with kings. In the seal in Figure 4.2 the seated figure is a divine king, noted by the presence of both the crescent and the dingir. This concept of divine kingship so common that it sometimes made the translation of the names of Sumerian kings difficult because it was hard to distinguish them from gods and because the dinger was originally taken as a phonetic symbol that was part of the name itself (Whiting 1977).

4.2 Early Dynastic Harappa

By ca. 2600 BCE important trade routes crossed the Near East and went through Susa on their way in Mohenjo-daro on the Indus River in modern-day Pakistan. The people of Susa had continued their use of

Figure 4.2: Hematite Seal
Babylonian, 1900 – 1600 BCE
Spurlock Museum - 1900.53.0061A_1024
Courtesy of The Spurlock Museum, University of Illinois at Urbana-Champaign

Figure 4.3: Seal Imprint
Tel Asmar, 2000 - 1750 BCE
Oriental Institute Chicago - A8546 (Frankfort 1955, Plate 68, 737)
Courtesy of the Oriental Institute of the University of Chicago

Figure 4.4: Seal of Ur-Nammu
Babylon - 2100 BCE
British Museum – 89126
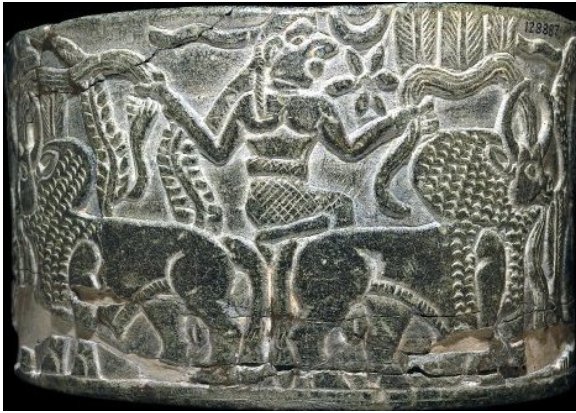
Figure 4.5: Chlorite Vessel Detail
Khafajah, Iraq, 2600 - 2400 BCE
British Museum - 128887

Figure 4.6: Chlorite Vase
Khafajah, Iraq, 2900 - 2350 BCE
Oriental Institute of Chicago - C754 & C755
Courtesy of the Oriental Institute of the University of Chicago

Figure 4.7: Steatite Relief
Mari, Syria, 2645 - 2460 BCE
National Museum of Damascus - 08-02-08-15

the Master of Serpents motif long after it was abandoned elsewhere. Among the trade goods was a particular type of vessel carved from chlorite that began to appear all over the Middle East by the third millennium BCE (Kohl 1974). These vessels are often carved in what is called the "Intercultural Style" because they depict imagery from several cultures and regions on the same artifact. They were apparently tied to a trade in medical botanicals from the Indo-Iranian plateau (Perrot and Madjidzadeh 2005).

Several of these vessels bear the Master of the Serpents motif (Figure 4.5), and quite a few also depicted other Master of Animals motifs such as the example of the Bull Man form the Temple of Sin, the Akkadian name for Nanna (Figure 4.6). It will be recalled that both images were already well established in Susa by this period, though the Master of Serpents enjoyed continued use there long after it was replaced by other Master motifs elsewhere (Figures 2.4 - 2.6, and Figure 3.8).

Many of these chlorite vessels were created at Tepe Yahya in Iran, and this site also yielded evidence of the exchange of both raw materials and finished goods traded with Susa in Iran and Mari in Syria (Kohl 1975). This trade with Susa would account for the sudden increase in the range of the Master of Serpents motif, and the appearance of new additions to the arrangement such as that of the Bull Man. A steatite relief from Mari depicting the Nude Hero gives us evidence that aspects of the motif had reached Syria by this time (Figure 4.7).

The trade routes had become much more extensive and not limited to the polities in the Near East. They actually connected Mesopotamia to the Iranian Plateau and the Indus (Parpola, Parpola, & Brunswig 1977). Scholars have argued that this trade, especially with and via Tepe Yahya, directly resulted in the development of Harrapan culture (Lamberg-Karlovsky 1972).

The Harappan culture sprang up along the Indus river in Pakistan and is considered the oldest civilization of south Asia. Many of the goods produced there show evidence of cultural exchange with Mesopotamia, and the tiles in Figures 4.8 – 4.10 show that the motif had also spread to the to the Indus Valley by ca. 2600. Of particular interest is the seal in Figure 4.8, which

depicts six divots along the crest of the head of the central figure. The number and placement of these divots is reminiscent of the six locks of hair often pictured in the Mesopotamian Nude Hero motifs.

Like the Egyptian dagger, the terracotta seal in Figure 4.10 is both evidence of cultural translation and a foreshadowing future divinity. For the first time the figure appears as Mistress, rather than Master, of Animals. It is suggested that this may be the earliest depiction of what would become the Hindu goddess Durga (Chakravarty 1971). This is bolstered by Durga's association with lions and tigers, the only animals depicted with the Mistress motif in this culture. The divinity of the image is confirmed by the six-spoked wheel pictured above

Figure 4.8: Stone Seal
Mohenjo-daro, 2600 – 2334 BCE
Harappa Museum – DK 11794
© J.M. Kenoyer/Harappa.com, Courtesy of Dept. of Archaeology and Museums, Govt. of Pakistan

Figure 4.9: Seal M308
Mohenjo-daro, 2600 – 2334 BCE
Harappa Museum - M308
© J.M. Kenoyer/Harappa.com, Courtesy of Dept. of Archaeology and Museums, Govt. of Pakistan

Figure 4.10: Terracotta Seal
Mohenjo-daro, 2600 – 2334 BCE
Harappa Museum - H95-2486, Lot 4651
© J.M. Kenoyer/Harappa.com, Courtesy of Dept. of Archaeology and Museums, Govt. of Pakistan

Figure 4.11: Signet Ring of Tiryns
Tiryntha, 1500 BCE
Athens Archeological Museum - 6208

the Mistress motif that is suggestive of the dingir. It is identical to the version of the dingir that will later appear along with the crescent on the gold signet ring of Tiryns (in southern Greece), dating to the 15th century BCE (Figure 4.11). The proto-Durga is not alone on this tile, as its reverse features another image thought to be the earliest depiction of Shiva (Hiltebeitel 1978).

Shitala is an aspect of Durga and is still revered across Pakistan and northern India in the areas crisscrossed by the trade routes with Mesopotamia. Like her counterparts in Mesopotamia and Egypt, Shitala is a deity associated with healing and disease (Ferrari 2015).

INTERCULTURAL STYLE AND THE NEAR EAST

The Master motif retained its importance long after the veneration of Nanna ceased. The Bull Man disappears from the images, and the Nude Hero starts to be replaced with images of kings. As before, the dingir and the crescent are added to the images to signal to viewers that they are looking at a divine king (Figures 5.1 and 5.2). In some seals the rulers went so far as to place themselves in poses traditionally reserved for Nanna, such as the image of the king on the backs of two cows in Figure 5.3 (Rochberg 2010).

Fantastic creatures such as griffins begin to appear on seals around 1500 BCE. But perhaps the most startling development was the appearance of the Mistress of Animals for the first time in the Middle East (Figure 5.4). Prior to this the only known Mistress imagery appeared in the Indus Valley almost a thousand years earlier (Figure 4.11).

But this was no simple homecoming. By this time the Sumerian Empire had collapsed, the rise and fall of the Akkadian Empire had supplanted the Sumerian dialect with its own Semitic language, and the Babylonian Empire had become history. Although the region was the birthplace of the motif, the Assyrians

Figure 5.1: Stone Seal and Imprint
Assyrian, 1400 - 1300 BCE
Metropolitan Museum of Art - ss43_102_37

Figure 5.2: Chert Cylinder Seal
Assyrian, 1300 - 1200 BCE
Morgan Library - Seal 600

Figure 5.3: Shell Cylinder Seal
Ur, 1500 - 1100 BCE
Penn Museum - 30-12-46 (Ur 1928-9)

Figure 5.4: Agate Cylinder Seal with Detail
Iran, 1550 - 1300 BCE
British Museum - 89745

of this time were a culturally different population from the one that that had originally created the Master of Snakes and later Nude Hero motifs. What is occuring is a continuation of the cultural translation that had taken place in outlying regions. By now enough change had occurred within the regional culture to obscure the common origin of the motifs, and to allow for the acceptance of newer interpretations.

The Lorestān Province in western Iran would come to serve as the crucible in which foreign Master and Mistress motifs were alloyed into new designs, and the region would become the largest producer of artifacts bearing these images. Because of its location

it enjoyed early trade with Mesopotamia and Susa as far back as the 4th to 3rd millennium BCE (Begemann et al. 2008). But it was not until after the Lorestān Iron Age, beginning about 1300 BCE, that craftsmen start producing a style of artifacts that scholars now refer to as the "Lorestān Bronzes" (Fleming et al. 2005).

Among the hundreds of examples of the Master and Mistress motif on these intricate bronzes are pins such as those seen earlier in Figures 1.5 – 1.8, horse bits (Figure 5.5), and finials (Figure 5.6). Unfortunately, most of the examples in museums were looted before the 1930s, so exact provenances and dates cannot be discerned. However, the majority of the museums date

Figure 5.5: Lorestān Horse Bit
Iran, 1000 – 600 BCE
Los Angeles County Museum of Art - M.76.97.106

Figure 5.6: Lorestān Finial
Iran, 1000 – 600 BCE
Los Angeles County Museum of Art - M.76.97.57
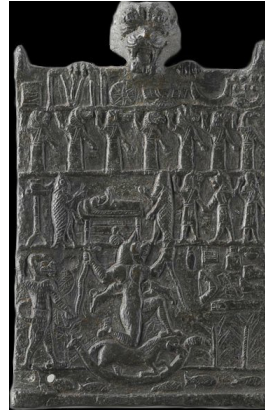
Figure 5.7: The Hell Plaque
Mesopotamia, 934 - 612 BCE
Louvre - AO 22205

the pieces from ca. 1000 to 800 BCE. These bronzes remain relevant to the investigation of the motif because they demonstrate the range of influences on the motifs during this period and may help to explain some of the blending of styles found later in the "Orientalizing" period of the Aegean Iron Age.

The most important piece from this era is a Neo-Assyrian plaque quaintly referred to as the "Hell Plaque" (Figure 5.7). This relief is significant because it not only includes a version of the motif that combines the Master of Serpents with lion imagery, but also provides direct evidence that both versions of the motif being associated with healing.

This plaque is believed to have been hung above the beds of the sick to effect a cure. The top register represents the holy symbols of various Assyrian deities. Included among them are the dingir-like sun disk representing Shamash, and the crescent moon of Sin (formerly Nanna). The figure at the bottom is said to represent an evil demon of disease named Lamashtu. She was the daughter of Anu and her name in Sumerian was spelled with a dingir. This suggests that we are seeing a demonization of an earlier deity, and her Assyrian name may actually be an irregular form of lamassu, a protective deity often set to guard gates (Kühne 2010). Whatever the case may be, Lamashtu were often used on healing amulets during this period.

ORIENTALIZING AND THE AEGEAN

These dynamics of translation and transference continued westward as the motif began to appear in the Aegean (Figure 6.1).
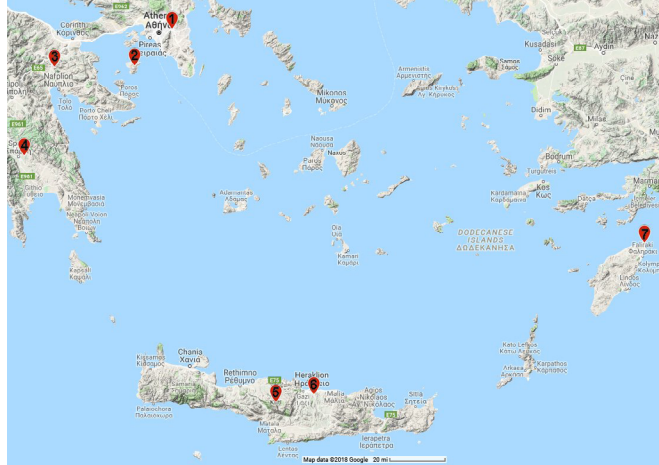
Figure 6.1: Locations of the Master/Mistress Motif in the Aegean

1 - Arkades   2 - Aegina   3 - Mycenae   4 - Sparta   5 - Crete   6 - Knossos   7 - Rhodes

Figure 6.2: Pendant, Sheet Gold
Aegina, 1850 - 1550 BCE
British Museum - 1892,0520.8

The earliest Aegean example of this motif occurs on a gold pendant from the Aegina Treasure hoard (Figure 6.2. It has been suggested that the central figure's attire shows strong Egyptian or Phoenician influences (Higgins 1957). However, there is a striking similarity between this so-called Aegina pendant and a jasper seal from Crete (Figure 6.3). Like the gold pendant, the seal features a topless figure holding birds, but the pronounced breasts on this figure make clear that it is female. It is very possible that the pectorals on the pendant may have actually been intended to have been female breasts.

This possibility of the figure being female is not as far-fetched as it may seem. Though the gold pendant was found in the island of Aegina, it was part of a famous burial hoard that is often argued to have been Cretan, or at least created by Cretan artists. Bronze Age Minoan art was dominated by females, both divine and mortal, and there are few examples of indisputable male deities from Minoan Crete.

The four snakelike curved lines on either side of the pendant's central figure are identical to the hornlike headdress worn by the females depicted the seals from Tomb 515 from Mycenae, which was just across the Saronic Gulf from Aegina (Figures 6.4 and 6.5). These seals are very similar to a specimen from Knossos on Crete (Figure 6.6). The figures in

Figure 6.3: Jasper Seal
Crete, 1600 - 1450 BCE
British Museum - 1923,0401.4

Figure 6.4: Agate Seal and Imprint
Mycenae, Necropolis - Tomb 515, 1450 - 1300 BC
Archäologisches Museum - (CMS-I-145)

Figure 6.5: Agate Seal and Imprint
Mycenae, Necropolis - Tomb 515, 1450 - 1300 BC
Archäologisches Museum - (CMS-I-144)

Figure 6.6: Agate Seal and Imprint
Knossos, Sanatorium Gräber, 1450 - 1300 BC
Archäologisches Museum - (CMS-II,3-063)

three seals are topless in Minoan style, and they all have the same headdress with the labrys double axe, a common symbol featured in the Cretan palaces.

But it is very possible that that one of the most famous Minoan symbols, the horned headdress, was acquired elsewhere. The Mycenaean and Minoan seals are from the same period, 1450 - 1300 BCE. The Aegina pendant predates those seals by at least a century, 1850 - 1550 BCE, but the jasper seal may have made within the period of the pendant, 1600 – 1640 BCE. Thus, the gold pendant predates the later horned seals, and the earliest seal attributed to Crete depicting the Mistress motif is pictured without horns but with the same animals as the Aegina pendant.

The assertion of Cretan craftsmanship seems to be another problem in tracing the symbol. The provenance of the jasper seal is unknown, but it was classified as Minoan due to the quality of the work even though the Mistress motif would not appear in Minoa until the Snake Goddess (ca.1600 BCE), and the motif would not be pictured with birds until almost a thousand years later. This was because it has become commonplace to attribute fine work to the Minoans, which is assumed and not always based on archaeological evidence (Muhly 2015). It is natural to want to compare artifacts of unknown provenance to those with secure archaeological context. However, simply categorizing artifacts based on assertions about the quality of craftsmanship to the exclusion of the context of the site is not only academically risky; it may have compromised our overall picture of the region and led to faulty conclusions about the evolution of motifs.

The seals in Figures 6.4 - 6.6 are from known burials. All three seals date to the same period, but the engravings from Mycenae are much more carefully and intricately carved than the specimen from Crete, which almost has the appearance of a copy from memory. Even the labrys, one of the primary symbols of Minoan civilization, is far more detailed on the Mycenaean specimens. This would suggest that the earliest examples of these elements in the Aegean came from Mycenae, not Crete. Yet a presupposition of Minoan craftsmanship or style is applied to them based on the quality of the work and the preconception of the origin of the image.

It was very rare for the motif to be pictured with birds at all, and the Aegina pendant and jasper seal are examples of a form of the Mistress/Master motif that does not appear outside the Aegean. As in other regions, the cultural adaption of the motif

foreshadows future divinity. Those two examples will be without parallel until after 1000 BCE, when temples to the goddess Artemis Orthia appear in the Aegean in the same region as the Bird Mistress imagery. She was a goddess of fertility and animals who was worshipped in southern Greece (Lawler 1942).

The votive imagery of Artemis Orthia often placed her in the Mistress motif with birds, and the composition later became associated with the Greek moon goddess (Figure 6.7). Many of these early motifs also depicted Artemis Orthia with symbols of healing such as the tree of life (Figure 6.9).

The seventh century BCE was a time of intense exploration and trade between the Aegean and the Syro-Palestinian coast; as Greek merchants interacted with the older cultures of the eastern Mediterranean, they were exposed to religious iconography that began

Figure 6.7: Ivory Pin
Sparta, Sanctuary of Artemis Orthia - 660 BCE
National Archaeological Museum, Athens - A15502
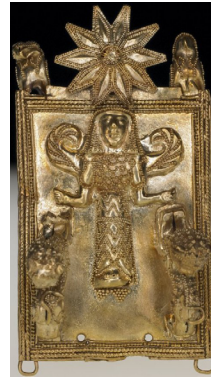
Figure 6.8: Gold Pendant
Kamiros, 700 - 600 BCE
British Museum - 1861,0425.3

Figure 6.9: Urn
Arkades – Grave L - 700 BCE
Levi 1969, 22 pl. 12
Courtesy of the Trustees of the American School of
Classical Studies at Athens

Figure 6.10: Ceramic Cup
Crete, 700 - 600 BC
Michael C. Carlos Museum, Emory University - 2003.011.001

Figure 6.11: Ceramic Cup
Kamiros, 700 - 600 BC
British Museum- 1860,0404.21

to creep into Greek art, and thus the century has been characterized as one of "Orientalizing". Pendants such as the one in Figure 6.8 represent the one of the most prolific forms of the Mistress of Animals motif in the Aegean. These pendants have been found in both gold and silver in several different locales. Variations exist but the majority retain the style and iconography of the Kamiros pendant. The hairstyle and clothing are consistent with that of the Ivory pin and Urn, but this is the first time the motif is pictured with wings. These compositions show strong influence from the Near East. They are very similar to the detail in the earlier seal from Iran (Figure 5.4), as the figures in both motifs are winged and holding large cats in the same manner. Many of the Aegean pendants also include the addition of asterisk patterns not unlike the dingir (Figure 5.12), and these symbols are carried over to other depictions of the motif during the period (Figure 6.10).

Variations of the motif continued to evolve into new combinations during the Orientalizing period, suggesting that there may have been synchronization of other deities with the Mistress motif at this time (Figure 6.11). The motif began to be depicted more frequently with many different animals, including both birds and large cats, as seen on the Boeotian amphora in Figure 1.3 and on the ceramic cup in Figure 6.10. The checkered dress and overall composition strongly suggests that they influenced the iconography of the François Vase (Figures 1.1 and 1.2).

CONCLUSION

The Master/Mistress of Animals is often viewed as an image that appears mysteriously and inconsistently through history, but as I have shown in the analysis above, there are clear patterns in the evolution of the image that can be recovered from the surviving iconographic evidence over a very wide region of the Old World. This motif has a lineage that can be traced well back into prehistory, and for which a demonstrable chain of cultural custody can be established. It is a motif associated with healing, divinity, and social power that continually was subject to stylistic evolution and reinterpretation based on beliefs and understandings of each adopting culture.

When I began this project, I thought I was researching a symbol that influenced a single Greek ideal of divinity. In actuality it was an archaic symbol that impacted countless cultures, each reinterpreting it based on the needs of the people at that time. Diffusion and translation become more a web of contacts and influences than a direct line of transmission, with each connection point creating new associations and ideas while retaining some aspects of prior concepts. The Master/Mistress motif shows itself to be not an occasional cultural manifestation, but a symbol that was constantly evolving with the cultures it encountered.

I have not used the term "derived" once in this paper. This is because rather than simple appropriative mimicry, populations picked up ideas from one another and incorporated them into their own cultural schemas. Ningizzada, Nanna, Sekhmet, Durga, and Artemis are all distinct aspects of the populations that venerated them, but within those deities can be found much older ideas. One of the most important concepts that can be gleamed from the study of the Master/Mistress motif is that no matter how very different

people and ideas may seem, it does not mean that they were are not once echoes from the same source.

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THE EFFECTS OF ULTRASOUND-GUIDED PERIPHERAL IV INSERTION ON PAIN AND PATIENT EXPERIENCE

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ABSTRACT

This study was conducted to investigate the use of ultrasound-guided peripheral intravenous (IV) insertion to minimize the pain patients experience with insertion. During this quantitative study, 201 adults were randomly assigned to have their peripheral IVs placed by ultrasound-guided insertion and insertion by the bedside nurse. After the procedure, nurses assessed the pain the subject felt during the procedure using a verbal pain scale, and asked how the patient compared the procedure to the last peripheral IV that they experienced. There were significantly lower pain scores with the use of ultrasound-guided insertion (p=0.021) and the number of attempts it took to successfully insert a peripheral IV (p=0.038) were significantly fewer with ultrasound-guided insertion. Additionally, there was a statistically significant correlation between insertion method and the experience of having an IV placed compared to previous IV insertions (X^2=0.648, p=0.008). Clinicians can improve the experience that patients have with the placement of peripheral IVs through ultrasound-guided peripheral IV insertion and limit the number of attempts required.

INTRODUCTION

1.1 Background

Nurses and other healthcare workers commonly use peripheral intravenous (IV) catheters in hospital settings to obtain vascular access for administering substances such as medications, fluids, and blood (Gabriel et al., 2005). Although obtaining vascular access through peripheral IVs is important for the patients' health, there are physiologic and psychologic complications associated with them. One of the main complications that researchers are looking at is the pain felt on peripheral IV insertion. Studies have been conducted on the use of lidocaine, distraction, vibration, and external cold to minimize the pain felt by patients during the procedure (Canbulat, Ayhan, & Inal, 2015; Vosoghi, Chehrzad, Abotalebi, & Atrkar Roshan, 2010; Brown, 2003). However, few studies were found that have looked at the effects of ultrasound-guided placement of peripheral IVs on pain during insertion. The purpose of this study is to examine the effects of ultrasound-guided placement of peripheral IVs on pain during insertion in medical surgical patients.

1.2 Literature Review

Peripheral IV access is frequently obtained by the nurse in the hospital, and patients may associate this procedure with great disfavor due to the painful insertion of the needle as well as the discomfort related to the IV being maintained while in the hospital. During insertion, patients experience a great deal of stress and anxiety because of the pain and trauma they have experienced from previous peripheral IV insertions (McGowan, 2014). Patients may become traumatized by the experience of distress during the procedure. To help reduce the trauma and distress that patients experience, studies have been conducted to find methods of limiting the pain patients experience during peripheral IV insertion (McGowan, 2014).

Previous studies have examined interventions to minimize pain on peripheral IV insertion in the pediatric population. One approach that has been studied is the

use of distraction (Vosoghi, Chehrzad, Abotalebi, & Atrkar Roshan, 2010). Distraction has been found to be an effective technique in reducing the pain felt by children between three and six years old (Vosoghi et al., 2010). Other nonpharmacological interventions that have been studied to minimize the pain on IV insertion are the use of external cold and vibration on the skin (Canbulant, Ayhan, & Inal, 2015). Canbulant et al. found significant pain reduction using these two methods compared to the control group. Some pharmacologic interventions that have been studied are the use of intradermal lidocaine, topical lidocaine, and bacteriostatic normal saline (Brown, 2003; Fein & Gorelick, 2006). Lidocaine administered intradermally and topically have been found to reduce the pain of the procedure (Brown, 2003; Fein & Gorelick, 2006). However, a study found that, although the use of lidocaine is more effective than the use of bacteriostatic normal saline, bacteriostatic normal saline is the most cost-effective method (Ganter-Ritz, Speroni, & Atherton, 2012).

The location and visualization of a vein can be a difficult task when preparing to place the peripheral IV. For example, a large patient may have veins that are deep in the tissue and hard to find, or a frail older patient may have veins that roll away when the nurse tries to insert the peripheral IV. Another reason for a difficult peripheral IV insertion is that the valves in the veins may prevent the needle from threading into the vein.

As a means to overcome these challenges, a method of peripheral IV insertion that has been investigated is the use of ultrasound-guided insertion (Bahl, Pandurangadu, Tucker, & Bagan, 2016). A study about emergency room nurses inserting peripheral IVs found that the success rate of peripheral IV insertion increased by 20% using ultrasound-guided IV insertion compared to the traditional technique of palpation (Bahl, Pandurangadu, Tucker, & Bagan, 2016). Furthermore, they found that the time it took to insert the IV also decreased (Bahl, Pandurangadu, Tucker, & Bagan, 2016). A study conducted by Ault, Tanabe, and Rosen (2015), found that a majority of nurses were capable of completing training in using ultrasound-guided peripheral IV insertion technique. The current literature shows that the use of this technique is an effective way to improve patient care. For this study, we expect that decreasing the number of peripheral IV insertion attempts and the time to insert them may diminish the pain experienced.

Currently in nursing research there is a lack of evidence regarding the effects of ultrasound-guided peripheral IV insertion. Many bedside nurses like to start the IV the traditional way, which is feeling for the vein and then sticking blindly, hoping the vein is good enough to use for an IV. There is a limited number of studies that look into interventions to minimize the pain on peripheral IV insertion on adults. A large proportion of the research focuses on limiting the pain for pediatric patients, but not for limiting pain during adult IV insertions (Canbulat, Ayhan, & Inal, 2015; Vosoghi, Chehrzad, Abotalebi, & Atrkar Roshan, 2010; Fein & Gorelick, 2006; Fanurik, Koh, & Schmitz, 2000). Many times nurses will use an ice bag or a warm towel to reduce discomforts on adult patients, but the research suggests that this adult treatment is vastly different from what the pediatric patients have received. Sometimes, the vein that is stuck for an IV placement interferes with the bony structures of the wrist, and patients complain that it is painful for days when they move that part of the arm. The pain from the movement can prevent or impede the use of a walker or cane, which interferes with the overall mobility of the patient who may be needing to ambulate for recovery. There is a lack of research in the relationship between the number of attempts taken to insert the peripheral IV, the pain associated with the insertion of the IV, and the ongoing pain from the location of the IV. Therefore, the purpose of this study was to investigate the use of ultrasound-guided peripheral IV insertion to decrease the amount of pain adult patients experience compared to peripheral IV insertion by the bedside nurse with palpation only or with a vein finder.

METHODS

2.1 Study Design and Setting

This was a quantitative quasi-experimental study that was conducted on five acute care units, at a hospital in North Texas, to determine the effect of ultrasound-guided peripheral IV insertion on pain. The study was approved by the hospital's institutional review board.

2.2 Recruitment

Recruitment was done in a face-to-face clinical encounter. The potential subjects were identified when a physician wrote orders to start an IV. When the IV was being started, the patients were informed about the study. Additionally, the researchers obtained written consent of the participant to be a part of the study. Participants were asked if the researchers could observe the IV sites daily with ultrasound and collect data about the IV site. The subjects did not receive compensation for participating in the study.

2.3 Inclusion and Exclusion Criteria

Subjects were between 18 and 89 years of age. Additionally, to be included in the study patients must have met the following criteria: 1) understand English; 2) be conscious and oriented; 3) agree to have an IV

started; and 4) agree to have a member of the research team observe the IV site daily through the use of an ultrasound. Subjects were excluded if they were: 1) unconscious or did not understand the situation; 2) refused ultrasound observations of the IV site; 3) had a condition that renders veins unsuitable for peripheral IV usage; 4) had a known pre-existing thrombus (blood clot) in both arms or any other evidence of bilateral arm thrombi; or 5) had a peripheral IV placed in both arms in the past 30 days since admission.

2.4 Power Analysis

A power analysis was conducted and assumed a multivariable linear regression, alpha= 0.05, desired power 0.80, two insertion methods, and an estimated effect size of f= 0.20. The analysis determined that a sample size of 175 was necessary to reject the null hypothesis. A sample of 175 subjects were divided into two equal groups. An additional 26 subjects were recruited to exclude incomplete data from the analysis.

2.5 Procedures

Randomization was achieved through the use of the patients' room assignments. Since the patients were randomly assigned to their rooms, this was used to assign subjects into different groups. The subjects in odd-numbered rooms had the IV inserted using the ultrasound-guided technique, and patients in even numbered rooms had an IV inserted using a vein finder, or by traditional placement. This allowed for proper randomization of the subjects. Two registered nurses from the vascular access team performed the ultrasound-guided peripheral IV insertions, and the others were done by the bedside nurse. The two groups were: 1) ultrasound-guided; 2) placed by the bedside nurse with palpation only or with a vein finder. The research members recorded their observations of the peripheral IV sites, and the nurses recorded the attributes related to the number of attempts required to obtain successful venous access. Data collected included the date of IV placement, vascular access nurse or bedside nurse,

whether the study IV placement was the subject's first, catheter gauge, subject's perception of the pain during insertion, subject's overall experience compared to a previous peripheral IV insertion, and method of insertion.

2.6 Data Analysis

With this data, a multivariable linear regression was used to determine the association between groups. Additionally, a chi square test was conducted to analyze the subjects' overall experience compared to a previous peripheral IV insertion. A critical F of 3.049 was required to reject the null hypothesis for the study's sample size. The data was manually cleaned for impossible entries and recoded manually. It was then imported to the IBM-SPSS statistical package for analysis.

RESULTS

3.1 Placement

Two hundred one patients were studied for this project. One hundred six patients (52.7%) had their peripheral IVs placed by the vascular access team using an ultrasound machine, and 95 patients (47.3%) had the peripheral IVs placed by the bedside nurse.

There were 201 patients total that had IVs started. It took one nurse to start the peripheral IV in 177 patients (88.5%), two nurses for 20 patients (10%), three nurses for 2 patients (1%), and four nurses for 1 patient (0.05%). In most patients (71.6%), it took one attempt to start a peripheral IV, two attempts in 37 patients (18.4%), three attempts in 11 patients (5.5%), four attempts in 5 patients (2.5%), five attempts in 1 patient (0.5%), six attempts in 1 patient (0.5%), and eight attempts in 2 patients (1.0%). The average number of attempts it took a bedside nurse to start the IV was 1.71 ± 1.227. The mean number of attempts for the ultrasound-guided and traditional placement of peripheral IV are displayed in Table 3.1. The average number of times it took for an ultrasound-guided peripheral IV to be placed was significantly lower than when a peripheral IV was placed by a bedside nurse (p=0.0001). Most patients (97.0%) reported that they

	Ultrasound-guided	Traditional
Participants	106 (52.7%)	95 (47.3%)
Never had a Peripheral IV in the Past	4 (3.8%)	2 (2.1%)
Average Number of Attempts	1.22±0.78	1.78±1.21

Table 3.1: Characteristics of Placements

had a peripheral IV started in the past, but a few patients (3.0%) never had a peripheral IV started in the past.

3.2 Location and Catheter

Most IVs were placed in the arm opposite of the dominant hand to allow for more unrestrictive movement. One hundred eleven patients (55.2%), out of all of the patients studied, had their peripheral IVs placed on the left arm, and 90 patients (44.8%) had their IVs placed on the right arm. The left arm was more preferred by the nurses compared to the right arm. The most common location for a peripheral IV was the forearm (64.7%). See Table 3.2 for the sites selected for peripheral IV insertion. See Figure 3.1 for the brand and gauge of the peripheral IV catheters used. The most commonly used catheter was the Introcan 20 gauge x 1.75 inch.

3.3 Experience

The overall mean pain level on peripheral IV insertion was 2.42 ± 2.453. See Table 3.3 for the mean pain scores for ultrasound-guided and traditional peripheral IV placement. One hundred twenty-four patients (61.7%) reported that the peripheral IV that was started in the study was better than last time, 64 patients (31.8%) reported that the experience was the same as last time, and 13 patients (6.5%) reported that the experience was worse than last time. Out of the 124 patients that said the study peripheral IV was better than the previous IV, 75 patients (60.5%) had their study peripheral IVs started using the ultrasound-guided method. Most of the patients (70.8%) that had their peripheral IVs placed using an ultrasound said that it was better than the last IV they had, and the remaining patients (29.2%) said that it

	Forearm	Upper Arm	Antecubital	Proximal Hand	Distal Hand	Finger
Peripheral IV Location	130 (60.7%)	24 (11.9%)	21 (10.4%)	5 (2.5%)	2 (1%)	2 (1%)

Table 3.2: Site of Peripheral IV

	Ultrasound-guided	Traditional
Mean Pain Score	1.95±1.94	3.04±2.93
Better than the Previous IV	75 (70.8%)	49 (51.6%)
Same or Worse than the Previous IV	31 (29.2%)	46 (48.4%)

Table 3.3: Patient Experience with the Procedure
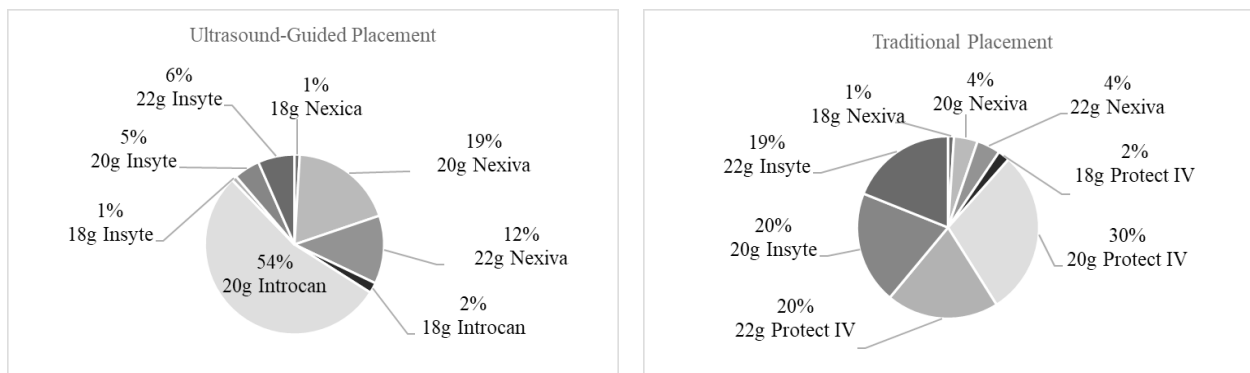
Figure 3.1: Peripheral IV Catheter Brand and Gauge

was the same or worse than last time. Approximately half of the patients (51.5%) that had peripheral IVs started by the bedside nurse said that it was better than last time, and the remaining said that it was the same or worse (48.4%). Only three of the patients (23.1%) who had their peripheral IV placed using an ultrasound reported that the peripheral IV was worse than their last experience. The remaining (76.9%) were placed by the bedside nurse.

The most common reason for removal of the IV was other (56.5%), which included discharge as a reason for removal. The most common symptom that led to the removal of the peripheral IV was infiltration (21.5%), followed by pain and inflammation at the site (2.5%). Five were removed because of accidental dislodgement (2.5%), and two were removed because four days had passed (1.0%). Thirty two patients' (16.0%) peripheral IV's were not removed during the study.

3.4 Analysis

The multivariable linear regression showed that the number of attempts (p=0.038) and the use of ultrasound-guided insertion (p=0.021) had a statistically significant effect on the pain score (r=0.252). It was an expected result that the use of ultrasound-guided peripheral IV insertion and the lower number of attempts would decrease the pain on insertion. A biserial correlation revealed that there was a significant correlation between the pain score of insertion and the number of attempts (r= 0.206, p=0.003). The vein finder did not contribute to the variation in pain score. No relationship between the pain score and the placement of the peripheral IV in the hand was found (p=0.812). The study was not conducted to answer the question of whether placing the peripheral IV in the hand correlated with the pain score. A biserial correlation was performed to assess the relationship between the use of an 18 gauge catheter and the pain scale. A significant, but small, effect was found (r=0.149, p=0.035).

A chi-square test was performed on the correlation between the use of ultrasound-guided insertion and the comparison to the previous peripheral IV. The correlation was statistically significant and expected (x^2=0.648, p=0.008). A biserial correlation was performed between the number of peripheral IVs attempted and the comparison to the previous peripheral IV. The correlation was statistically significant and expected (r=−0.244, p =0.0001).

DISCUSSION

4.1 Placement

The primary aim of this study was to identify if the use of ultrasound-guided peripheral IV insertion could minimize the pain experienced by patients during insertion. With better visualization of the patients' veins, we hoped that this would limit the number of insertion attempts and decrease the pain scores of the procedure.

We had expected that the number of ultrasound-guided and bedside nurse started peripheral IV insertions to be the same amount. However, the lower number of bedside-nurse-started peripheral IVs (47.2%), compared to the ultrasound-guided peripheral IV insertions (52.8%), may be because the bedside nurse was unable to start the IV. In some instances, the bedside nurse would attempt to start a peripheral IV on patients that were assigned to them for the day. Patients would have their IV started by the bedside nurse, but these were unsuccessful because the patient had few viable veins. This led to the bedside nurse calling the physician to obtain an order for an ultrasound-guided IV, peripherally inserted central catheter, or other central venous access catheter. The patient was then not a candidate for the study. Because of this, the IVs started by the bedside nurse may have been fewer than the other types of IV starts. The patients that were more difficult to start a peripheral IV on, without the use of an ultrasound, may have been excluded because ultrasound-guided peripheral IVs are known to have a higher success rate as reported by a previous study (Bahl, Pandurangadu, Tucker, & Bagan, 2016).

The use of vein-finder-guided IV placement was also lower than expected. During the study, many nurses reported that they did not want to use the vein finder for peripheral IV insertions because they found it cumbersome and unavailing. No literature was found to explain this finding, but this may have led to the lower number of vein-finder-guided placements as well as the higher mean number of attempts to start a peripheral IV.

The number of attempts it took nurses to insert a peripheral IV using an ultrasound was expected to be lower than the attempts to insert an IV while using a vein finder or palpation only. This was found to be correct. The proper visualization of the vein when using ultrasound-guided placement was likely the cause of the lower number of attempts it took nurses to start a peripheral IV. Bahl, Pandurangadu, Tucker, and Bagan (2016) support this finding with their report that nurses were more successful starting peripheral IVs using an ultrasound compared to palpation only.

Overall, the number of nurses who attempted to start a peripheral IV were lower than expected. In all instances that the peripheral IV was inserted with an ultrasound, the procedure was conducted by a single nurse from the vascular access team. This most likely caused the low number of overall nurses who attempted to start an IV on the patient. As mentioned above, patients who were assigned to have their IV started by a bedside nurse with unsuccessful attempts were eliminated from the study.

This also may have caused the lower than expected number of nurses attempting to start an IV on the patient. The same rationale may explain the low number of peripheral IV insertion attempts by the nurses because the patients who were the most difficult to start a peripheral IV on may have been excluded from the study.

The number of patients who had peripheral IVs started in the past was higher than expected. The high level of patients reporting that they have had a peripheral IV in the past may be because many of the patients that participated in the study were admitted through the emergency department and had peripheral IVs started in the field. No literature was found to support this finding, but we think that a high number of patients who were admitted to the hospital through the emergency department had peripheral IVs started prior to reaching the units.

4.2 Location and Catheter

We expected that the number of peripheral IVs started on the left arm would be higher than those started on the right arm. Nurses reported that they preferred inserting a peripheral IV in the left arm to allow right-handed patients to have free movement on their dominant hand. The slightly higher rate of left arm peripheral IV insertions compared to the right may be explained by this. However, no literature was found to support this finding.

The most common location for the peripheral IV to be placed was the forearm, and this may be because there are less bony protuberances in that area compared to the hand and fingers. Additionally, bedside nurses reported that they had the most success in starting a peripheral IV in the forearm compared to other areas. The upper arm may have been used less because the vascular access team wanted to preserve the veins of the upper arm for peripherally inserted central catheters and midline catheters. Hadaway (2007) also found that placing IVs in the hand, and antecubital areas, may be more prone to complications, and nurses should avoid using these locations. All of these factors could have led to the high number of peripheral IVs being placed in the forearm rather than other areas.

Nurses preferred to use the Insyte IV catheter. Nurses available reported that they thought that it was the shortest and most pliable catheter out of the four and, therefore, may cause less irritation to the vein. However, the bedside nurses reported that they did not like the Insyte because the button to retract the catheter was inconvenient to use. Vascular access nurses reported that they did not prefer to use the Introcan catheter. The nurses thought that it was the stiffest and the longest catheter and may cause more injury to the vein than the Insyte catheter. Nurses

who used the Nexiva catheter reported that they used the catheter because it was convenient to have the extension tubing attached to the catheter before insertion. The ProtectIV may have been used more, but at the facility the ProtectIV was replaced by the Insyte catheter. Because of these factors, all of the brands of catheters were used by nurses in similar amounts.

Nurses believed that they should use the smallest gauge of catheter that they could to minimize the possible irritation to the vein, but they preferred not to use a 22 gauge catheter. This is because it is a very small catheter and patients cannot receive IV contrast through the 22 gauge; therefore, nurses commonly used the 20 gauge catheter or larger, such as the 18 gauge catheter. However, no literature was found on what factors nurses look at when deciding which the peripheral IV catheter to use. Nurses reported that, based on their experience, the larger the diameter of the needle and lumen, the more types of fluids, drugs, and blood can be given. If the diameter of the needle and lumen is not large enough, the drug can be impeded, and blood can be hemolyzed, which does no good for the patient.

4.3 Experience

The mean pain score for all peripheral IVs started was lower than expected, and this may be due to the use of a vapocoolant spray used by nurses before peripheral IV insertion. The vapocoolant spray has been found to lower the pain score during peripheral IV insertion (Mace, 2016). The number of patients who reported that their current peripheral IV was better than the previous IV was an expected finding. The high proportion of patients that reported their study peripheral IV was better than the previous IV may be because many patients had peripheral IVs started in the field. Field start IVs may be perceived as worse because of the stress the patient is experiencing.

A lower number of patients than expected experienced pain or inflammation of the peripheral IV site. Very few patients in the study had their IV removed because of pain or inflammation of the site. However, infiltration was a common problem that led to the removal of the peripheral IVs, and this may be due to the fact of administering vesicants and irritants through the IVs. These medications may cause more damage to the vessels and the surrounding tissues (Hadaway, 2007).

4.4 Pain Score

The primary hypothesis that the use of ultrasound-guided peripheral IV insertion would help to decrease the pain the patient experienced was substantiated. The belief that the use of an ultrasound machine during peripheral IV insertions would help to minimize the pain on insertion was substantiated. This may have

been due to the fact that with the use of the ultrasound-guided peripheral IV insertions, nurses are able to better visualize the vein. The use of an ultrasound machine increasing the success rate and decreasing the time it takes to obtain successful venous access may have also contributed to decreasing the pain (Bahl, Pandurangadu, Tucker, & Bagan, 2016). Patients may also have had a decreased anxiety level because they knew that the nurse had properly located the vein, rather than guessing, before attempting to insert the IV. The decreased anxiety levels, related to the procedure, may have affected the pain score. Tang and Gibson (2005) found that an increase in anxiety levels was related to an increase in the pain that people perceived. Because of all these factors the use of ultrasound-guided peripheral IV insertion may have been less painful for patients. This agrees with previous literature that found that the use of ultrasound-guided peripheral IV insertions decreased the amount of pain experienced by patients (Ismailoglu, Zaybak, Akarca, & Kiyan, 2015).

The number of attempts having an effect on the pain score was an expected finding. The greater number of times nurses had to insert a catheter into the patient, the greater the pain score they reported. Furthermore, with the greater number of attempts by the nurse to insert an IV, the patient may have experienced more stress. This could have led to an increased perception of pain by the patient. The 18 gauge catheter being related to an increase in the pain score may be because with an 18 gauge catheter, the diameter of the needle and lumen increase. Patients may experience more pain with a larger needle being used during peripheral IV insertion. However, the difference in pain levels is not clinically significant. Beck, Zbierajewski, Barber, Engoren, and Thomas (2011) also found that 18 gauge catheters had no significant difference in pain scores during peripheral IV insertion.

We expected that the use of an ultrasound would improve the experience that the patient would have with the procedure. The use of ultrasound-guided peripheral IV insertion was found to be positively correlated with having a better experience using the peripheral IV. Because the ultrasound-guided peripheral IV insertion was always conducted by one nurse, the patient may have felt less anxious than multiple bedside nurses attempting to start an IV. Frequently, when bedside nurses were unable to successfully start an IV, they would ask for help from colleagues, charge nurses, and nursing house supervisors. Furthermore, the use of an ultrasound could have eased the stress of the procedure because the patient knew that the nurse was able to properly visualize the vein before attempting to start an IV. The use of ultrasound-guided insertion has been shown to lower the amount of time it took to start a successful IV, and this may have led to patients having a better experience

(Bahl, Pandurangadu, Tucker, & Bagan, 2016). No other literature was found that supported these findings, but it appears that these factors made the experience that patients had with ultrasound-guided insertion better than previous experiences with peripheral IV insertions.

We expected that the lower number of attempts to start a peripheral IV would lead to a better experience with the procedure. Patients reported a better experience with the current IV when the number of attempts to start a peripheral IV were lower. The lower the number of attempts nurses took to start an IV, the less pain the patient reported. Additionally, the patient may have experienced less stress from the procedure with fewer attempts of IV insertion. No literature was found supporting these findings, but these may be the reasons why the patient experienced a better IV insertion with fewer attempts.

4.5 Future Implications

Ultrasound-guided insertions should be used more often to decrease the pain that patients feel and to improve patient experience. Especially for patients whose veins are difficult to visualize or palpate, the use of an ultrasound-guided peripheral IV insertion should be considered. Additionally, the bedside nurse should consider calling the physician to obtain an order for an ultrasound-guided peripheral IV before the patient experiences multiple attempts. Nurses should attempt to minimize the number of attempts it takes to successfully insert a peripheral IV. Doing this can help to limit the pain that a patient feels as well as improve the experience of the procedure. Facilities should consider training more nurses in ultrasound-guided peripheral IV insertion. Furthermore, nurses should be educated on the benefits of using ultrasound-guided insertion, when to request an order for one, and the skills necessary to perform the procedure.

More studies should be done to look at the effects that ultrasound-guided peripheral IV placement may have on patient anxiety during the procedure. Additionally, more studies should be done to examine the effects of ultrasound-guided peripheral IV insertion on the pain for patients who have difficult IV access. More studies should also be conducted on the effects of vein finders on peripheral IV insertion. Through this, we can better understand the effects that these methods of insertion have on the patient's experience with the procedures.

CONCLUSIONS

The results show that with the use of ultrasound-guided peripheral IV insertion, the pain a patient feels can be minimized and the experience of starting an IV can be improved. Even though inserting a peripheral IV will still be painful and stressful for the patient, these

problems can be minimized. Through educating bedside nurses on the benefits of using an ultrasound machine and forming guidelines to consider when to obtain an order for an ultrasound-guided peripheral IV, more patients will benefit from this method. Limiting the number of attempts nurses take to start a peripheral IV is an important factor to limit the pain and improve the patient's experience of this procedure. The number of nurses that are trained in placing ultrasound-guided peripheral IVs should be expanded to make this procedure more accessible to patients. Students in nursing schools may be better prepared for working in the clinical area if they are trained to start peripheral IVs by palpation and with an ultrasound machine. Clinics may need to consider holding training sessions to educate more bedside nurses on ultrasound-guided peripheral IV insertion, as well as making ultrasound machines more available in the units. This study has provided clinicians with a means to help control pain on peripheral IV insertion through changing the methods of the placement. Research on IV placement should continue with a focus on reducing the effects of anxiety experienced by the patient. All of these implications can improve the patient experience.

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DETERMINING THE HABITABILITY OF EXOPLANETS IN TRIPLE STAR SYSTEMS

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ABSTRACT

Understanding the habitability of exoplanetary bodies in triple star systems begins by observing the formation timeline of all involved objects and their interactions with one another. If an exoplanet is to flourish in a system with multiple stellar components, it must possess favorable characteristics (e.g., prominent magnetic field) that can withstand the early formation and evolution of those components. Using the parameters of habitability known for Earth, habitable zone models, and a recently constructed Triple System Exoplanet Catalogue (TSEC), we can determine regions where single and combined stellar radiation do not inhibit biological growth. Using a previous definition for a hierarchical system, results show approximately 38% of discovered triple systems are hierarchical in nature. Circumbinary orbits make up approximately 8% of exoplanet orbits, S-type binary orbits account for 21%, and single S-type orbits account for 71%. Furthermore, exoplanets in the habitable zone of a K-type single star or those in a circumbinary orbit around a binary of similar stellar radiation are thought to be the best candidates for habitability. This preliminary research integrates current studies with the TSEC to provide new insights into the overall picture of how habitability establishes itself in the system. It also highlights the need for further research over specific topic areas covered in the paper.

There are several conditions that must be met for an exoplanet to be considered habitable, as outlined by numerous previous studies (Bowring & Housh, 1991; Kaltenegger et al., 2007; Airapetian, 2016). Unfortunately, there are even more conditions to be satisfied when we specify that this habitability must coincide with a triple star system. As emphasized by Toonen et al. (2016), understanding triple systems heavily relies on merging three-body dynamics and stellar evolution. While numerous works have combined these two components (Kratter & Perets, 2012; Perets & Kratter, 2012; Hamers et al., 2013; Shappee & Thompson, 2013; Michaely & Perets, 2014; Naoz et al. 2016), the overall study of such systems is lacking compared to those of single and binary systems. However, it is from these observations of simpler systems that we have been able to distinguish basic parameters for habitability and outline the most prominent conditions that have allowed life on Earth not only to form but also to have enough time to grow complex.

Although we have a better understanding of how these conditions are vital for a planet to survive and to support life, such conditions become more complex with the addition of stellar components in the system. As stated before, there is not an abundant amount of research material available that combines three-body dynamics and the evolution of each stellar component for a triple system. Thus, there is much more research needed to validate observations made over triple systems (hence, the production of this early Triple System Exoplanet Catalogue [TSEC]; see Appendix A). Despite this setback, we can use the fact that exoplanets in triple-star systems orbit their stellar components in such a way that it is possible where they are only majorly affected by either one or two components. Thus, data gathered from single stars and binary systems can be used to infer the type of relationship between the possible exoplanet and the stellar component(s). In a three-star system an exoplanet can possibly be habitable if the energy it receives is enough to sustain itself but is not enough to have its ability to sustain life stripped away by the stellar flux. Such in-depth discussions will be left for Section 3.1, but before delving into the habitable

conditions that must be present we must attempt to understand the composition of the system that could provide such conditions. Focusing on the history of all components in the system is the first step toward understanding how a three-body problem is affected by the evolution of each stellar component and what effects such a combination has on habitability in a system.

FORMATION

It is crucial to understand the very beginning of the formation timeline for stellar objects and how the formation affects the space environment around the forming star(s). The evolution of single and binary star systems has been studied much more extensively than triples, and there is a consensus over the dominant physical processes that govern the evolution (Postnov & Yungelson, 2014; Toonen et al., 2014, 2016). These studies have shed light on how habitability eventually becomes plausible only after the components of the systems undergo radical changes to become more stable. For example, in a single system such as that of our Solar System, the early Sun (approximately 100 million years ago) was thought to possess far-UV and X-ray emissions as much as 30–50 times and 100–500 times, respectively, higher than today (Guinan et al., 2003). To compensate for such intense stellar radiation, early Earth must have possessed a magnetic field for protection (Grießmeier et al., 2004). However, not all objects can protect themselves, as we see with Venus and Mars. Venus succumbed to the Sun's high magnetic activity, which has led it to being hot, dry, and inhospitable (Kulikov et al., 2006); Mars lost its geomagnetic field approximately 3.5 billion years ago and has now become too cold and dry for life to exist on the surface (Fairén et al. 2010). This example demonstrates how one stellar component can affect neighboring planets very differently and how properties during formation drastically effect the future of a possible habitable exoplanetary body.

2.1 Three Body Stellar Components

According to Hut & Bahcall (1983), triple systems tend to be hierarchical in nature with a distant star in orbit as the center of mass of an inner binary. For a large majority of such systems, they can be treated as a combination of a binary and single (Valtonen et al., 2008) due to the vast distances between components, and we can apply the Lidov-Kozai (LK) mechanism (Toonen et al., 2016). Introducing more stellar components into the system increases the chances of developing instabilities, and systems that are highly unstable eventually dissolve into lower order systems on dynamical timescales (Georgakarakos, 2008). Even systems that begin in stable

configurations can develop into stages of unstable orbits (Van der Berk et al., 2007). Thus, a prominent topic of triple-system formation is stability. It was quickly found out that a three-body system is a much more difficult problem to solve compared to a two-body; and while various criteria have been established to deal with certain situations over large timescales (Georgakarakos, 2008), it can be hard to establish a stable/unstable state because of the sheer unpredictability of space and the amount of time processes take. One way of modeling stability is using the criteria established by Mardling and Aarseth (1999). (See Appendix B.)

Using this criterion, Perets & Kratter (2012) show that triple evolution leads to instability in the form of close encounters and collisions between the stellar components (see publication for definition of variables). As noted by Toonen et al. (2016), this equation is based on the consequence of chaos and overlapping resonances. In the inner binary of the triple, the two components can vastly affect each other via stellar winds and mass transfer as the triple begins to evolve (Kiseleva et al., 1994; Iben & Tutukov, 1999; Freire et al., 2011; Portegies Zwart et al., 2011). As noted by Toonen et al. (2016), LK cycles cause angular momentum to be exchanged between the inner and outer binary. As a result, the orbital inner eccentricity and mutual inclination vary periodically. This is but one way the inner binary can affect the overall system. For more information regarding the orbital inclination affecting stability in triples (such as inner binary mass stability, stability of p-type orbits, and LK cycle effects that cause initially circular orbits to become highly eccentric) see Georgakarakos (2013). Winds and mass transfer in the inner binary can potentially influence the outer star depending upon the stability of the relationship between the inner components. If mass transfer is limited and stable, the outer orbit remains unchanged (Toonen et al., 2016). If the mass transfer is enhanced for the inner binary, the outer star is affected depending upon the mass lost from the inner binary (Toonen et al., 2016). Also, depending upon the spectral types of the inner binary, the star may be more willing to initiate mass transfer (as stars with extended envelopes are more likely to engage in mass transfer). Evolutionary aspects of stellar components that could affect the evolution of triples such as supernovas, neutron stars, and white dwarfs have been studied by Pijloo et al. (2012), Cordes et al. (1993), and Camacho et al. (2014), respectively. In Tokovinin's catalogue of multiple star systems, approximately 20% of the systems contain an outer star that is more massive than the inner two stars. More studies, however, are needed regarding mass transfer occurring from the outer component of the hierarchical triple and how it can potentially affect the inner binary.

Up until this point the focus has been on hierarchical triple systems of structure "2-1," in which an inner binary is orbited by an outer component that may initiate mass transfer or remotely affect the inner binary. However, of the 24 triple systems with exoplanet components, approximately 38% follow a hierarchical orbit of this definition. The majority are found to follow a "1-2" orbit configuration in which an outer binary orbits the center of mass of a primary component. If the primary component is massive enough and the outer binary consists of considerably lower mass stars, it can be assumed the primary will consume the binary and complete its stellar evolution over large timescales. As noted by Darwin (1879), there is no solution for stability in systems containing components of large mass ratios. The TSEC reflects how in exoplanetary triple systems all stellar components either decrease in stellar type or remain the same for all three components. This is a prime example of how systems form differently, and with further research it could point to how such differing formations affect the evolution of exoplanets as well as the possible physical structure of the expected exoplanet. However, more studies are needed to understand why the presence of exoplanetary bodies cause the system to form in a "1-2" hierarchy as opposed to a "2-1" formation more often, and how such bodies affect the overall formation of the system. (as we will discuss below, the presence of Jupiter may have very much affected the evolution of all planets in our Solar System.) These studies will be aided by the fact triples are becoming more commonly observed, as seen with the research conducted by Duchêne and Kraus (2013) detailing how the fraction of triple systems increases with rising stellar types with approximately 50% of spectral B types being in such systems (Remage, 2016). The prevalence of stars in triple systems is further elaborated with the research conducted by Moe and Di Stefano (2016), who detail how 10% of low mass stars are in triple systems.

As expressed before, the evolution of the components is important to detail when considering a three-body problem. We have considered how all three components affect each other and the results of different scenarios. Understanding the environment caused by the stellar components allows us to gauge the parameters the planetary object must possess to survive through the early formation process of one or multiple stellar components. The planet must contain some sort of lengthy "relationship" (e.g., Earth-Sun) with the stellar component so conditions of habitability can form. In-depth discussions regarding inclinations,

amount of angular momentum conservation of stellar components, tidal friction, Roche Lobe overflow, and differing configurations of orbits have been reserved for previously mentioned papers. This paper sheds light on using the TSEC to conduct preliminary studies on how formation is related to stellar evolution combined with a three-body dynamic. There will be more focus on how habitable locations transform throughout the stellar evolution and how the complexity of a three-body problem affects these locations as well in Section 3.1.1.

2.2 Earth and The Solar System

Prior to discussing the formation of exoplanets, a short review of how the Earth was formed is illustrative and also allows us to examine what initial conditions were present that eventually led to the origin of life. Knowing this information will help us distinguish possible habitable Super-Earths and exoplanets that could possess formation characteristics like that of primordial Earth. This review will only cover the formation aspect; results discussing the biochemistry of Earth's habitability can be seen in Section 3.2.

We know Earth formed approximately 4.5 billion years ago (Manhes et al., 1980; Dalrymple 1991, 2001), and the oldest material in the Solar System is dated to be 4.5672 ± 0.0006 Byr (Bowring & Housh, 1995). Planet formation begins during star formation, where planets are born from the circumstellar disk around a forming star (Safronov, 1972). In early stages, protoplanetary disks consist of 99% gas and 1% dust grains or ice particles (Williams & Cieza, 2011). Utilizing nebular theory, planets form from accretion, and primordial Earth formed in approximately 10–20 Myrs (Télouk et al., 2002). Earth's thermal and volatile beginnings (as well as those of Venus) were researched by Franck & Bounama (1995), who used the information to determine scaling laws for mass-dependent Super-Earths (rocky planets from one to ten Earth masses with the same chemical and mineral composition as Earth) (Valencia et al., 2006). The formation of terrestrial planets and the early Solar System is discussed in the works of Izidoro and Raymond (2018) in which the formation process of terrestrial and gaseous planets is analyzed under several differing models. It is also discussed how a possible chain of events highlights why our Solar System differs more than 99% from other observed systems. Differences include a lack of Super-Earths and a wide-orbit gas giant on a low-eccentricity orbit; in fact, early Solar System formation models suggest that Jupiter prevented the other gas giants from invading the inner Solar System

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[1] There are numerous mass transfer scenarios in which the transfer is stable and unstable. Circumstances include angular momentum loss if accretor star is not capable of accreting the matter conservatively, the donor star loses envelope, the effects of tides on each component, Common Envelope (CE) phase, etc. For a complete reference consult Toonen et al. (2016).

and that the stability between Jupiter and Saturn may have prevented the destruction of the terrestrial planets during the early stages of formation. We can utilize Solar System constraints by inputting the masses and orbits of terrestrial planets into the Angular Momentum Deficit (AMD) and the Radial Mass Concentration (RMC) equations. (Laskar, 1997; Chambers, 2001). (See Appendix B). The AMD is a diagnostic of how well simulated terrestrial planetary systems match the real terrestrial planets' level of dynamical excitation, while the RMC measures a planetary system's degree of radial concentration (Izidoro & Raymond, 2018). Such constraints can help us with formation models of observed systems and help us distinguish certain events that would be plausible in early Solar System situations.

As previously stated, Earth's formation was occurring about the same time as the Sun. The early yellow dwarf constantly bombarded Earth's magnetic field with far-UV and X-ray emissions 30–50 times and 100–500 times as much, respectively, as compared with today. Work by Güdel et al. (1997) shows that zero-age main-sequence (MS) stars rotate over 10 times faster than today's Sun, and it is quite possible the Sun may have had strong magnetic events as well as relatively quiet times during its evolution. This would account for the Sun's prominent magnetic dynamo and high energy emissions during its early age, and it showcases the impact the stellar object had on its space environment (Guinan & Ribas, 2002; Airapetian et al., 2017b). This initial stage of the Sun varied the habitable zone (HZ) in the Solar System from today, as discussed above; Stevenson et al. (1983) and Sleep (2000) give specific attention to the thermal evolution of the Sun affecting the inner planets of the Solar System. Diffey et al. (1991) has completed a lengthy analysis of the relationship between Earth and the UV effects of the Sun. Such a relationship details the importance of considering stellar evolution for habitability in a triple system. While a

three-body problem encounters a whole range of issues a single does not, it is important to note we have a better understanding of how a single star system interacts with planets through formation. If an exoplanet eventually becomes habitable after the formation process, it is through our studies of the Sun's evolution that we can begin to parameterize the conditions the stellar component imposes upon the planets of the Solar System. It serves as the only model we have thus far of how an evolving stellar component directly affects habitable conditions on a system. The only issue here, compared to our study, is the lack of a three-body problem.

2.3 Exoplanets

As noted in Izidoro and Raymond (2018), our system seems to have formed atypically compared to others. Some of these effects in which our system operated differently have already been discussed (e.g., Jupiter's possible role in preventing gas giants from entering the inner system, stability between Jupiter and Saturn). Unlike Earth, exoplanets generally form within a few million years of their star forming (Télouk et al., 2002; Rice & Armitage, 2003; Mamajek, 2009). The general formation of exoplanets follows those processes listed in Section 2.3 and those detailed in the work of Izidoro & Raymond (2018) (for terrestrial exoplanets). Kepler data has found a correlation between the stellar components metallicity and the presence of exoplanets; thus, stars with higher metallicity are more likely to have planets (particularly giant planets) than stars with lower metallicity (Wang & Fischer, 2013). Methods of detection will be discussed further in Section 4.

As of April 1 2018, there are 3,758 confirmed planets in 2,808 systems, with 627 systems having more than one planet (http://exoplanet.eu/catalog/). Utilizing the TSEC, we find that most of the masses lie with approximately 1000 $M_\oplus$ (see Figure 2.1).
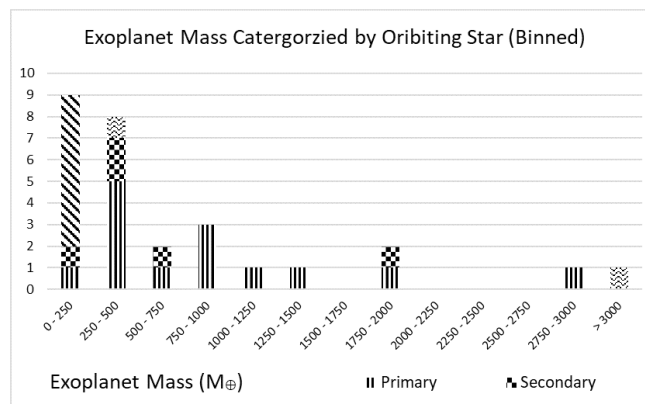

Figure 2.1: Exoplanet Mass Categorized by Orbiting Star (Binned)

In Appendix C we can see characteristics of the exoplanets such as distance from Earth, Earth mass, Earth radius, and effective temperature. These values are a part of the TSEC we will be utilizing throughout the paper.

HABITABILITY

Being the only location we know of capable of supporting complex life, Earth serves as an prime example of what a habitable planet could look like. Many of the conditions we impose upon possible exoplanetary candidates come from the set of parameters we have developed observing Earth's interaction with its space environment over time. However, these parameters we impose upon other objects cannot account for conditions that we do not find in our Solar System. Despite this difficulty, we understand there are underlying conditions that make life more probable in certain locations, and it is productive to explore such areas with an attempt to compare observations with already established criteria for habitability. By understanding the processes that have enabled habitability on Earth, namely those of the Sun and the Earth itself, we can attempt to understand and characterize possible habitable worlds in similar as well as more complex systems.

3.1 Habitability—Stellar Components

While it is assumed that most, if not all main-sequence (MS) stars can support extreme forms of life, it is the habitable conditions needed for complex forms of life to develop and evolve that piques our interest most. When a possible exoplanet candidate is found, a high priority is determining the architecture of the system around it, that is, the relationship between the possible candidate and the stellar components of the system (if there are any). Detection methods, which will be discussed in further detail in Section 4, allows us to determine basic information (e.g., luminosity, stellar age) of the stellar components that affect the habitability of the space environment. Using this information, we can acquire the identity of stellar components and therefore infer habitability conditions. The search for habitable locations centers on F–M type MS stars, as the nuclear evolution timescale for more massive stars evolves much faster and their lifespans are much shorter compared to F–M types, which can sustain themselves for extended periods of time (see Salaris & Cassisi, 2005; Eker et al., 2015; Toonen et al., 2016). Theoretical HZs have been studied for those stars of higher spectral class (O–A), but there are so many hindrances to the formation of life (stellar winds, short stellar lifetime, radiation, effective temperature, etc.), it is not promising to search for life around such stars. Studies over F type stars and

their habitability have been completed by Meynet et al. (1993), Cockrell (1999), Mowlavi et al. (2012), and Sato et al. (2014). Out of the F–M type group, F types suffer an extreme disadvantage for habitability, as they evolve from the MS much faster than the other lower mass stars. This consequently results in any chance of habitability to be highly improbable but not impossible. Conditions of habitability are already widely known for G types, as our Sun has been under much research in several regards (Durney, 1972; Skumanich, 1972; Guinan & Ribas, 2002). K types have been discussed and a part of research as well, especially regarding the search for astrobiology (Cuntz, 1998, 1999; Cuntz & Guinan, 2016; Kaltenegger, 2017). These orange dwarfs possess some of the best characteristics to support life; however, exoplanetary bodies orbiting a K-type component are subjected to high levels of X-ray and UV irradiances, while the star is young, similar to the early environment Earth was subjected to (as discussed in Section 2.2). M types are perhaps the most researched MS stars, more than likely because they account for 75% of the MS stars in the solar neighborhood (LeDrew, 2001). Papers studying physical characteristics of M types, as well as their capability of providing habitable conditions, include Cuntz (1998, 1999), Tartar et al. (2007), Tabataba-Vakili (2016), Guinan et al. (2016), Airapetian et al. (2017a); Cuntz & Guinan (2016) include a plethora of references throughout.

Regarding HZs, I will be adopting notation from Cuntz and Guinan (2016), as well as the varying definitions of HZ criteria established in the same paper. Research over finding a stable HZ around a single-star system has been conducted by Kasting et al. (1993) and Kopparapu et al. (2013, 2014), while higher-order systems (such as a binary and multiple systems) have been studied by Cuntz (2014a, 2015). A general HZ (GHZ) accounts for the greenhouse effects that give inner and outer limits to HZs; GHZs have been measured for differing stellar components ranging from F to M types. Studies conducted by Grießmeier et al. (2005) and Güdel and Náze (2009) demonstrate how active low-mass MS stars have high XUV fluxes comparable to the Sun at age 0.7 Byrs old (with the latter specifically outlining K-, M-, and G-type stars). Models used by Cuntz and Guinan (2016) also demonstrate X-ray and far UV irradiances for G0 V thru M5 V stars over a range of ages. Like Earth, any exoplanetary body would have to have an established magnetic field that could protect it from the early formation of a stellar component. Of course, interdependencies are a bit more complex when a higher order system contains stellar components comprising different spectral classifications that form and affect the primordial exoplanet differently. As discussed in Section 2.1, triple systems form being composed of a binary and a single component. Therefore, exoplanets in orbit of one

component in the system may follow HZ models as laid out by the work of Kasting et al. (1993). Likewise, those in circumbinary orbits can be treated as orbiting one stellar component (except when the two components eclipse one another) depending on the distance the exoplanet is from the binary and the spectral types of the components. With the background of formation alongside habitability studies of differing stellar components, we can now look at specific triple systems and distinguish whether the spectral components of the systems inhibit or provide habitability.

Of the currently cataloged triple-star systems, most components are of either K- or M-type, which shows that the majority of the triple-star systems found will contain stellar components of smaller mass and lower luminosities as expected. Of the 24 catalogued exoplanetary triple systems, along with four quadruple systems, those components of which we know the spectral type can be used to calculate the expectation values using already obtained information

found from observing the solar neighborhood. These expectation values are listed in Table 3.1 below using information from Bennet & Shostak, 2016.

Using the information from Table 3.1, we created a bar graph (Figure 3.1) detailing the number of stars in each spectral type. This graph highlights which spectral types dominate component groups. For example, we can see that the primary components of triples occupy all spectral classes, but the majority is focused on later spectral types such as A, F, and G. Likewise, tertiary components are mostly smaller M-types. The overall trend details how spectral class lowers with each progressing star; therefore, the stellar components decrease in mass, radius, and effective temperature as we progress from the primary to tertiary component.

Those exoplanets with a G-type or lower primary component are more likely to be in a habitable system, as the rest of the components would be of lower spectral class. Depending upon the stability of the lower-class components, these systems could provide the best

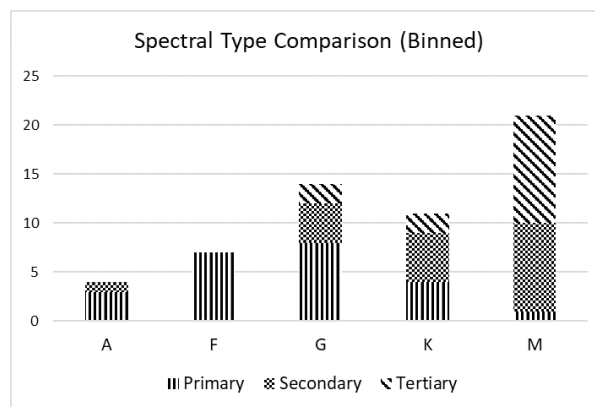| Expectation Values Table			
Spectral Type	# of Stars	Frequency	Expect Value
A	4	1%	0.57
F	7	2%	1.14
G	14	7%	3.99
K	11	15%	8.55
M	21	75%	42.75

Table 3.1: Expectation Values

Figure 3.1: Spectral Type Comparison (Binned)

chances of life. Studies completed by Tabataba-Vikili (2016) detail flare activity around M dwarfs stars, and further research regarding super-flare activity on exolife in general has been completed by Segura et. al (2010) and Kasting et. al (2014). Generally, flare activity is considered incredibly harmful and preventative of habitability, but recent work by Airapetian et al. (2016) has identified how super-flares can have favorable outcomes to kick-start biology on G- and late K-type stellar components. This will be taken into consideration when considering exoplanet habitability in Section 3.2. All information thus far would suggest the best spectral type for habitability would be K-type. This is due to the fact it is less prone to flares than M-types, has a longer lifetime than G-type stellar components, and is less prone to tidal locking during formation.

In future research we can utilize the TSEC and combine previous research conducted by Cuntz & Guinan (2016) over HZ calculations as well as UV irradiance for G-, K-, and M-type dwarf stars over time to determine HZs around the most stable stellar components of the system. Those exoplanets within their stellar components' HZ can retain liquid water on their surface and therefore be habitable. This is, of course, using a standard model set by the previous research of one team. Subsequent models formed from different research must be used in conjunction with the TSEC to validate the HZ and GHZ values used. Those exoplanets within the primary component's HZ require further research and criteria to establish their habitability. When further research is completed and results are validated, the combined research efforts covering differing spectral types, HZ calculations for single and binary systems, and the TSEC can help us distinguish habitable conditions in triple-star systems. This is due to the fact that most triples follow a hierarchical formation and they act as single and binary systems. However, not all triple systems follow this format. Those that follow

different orbits, such as cases of unstable systems and exoplanets that orbit one component of a binary, are described in further detail in the following subsection.

3.1.1 ***Habitable Zone*** (***HZ***) ***Variation in Triple Systems*** Established boundaries and formulas for HZs as well as GHZs have already been discussed for single and binary systems in Section 3.1, but the addition of a third component in the system can either cause drastic or little variation in the system. As stated before, a hierarchical formation for a triple system is the most stable configuration that can provide a long lifespan to all relevant components. Triples that do not follow this hierarchical regimen are more likely to be unstable and even lose components due to erratic orbits. Studies conducted by Valtonen et al. (2008), using the stability condition for hierarchical stability (Eggleton & Kiseleva, 1995), showed how the energy of the system changed if a single component entered a binary formation. The role of orbital inclination in the stability of a system was studied by Georgakarakos (2013), who demonstrated how differing orbital angles can cause variations in the orbits resulting in stellar components being ejected from the system during the integration time. Approximately 8% of exoplanets fall into circumbinary orbits (P-type orbit), while 92% into S orbits. Of that 92%, 21% orbit one component of a binary pair (SB-type orbit) while 71% orbit one component (S-type orbit). Therefore, we can roughly treat 71% of exoplanets as a single system while the other 29% will be treated as a binary (depending upon circumbinary information). For the binary studies, habitability is greatly dependent upon the spectral class of the stellar components. In Table 3.2 I have listed such components for further discussion.

Using the table, we can see the first two encompass circumbinary orbits. While the spectral classes match accepted types for habitability, the presence of an M-type can hinder chances of probability. HW Virgins

P & SB Systems					
System	Comp A	Comp B	Comp C	ToS	ToO
HW Virgins	M	M	---	"2-1"	P
KOI-2939	F	G	---	"2-1"	P
Formalhaut	A3V	K4Ve	M4V	"2-1"	SB
Psi1 Draconis	FV	G0V	K/M	"2-1"	SB
HD 126614	K0	MV	M4	"2-1"	SB
HD 2638/2567	G0	G5	M1V	"1-2"	SB
HD 4113	G5V	M0	T9	"2-1"	SB

Table 3.2: P & SB Systems

contains two M-types, which are susceptible to flares and high magnetic activity that have higher chances to hinder a planet's biological production. For KOI-2939, a triple system where the binary is composed of two different spectral types, studies by Cuntz (2014b) and Moorman et al. (2018) are of benefit in understanding how the two different spectral classes cause variation in the orbit and HZ. These same papers can be applied to other cases in the table such as Formalhaut, HD 126614, Psi 1, and HD 4113. The last system contains a binary configuration in which the exoplanet is in a binary where the two stellar components are roughly the same spectral class. This is a much more stable configuration that can prevent the orbit from becoming too eccentric. In future papers we can use established HZ models to observe binary components in the triple systems and distinguish regions in which the flux would not be too little or too high for the exoplanet to thrive.

3.2 Habitability—Exobiology

Understanding the formation of Earth and the processes that allowed life to grow complexly, allows us to observe exoplanets that could be in similar circumstances around their parent stars. We now have come to understand that Earth was formed in an atypical system (see Section 2.2), but it is believed that the same conditions of habitability on Earth can be reached in other systems. While these conditions greatly minimize possible habitable exoplanets, each category helps to fine-tune the wide range of objects observed in interstellar space. Such categories include formation, physical characteristics, and neighboring space environment. Turning to the biological and chemical aspects of exoplanets, if they are to be habitable they should possess observable signatures of life that need to modify the atmosphere or surface, as well as other atmospheric components such as stellar irradiance, or atmospheric composition that determines climate and orbital flux variations (Kaltenegger, 2017). If the exoplanet is biologically active, atmospheric biosignatures should be detected (Kaltenegger, 2017). If an exoplanet does lie within the HZ and its stellar component does not damage its surface, the next step is to closely monitor its progression and see if we can detect biological activity like that on Earth.

3.2.1 Earth Habitability

Despite our best efforts, the only signs of life detected have been on Earth. But as we know, life can form in the harshest of conditions (Kashyap, 2018). During its birth, Earth was covered in incandescent pools of magma and was constantly in battle with the prolific boulders colliding with its surface—some averaging 75 times the speed of sound (Hazen, 2001). This war sterilized the planet's surface for another half billion years, and the dense iron from the oceans of magma sank, forming the metallic core of current Earth (Valley et al., 2002). Deep underground, the radioactive decay of elements produced heat at rates more than six times greater than they are today (Valley et al., 2002). At some point, within a few hundred million years of this hellish age, microscopic life crafted from air, water, and rock appeared in abundance (Hazen, 2001). There is a general understanding that the first major component of life's origin started with carbon-based molecules that could make copies of themselves, and there are numerous papers discussing the advantages of carbon over other molecules as well (Goldsmith & Owen, 2002; Von Bloh et al., 2007; Airapetian, 2017b). There have been attempts to recreate the environment of primordial Earth with only the known compounds available, such as Stanley L. Miller's famous experiment in the early 1950s. This is possibly how intricate organic compounds could have formed from simple molecules present on the surface.

Current methodologies for detecting biological activity on exoplanets arise from the presence of chemical compounds that are out of chemical equilibrium due to the complex biochemistry of life (Seager, 2013; Lovelock, 1975). Common molecules in Earth's troposphere such as molecular oxygen, ozone, water vapor, carbon dioxide, nitrous oxide, and methane should be detectable on a biologically active exoplanet (Kaltenegger et al., 2007; Berdyugina, 2016; Seager et al., 2016; Meadows et al., 2017). The ability for life to be sustained on Earth is due to several considerable factors, such as Earth forming in the HZ of its parent star, Earth developing liquid water as a solvent, and a domination of the carbonate-silicate cycle that maintains the long-term climatic stability of the planet (Von Bloh, 2007). Its continued success as a habitable planet is quite apparent, with its abundant oceans, greenhouse atmosphere, global geochemical cycles, and life itself (Kaltenegger, 2017). Although we are not able to observe Earth at different geological ages, rock records contain critical information for determining the atmospheric makeup of primordial Earth. We can also constrain the stellar irradiance on Earth as well, since we know the evolution of our Sun. It is assumed that more massive planets (i.e., Super-Earths) convect in plate tectonics similar to Earth (Valencia et al., 2006) and that biologically active planets will retain several characteristics similar to that of Earth's early atmosphere depending upon their age (Cockrell, 2002; Lyons et al., 2014; Airapetian et al., 2017; Reinhard et al., 2017b).

3.2.2 Triple-Star Systems

With this information, we can observe Earth's timeline and compare it to other exoplanets in different geological ages, which could possibly harbor life. As expected, this information is limited by the fact it derives from a system of one stellar

component, but as we calculated earlier 71% of exoplanets can be treated as a single system in their triple orbit, while 29% can be treated as a binary or higher system. Further studies are needed to complete the analysis of habitability among the systems themselves. The TSEC can be used in conjunction with previous studies to determine the state of exoplanets relative to their stellar components and their formation. Information over the exoplanets in these systems can be found in Table 3.3.

Within the triple-star systems found, there are a total of 33 exoplanets. Exoplanets can be classified as being either jovian or terrestrial. Out of the 33, approximately

Exoplanets				
Exoplanet Name	$M_\oplus$	$R_\oplus$	Temp(K)	Type
91 Aquarii Ab	1017			---
Prox Cent b	1.27			Terrestrial
Dagon Ab	953.7			---
HAT-P-8 Ab	425.98	16.45		Hot Jupiter
HD 178911Bb	2000			---
Psi1 Draconis Bb	486.4			---
WASP - 12 Ab	446.32	19.04		Gas Giant
Gliese 667 Cb	5.595			---
Gliese 667 Cc	3.8147			Terrestrial
Gliese 667 Cd	5.1			---
Gliese 667 Ce	2.702			---
Gliese 667 Cf	2.702			---
Gliese 667 Cg	0.461			---
16 Cygni Bb	534.07			---
Kelt - 4Ab	281.02	18.71		Hot Jupiter
51 Eridani b	2892.88	12.17		Jupiter-like
HAT-P-57 Ab	588.11	15.49		---
HD 126614 Ab	120.8			---
HD 132563 Bb	473.67			---
HD 196050 Ab	899.65			---
HD 2638 Bb	152.59	11.4		Hot Jupiter
HD 40979 Ab	1274.77			Gas Giant
HW Vir (AB)b	4545.95			---
Kepler 444 Ab		3.73		Terrestrial
Kepler 444 Ac		0.48		Terrestrial
Kepler 444 Ad		0.48		Terrestrial
Kepler 444 Ae		0.052		Terrestrial
Kepler 444 Af		0.66		Terrestrial
HD 4113 Ab	495.92			Gas Giant
Kepler - 13 Ab	1926.46	15.42	2750	Hot Jupiter
KOI-2939 (AB)b	483	17.54		---
HD 185269 Ab	298.82			---
HD 41004 Ab	807.46			---

Table 3.3: Exoplanets

Exoplanet Types						
Exoplanet Name	ToS	ToO	$M_\oplus$	$R_\oplus$	Temp(K)	Type
Prox Cent b	"2-1"	S	1.27			Terrestrial
HAT-P-8 Ab	"1-2"	S	425.98	16.45		Hot Jupiter
WASP - 12 Ab	"1-2"	S	446.32	19.04		Gas Giant
Gliese 667 Cc	"2-1"	S	3.8147			Terrestrial
Kelt - 4Ab	"1-2"	S	281.02	18.71		Hot Jupiter
51 Eridani b	"1-2"	S	2892.88	12.17		Jupiter-like
HD 2638 Bb	"1-2"	SB	152.59	11.4		Hot Jupiter
HD 40979 Ab	"1-2"	S	1274.77			Gas Giant
Kepler 444 Ab	"1-2"	S		3.73		Terrestrial
Kepler 444 Ac	"1-2"	S		0.48		Terrestrial
Kepler 444 Ad	"1-2"	S		0.48		Terrestrial
Kepler 444 Ae	"1-2"	S		0.052		Terrestrial
Kepler 444 Af	"1-2"	S		0.66		Terrestrial
HD 4113 Ab	"2-1"	SB	495.92			Gas Giant
Kepler - 13 Ab	"1-2"	S	1926.46	15.42	2750	Hot Jupiter

Table 3.4: Exoplanet Types

15 can accurately be placed into one physical class, with 7 being terrestrial in nature and the other 8 being jovian. Using the TSEC we can also include the types of systems these exoplanets are in (see Table 3.4).

With the exception of two systems, we can see that the majority of exoplanets are located in systems where they could be treated as a single component (classified as S under heading "ToO"). Also, it can be noted that all of the terrestrial class exoplanets lie in single systems. Therefore, for terrestrial planets, we can use conditions founded in our Solar System to make comparisons of habitability (assuming the binary component of the triple does not affect the exoplanet). Likewise, we can use information over the jovian planets in our Solar System to infer conditions of habitability of gas giants we find in S-type orbits in triples. What is peculiar is how the two exoplanets with SB-type orbits are jovian in nature. With further study some light could be shed on how gas giants are more likely to form in these types of orbits and terrestrial planets are more likely to form in stable orbits regardless of the multiplicity of the system. Binary studies on gas giants will help distinguish habitable characteristics for exoplanets that find themselves in similar circumstances.

DETECTING HABITABLE SYSTEMS

The majority of exoplanets studied are found using the transit method. As seen in Table 4.1, there have been a variety of methods used to detect exoplanets and their spectral information. This table details the various detection methods that have found planetary systems and planets as of October 14, 2017. As we can see, the main methods used are Primary Transit and Radial Velocity (exoplanet.eu).

As technology and telescopes become more sophisticated, we will be able to observe farther and more in depth. This will be vital to detect possible biosignatures through observing the spectra of exoplanets. As noted in studies by Snellan et al. (2015) and Stark et al. (2015), detecting major biosignatures from an Earth-like active planet around a Sun-like star is difficult with current telescopes and requires long exposures with high spectral, high contrast, and high spatial resolution coronographic instruments on ground-based telescopes. These elusive biosignatures can be indicative of the biological activity on the surface of an exoplanet, and they detail a plethora

Detection Methods	Systems	Planets	Multiple Planets
Radial Velocity	544	728	131
Pulsar	20	25	4
Microlensing	61	63	2
Imaging	81	88	5
Primary Transit	2059	2748	455
Astrometry	1	1	0
TTV	6	7	1
Other	13	14	1
Secondary Transit	0	0	0
TOTAL	2752	3672	616

Table 4.1: Detection of Systems nd Planets
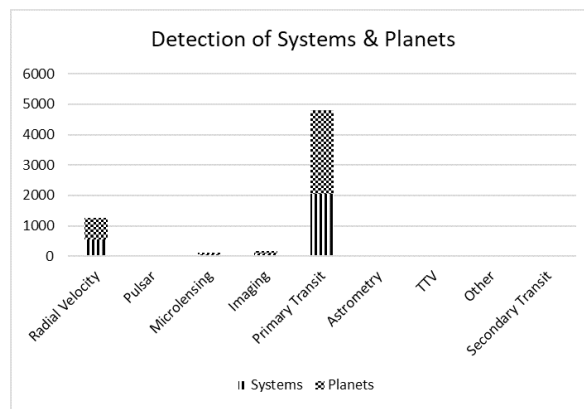
Figure 4.1: Detection of Systems nd Planets

of information including atmosphere composition, magnetic field presence, and surface activity.

4.1 Atmospheric Biosignatures

When attempting to find exoplanets or exomoons that could possible harbor life, it is a key factor to try and detect atmospheric biosignatures that modify the atmosphere or surface. The term "biosignatures" is used to represent gases that are produced by life, accumulate in the atmosphere, are not readily mimicked by abiotic processes, and can be detected by space telescopes (Kaltenegger, 2017). There are also multiple types of biosignatures one could detect, such as abiotic, biological, and technology-based (Kaltenegger, 2017). It is crucial to be able to separate these signatures and understand each one when attempting to detect them. As noted in Section 3.2.1, the first forms of life on Earth did not rely on oxygen, but on carbon dioxide (Goldsmith & Owen, 2002). Studies led by Sagan et al. (1993) studied the emergent spectra of planet Earth and detected copious amounts of oxygen and methane, which strongly suggest the presence of biology. But the mere detection of just one of these gases is not enough to conclude that it is a biosignature being observed, because an individual gas could very well be produced abiotically and build up in the atmosphere without the presence of life (Kaltenegger, 2017). In fact, oxygen alone was thought to be a tracer of life, but several teams of scientists have shown that oxygen can build up abiotically through photodissociation at the edges of or the outside of the HZ. Similar to oxygen, methane alone was also thought to be a possible tracer of life,

with approximately one-third present day methane on Earth being produced via geological activity and the rest produced via human activity (Krüger et al., 2001). Only a small amount is produced abiotically, but the amount of methane depends on the degree of oxidation of a planet's crust and upper mantle (Kaltenegger, 2017). Therefore, the detection of methane alone cannot be considered as a biosignature. However, if detected together as a pair, these two could allow for the formation of carbon dioxide and water, which are required for life to exist. Carbon dioxide and water also serve as vital greenhouse gases and could highlight possible concentrations of oxygen on the surface of the subject of study (Kaltenegger, 2017). Detecting such signs of possible life from vast interstellar distances can be quite a challenge, and if a ground-based telescope was to be used (e.g., the ELT [Extremely Large Telescope]), they would have to use high-resolution spectra and detect the possible biosignatures via doppler-shifted lines caused from observing over some prolonged period of time (Kaltenegger, 2017). Another type of biosignature that could be observed is called a technology biosignature such as CFCs (CCl_2F_2 and CCl_3F), which are not produced naturally but rather by technology on our planet. While these could be used to detect advanced civilizations, they are extremely hard to detect spectroscopically and their abundance on Earth is quite small (Kaltenegger, 2017). In regard to finding these elusive biosignatures, their effects on spectral features depends on the wavelength observing the effect. For example, on Earth the spectral features seen in reflected light (UV to NIR) is dependent on the abundance of a chemical as well as the incoming stellar radiation at that wavelength (Kaltenegger, 2017). For detecting a biosphere similar to that of our Earth, the key pairing to look for would be a combination of oxygen and methane in the visible to NIR from 0.7 to 3 µm to include the 2.4-µm CH_4 or observations in the IR between 5 and 10 µm (Kaltenegger 2017). The UV wavelength range is extremely sensitive to even the smallest of molecular abundances, making it a poor candidate for searching for biosignatures. Remote direct detection of surface life in reflected life becomes possible when organisms modify the detectable reflection of the surface (Kaltenegger, 2017). An example of this would be the vegetation of Earth. Vegetation requires photosynthesis, and this process adapts to the spectrum of light that reaches the organism. Therefore, any color from deep violet through the near-infrared could power photosynthesis (Kiang, 2008). This means around hotter and bluer stars, compared to our Sun, plants would tend to absorb blue light and could look green, yellow, or even red. Around cooler stars, such as red dwarfs, planets would receive less visible light, resulting in plants attempting to absorb as much visible light as possible and making

them look black (Kiang, 2008). Vegetation is but one of the many surface features that life produces on Earth. An experiment conducted by S. Hegde in 2015 showcased the spectral characteristics of 137 phylogenetically diverse microorganisms containing a range of pigments, including ones isolated from Earth's most extreme environments (also known as extremophiles). This experiment used an integrating sphere that mimicked the observations of an exoplanet modeled as a Lambertian sphere. This provided high-resolution hemispherical reflectance measurements for the visible and NIR spectra for a subset of life known on Earth (available at http://carlsaganinstitute.org/data) (Kaltenegger, 2017). When observing any object for potential biosignatures, it is always important to determine what stage of its life cycle the object is in. It has already been well established that Earth has undergone drastic changes during its lifetime, but throughout its evolution there have been periods in which biosignatures were more prominent or just beginning to form. At the beginning of its 4.5 billion year lifespan, the Earth received a different amount of stellar radiation than it does today. This affected not only the temperature of the planet, but also the spectrum, chemical makeup, and surface morphology over time. It was not until 2.3 billion years ago that the Earth first formed abundant amounts of oxygen and ozone, which affected the atmospheric absorption of the spectrum. This rise in oxygen made the biosignature pairing with the reduced gas methane detectable in the IR and NIR (Kaltenegger, 2017). This has resulted in Earth showcasing a strong infrared signature of ozone compared to methane for more the two billion years. Knowing this historical information of our planet, we can establish potentially habitable planets exhibiting a similar observed spectrum as that of our past Earth.

4.2 Locations for Habitability

K- and M-types combined make up approximately 90% of the observed stars in the solar neighborhood (see Table 3.1). Despite the heavy presence of M-types in triple systems, the most probable location to find a habitable planet would be around a K-type dwarf star (see Section 3.1 regarding flare activity and M-type habitability). However, there have been drawbacks to this conclusion, such as planets becoming tidally locked to the K- or M-type star owing to complicated orbital distances, or X-ray and EUV flare activity with occurrences up to 10–15 times per day (for young M dwarfs) (Cuntz & Guinan, 2016). Despite some of these drawbacks, it is entirely possible for life to find shelter on the subsurface of a planet. While this makes detection more difficult, it could be that intelligent life would take shelter from UV radiation underneath an ocean or soil layer of a planet.

There are several subjects under study for the search for life, and one such example is our closest neighboring star, Proxima Centauri. The active M5 flare star experiences intense flares every 10–30 hours, exposing the terrestrial exoplanet in its HZ Proxima Ab to 30 times more EUV than Earth and 250 times more X-ray radiation (Ribas et al., 2016). If the exoplanet does not have a strong planetary magnetic field, then its atmosphere would be thinner and therefore allow more UV radiation to affect the planet. If life was to be found on such a planet, it would show just how tenacious life can be and help confirm that life can form in harsh environments. For those exoplanets in the catalogue that orbit M-type stars, habitability would likely be reduced to the termination line. Where the tidally locked exoplanet has one side that constantly faces the star and the other side is shrouded in darkness. In between these two areas is a small sliver (i.e., the termination line) that could possibly possess the necessary conditions for liquid water to form. In future studies, data should be collected for exoplanets in S-type orbits around single stellar components of spectral class G–M. This is considered the best-case scenario for habitability in stellar triples. Once an abundant amount of information exists concerning this scenario, the next step would be to focus on collecting data for SB-type orbits in the binary of a triple.

CONCLUSION

In conclusion, research yields that all observed triple systems are hierarchical in nature, with the majority of systems taking on a "1-2" type orbit (as opposed to the original definition of "2-1"). Possible exoplanetary bodies must possess a strong magnetic field capable of withstanding far-UV and X-ray stellar emissions as much as 30–50 times and 100–500 times, respectively, higher than on Earth today during the formation process of the stellar components (for a Sun-like star). Triple systems currently have but one observed formation that provides optimal stability, and this in the form of a hierarchical triple. We can use stability equations and Solar System constraints to determine the formation process of our Solar System and relate it to other systems as well as distinguish it from others. Those systems that contain higher spectral components (A–F) are more likely to cause instability within the system due to short life spans and stronger fluxes of magnetic activity. Likewise, exoplanets orbiting M-type stars are more susceptible to tidal locking and lower chances of habitability.

Utilizing the TSEC, we can obtain expectation values of the spectral types by using data collected over observing the solar neighborhood. The primary components of stellar triples contain the highest spectral type of all three stars, with most systems losing spectral class with each following stellar component. All triples in the catalogue are constructed of a binary and a single component; however, the old "2-1" model of hierarchical triples accounts for approximately 40% of components and is replaced by a higher percentage of "1-2" orbits with approximately 60% of triples following this new hierarchy. K-type stars would provide the most productive search for habitable life, as the orange dwarfs are less prone to tidal locking and flares compared to M-types and have stellar lifetimes that would be less likely to inhibit triple stability, unlike higher spectral types such as A-, F-, and G-types. This preliminary study shows approximately 8% of exoplanets are in circumbinary orbits, while 21% are in SB-type orbits, and 71% are in S-type orbits with single stellar components. Exoplanets in single S-type orbits are mostly terrestrial in nature, and SB-type orbits observed belonged to gas giants. In future studies we can combine previous research into single and binary systems with data from the TSEC to determine which exoplanets lie within the HZ and GHZ of their parent stars. Once an exoplanet has been classified as possibly habitable, any presence of biology should be indicated by observed atmospheric biosignatures with the most likely indicator being in the form of a combination of methane and oxygen.

If future studies conclude the same calculated orbital percentages for the P-, SB-, and S-type orbits within the triple, this will accomplish several things: (1) The habitability of exoplanets in triple systems will be distinguished much quicker, as most components in triple systems would then follow a S-type orbit around a single component, much like that of our heavily researched Solar System; (2) the structure of exoplanet orbits in triples would have a foundation stating the majority should orbit only one component; (3) exoplanets would be approximately three times more likely to have an SB-type orbit compared to a P-type, and there would be a higher chance of the planet being jovian; and (4) exoplanets could orbit in only one of three configurations if the system is to maintain long-term stability. All four statements have heavy implications, but all touch on the fact more research is needed to verify such conclusions. Should these statements hold true, future studies can begin discussing more complicated aspects of habitability such as SB-type and P-type orbits around stellar components composed of two different spectral types in triple systems.

APPENDIX A

TSEC DATA: STELLAR COMPONENTS

For the following catalogue, there is a specific notation used to designate the origin of the data. Superscript A defines information that was pulled

from an exoplanet catalog that can be found at openexoplanetcatalogue.com/. Superscript B defines information that was pulled from an exoplanet catalog that can be found at http://exoplanet.eu/.

If the column has a superscript of A or B, then all information below it is from that source unless otherwise specifically noted elsewhere. Superscripts next to star names indicates the information in that row comes from a different catalogue than that which is referenced in the table headings. Data with a superscript indicates only that piece of information came from the opposing catalogue. All information pertaining to the stellar components and exoplanets is retrieved from these two catalogs. The graphs and tables throughout the paper are of my own creation based upon the data I have reconciled from the catalogs.

TSEC DATA—STELLAR COMPONENT A

Star Name	App Mag[B]	ToS[A]	ToO[A]	Distance (pc)[B]	Spectral Type[B]	$M_\odot$[B]	$R_\odot$[B]	Temp (K)[B]	Metallicity[B]	Age (Gyr)[B]
91 Aquarii A	4.21	"1-2"	S	45.9	K0III	1.4	11	4665	-0.03	3.56
Alpha Centauri A[A]	0.01	"2-1"	S	4.37	G2V	1.1	1.227	5790	0.2	
Formalhaut	1.16	"2-1"	SB	7.704	A3V	1.92	1.184	8590		0.44
HAT-P-8 A	10.17	"1-2"	S	230	F	1.28	1.58	6200	0.01	3.4
HD 178911Aa[A]		"2-1"	S		G	1.1				
Psi1 Draconis Aa[A]	4.56	"2-1"	SB	22.93	FV	1.43	1.2	6546	-0.1	2.3
WASP-12 A	11.69	"1-2"	S	427	G0	1.35	1.599	6300	0.3	1.7
Gliese 667 A		"2-1"	S							
16 Cygni A	5.96	"2-1"	S		G2V	1.11	1.243	5825	0.1	6.8
Kelt - 4A		"1-2"	S	211	F	1.204	1.61	6207	-0.116	4.38
51 Eri A	5.223	"1-2"	S	29.4	F0 V	1.75			-0.027	0.02
HAT-P-57 A	10.47	"1-2"	S	303	A	1.47	1.5	7500	-0.25	1
HD 126614 A	8.81	"2-1"	SB	72.4	K0	1.145	1.09	5585	0.56	7.2
HD 132563 Aa[A]	8.966	"2-1"	S		F8V	1.081		6168		
HD 196050 A	7.5	"1-2"	S	46.9	G3 V	1.17	1.29	5874	0.23	3.17
HD 2567A	7.76	"1-2"	SB		G0					
HD 40979 A	6.74	"1-2"	S	33.3	F8V	1.1	1.21	6205	0.194	1.48
HW Virgins A[A]	4.22	"2-1"	P	181	sdB+M	0.485	0.183			
Kepler 444 A	9	"1-2"	S		K0V	0.758	0.752	5046	-0.55	11.23
HD 4113 A	7.88	"2-1"	SB	44	G5V	0.99		5688	0.2	4.8
Kepler - 13 A	10	"1-2"	S		A	2.05	2.55	8500	-0.14	
KOI-2939 A[A]		"1-2"	P		F	1.221	1.79	6210	-0.14	4.4
HD 185269 A	6.68	"1-2"	S	47	G0IV	1.28	1.88	5980	0.11	4.2
HD 41004 A	8.65	"1-2"	S	42.5	K1V	0.7		5035	-0.09	1.64

TSEC DATA—STELLAR COMPONENT B

Star Name	App Mag[B]	ToS[A]	ToO[A]	Distance (pc)[B]	Spectral Type[B]	$M_\odot$[B]	$R_\odot$[B]	Temp (K)[B]	Metallicity[B]	Age (Gyr)[B]
91 Aquarii B	9.9	"1-2"	S		K3 V	0.78				
Alpha Centauri B[B]	1.33	"2-1"	S		K1V	0.907	0.865	5260	0.23	
TW Piscis Austrini	6.48	"2-1"	SB		K4Ve	0.73		4594		
HAT-P-8 B		"1-2"	S		M5V	0.17		3216		
HD 178911 Ab		"2-1"	S		K	0.79				
Psi1 Draconis B	5.7	"2-1"	SB		G0V	1.19		6213		2.5
WASP - 12 B		"1-2"	S		M3V	0.56		3786		
Gliese 667 B		"2-1"	S							
16 Cygni B	6.2	"2-1"	S	21.41	G2.5Vb	1.01	0.98	5766	0.08	8
KELT - 4B		"1-2"	S							
GJ 3305 A	7.7	"1-2"	S		M0	0.67				
HAT-P-57 B		"1-2"	S			0.61				
HD 126614 B		"2-1"	SB		MV	0.324				
HD 132563 Ab		"2-1"	S			0.5				
HD 196050 Ba		"1-2"	S		M3	0.29				3.55
HD 2638 B[B]	9.44	"1-2"	SB	53.71	G5	0.93		5192	0.16	3
HD 40979 B		"1-2"	S		K5	0.833				1
HW Virgins B	15.59	"2-1"	P		sdB+M	0.142	0.175			
Kepler 444 B		"1-2"	S		M	0.29		3464		
HD 4113 B	12.7	"2-1"	SB		M0	0.55		3833		5
Kepler - 13 B	10.2	"1-2"	S		A	1.68	1.68	7530	0.2	0.5
KOI-2939 B		"1-2"	P		G	0.968	0.966	5770		4.4
HD 185269 Ba		"1-2"	S			0.17				
HD 41004 Ba	12.33	"1-2"	S		M2	0.4				

TSEC DATA—STELLAR COMPONENT C

Star Name	App Mag[B]	ToS[A]	ToO[A]	Distance (pc)[B]	Spectral Type[B]	$M_\odot$[B]	$R_\odot$[B]	Temp (K)[B]	Metallicity[B]	Age (Gyr)[B]
91 Aquarii C	10.1	"1-2"	S		K	0.73				
Alpha Centauri C[B]	11.3	"2-1"	S	1.295	M5.5	0.12	0.141	3050		
LP 876-10		"2-1"	SB		M4V	0.18		3132		
HAT-P-8C		"1-2"	S		M6V	0.131		3058		
HD 178911 BB	7.98	"2-1"	S	46.73	G	1.07	1.14	5650	0.28	5.2
Psi1 Draconis Ab		"2-1"	SB		K/M	0.526				
WASP - 12 C		"1-2"	S		M3V	0.54		3748		
Gliese 667 C	10.22	"2-1"	S	6.84	M1.5	0.33		3600	-0.55	2
16 Cygni C	13	"2-1"	S		M	0.17				
KELT - 4 C		"1-2"	S							
GJ 3305 B	10.9	"1-2"	S		M0	0.44				
HAT-P-57 C		"1-2"	S			0.53				
NLTT 37349		"2-1"	SB		M4	0.16				
HD 132563 B[B]	9.47	"2-1"	S	96	G	1.01		5985		5
HD 196050 Bb		"1-2"	S		M3.5	0.19				3.55
HD 2638 C		"1-2"	SB		M1V	0.46				
HD 40979 C		"1-2"	S			0.38				1
HW Virgins C		"2-1"	P			0.0186				
Kepler 444 C		"1-2"	S		M	0.25				
HD 4113 C		"2-1"	SB		T9	0.063	0.144	500		
Kepler - 13 C		"1-2"	S			0.57		4700		
KOI-2939 C		"1-2"	P							
HD 185269 Bb		"1-2"	S			0.154				
HD 41004 Bb		"1-2"	S			0.0181				

APPENDIX B

EQUATIONS

Where mj and aj are the mass of the semi-major axis of each planet j, N is the number of planets in the system, and ej and ij are the orbital eccentricity and inclination of each planet j (Laskar, 1997; Chambers, 2001).

$$AMD = \frac{\sum_{j=1}^{N}\left[m_j\sqrt{a_j}\left(1-\cos i_j\sqrt{1-e_j^2}\right)\right]}{\sum_{j=1}^{N} m_j\sqrt{a_j}} \quad RMC = \left(\frac{\sum_{j=1}^{N}[m_j]}{\sum_{j=1}^{N} m_j\left[\left[log_{10}\left(\frac{a}{a_j}\right)\right]^2\right]}\right)$$

$$\left.\frac{a_{out}}{a_{in}}\right|_{crit} = \frac{2.8}{1-e_{out}}\left(1 - \frac{0.3i}{\pi}\right) \times \left(\frac{(1.0+ q_{out})\times(1+ e_{out})}{\sqrt{1-e_{out}}}\right)^{\frac{2}{5}},$$

where instability is defined as $\left.\frac{a_{out}}{a_{in}}\right| < \left.\frac{a_{out}}{a_{in}}\right|_{crit}$ and $q_{out} \equiv \frac{m_3}{m_1+m_2}$

Mardling and Aarseth (1999).

APPENDIX C

TSEC DATA: EXOPLANETS

Exoplanet Name	System	ToS[A]	ToO[A]	Dp(AU)[B]	$M_{\oplus}$	$R_{\oplus}$	Temp (K)[B]	Type[A]
91 Aquarii Ab	91 Aquarii	"1-2"	S	0.7	1017			---
Prox Cent b	Alpha Centauri	"2-1"	S	0.0485	1.27			Terrestrial
Dagon Ab	Fomalhaut	"2-1"	SB	115	953.7			---
HAT-P-8 Ab	HAT-P-8	"1-2"	S		425.98	16.45		Hot Jupiter
HD 178911Bb	HD 178911	"2-1"	S	0.32	2000			---
Psi1 Draconis Bb	Psi1 Draconis	"2-1"	SB	4.43A	486.4A			---
WASP - 12 Ab	WASP-12	"1-2"	S	0.02293	446.32	19.04		Gas Giant
Gliese 667 Cb	Gliese 667	"2-1"	S	0.0505	5.595			---
Gliese 667 Cc	Gliese 667	"2-1"	S	0.125	3.8147			Terrestrial
Gliese 667 Cd	Gliese 667	"2-1"	S	0.276	5.1			---
Gliese 667 Ce	Gliese 667	"2-1"	S	0.213	2.702			---
Gliese 667 Cf	Gliese 667	"2-1"	S	0.156	2.702			---
Gliese 667 Cg	Gliese 667	"2-1"	S	0.549	0.461			---
16 Cygni Bb	16 Cygni	"2-1"	S	1.68	534.07			---
Kelt - 4Ab	KELT - 4	"1-2"	S	0.04321	281.02	18.71		Hot Jupiter
51 Eridani b	51 Eri	"1-2"	S	14	2892.88	12.17		Jupiter-like
HAT-P-57 Ab	HAT-P-57	"1-2"	S	0.406	588.11	15.49		---
HD 126614 Ab	HD 126614	"2-1"	SB	2.35	120.8			---
HD 132563 Bb	HD 132563	"2-1"	S	2.62	473.67			---
HD 196050 Ab	HD 196050	"1-2"	S	2.47	899.65			---
HD 2638 Bb	HD 2638	"1-2"	SB	0.044	152.59	11.4		Hot Jupiter
HD 40979 Ab	HD 40979	"1-2"	S	0.846	1274.77			Gas Giant
HW Vir (AB)b	HW Virgins	"2-1"	P	4.69A	4545.95A			---
Kepler 444 Ab	Kepler 444	"1-2"	S	0.04178		3.73		Terrestrial
Kepler 444 Ac	Kepler 444	"1-2"	S	0.04881		0.48		Terrestrial
Kepler 444 Ad	Kepler 444	"1-2"	S	0.06		0.48		Terrestrial
Kepler 444 Ae	Kepler 444	"1-2"	S	0.0696		0.052		Terrestrial
Kepler 444 Af	Kepler 444	"1-2"	S	0.0811		0.66		Terrestrial
HD 4113 Ab	HD 4113	"2-1"	SB	1.28	495.92			Gas Giant
Kepler - 13 Ab	Kepler - 13	"1-2"	S		1926.46	15.42	2750	Hot Jupiter
KOI-2939 (AB)b	KOI-2939	"1-2"	P	2.72	483	17.54		---
HD 185269 Ab	HD 185269	"1-2"	S	0.077	298.82			---
HD 41004 Ab	HD 41004	"1-2"	S	1.64	807.46			---

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A CITY WITHOUT A CENTER:
HOW THE KESSLER PLAN CAUSED DALLAS TO LACK
A CENTRAL IDENTITY

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ABSTRACT

How a city is planned and developed impacts how people can connect with that place. Dallas is a city that has struggled with identity since its founding; it does not fit the typical "rules" that a successful city plan follows. In this study I argue that the roots of this problem lie in Dallas' first city plan, designed by George Kessler. Kessler, a Kansas City based landscape architect and planner, developed his own standards of city planning based on ideas popular from 1890 to 1920 and worked from a standard idealized city prototype. Through a close reading of the Kessler plan for Dallas, site visits, and visual analysis of maps, plans, and photographs, I analyze Dallas' urban form relative to Kessler's ideal plan and his vision for Kansas City. Rather than arguing that it is a successful or unsuccessful city because it does not fit accepted ideas about good city form, these comparisons allow us to understand the origins of Dallas' identity struggle in context. The alterations he made to this prototype—including subtraction, shifts in scale, and insufficient mediation—allowed Dallas to fall victim to urban sprawl and lack a clear identity.

The way a city is designed creates a link between the people in that city and the overall context. A good city is hard to define, and while there have been checklists made by noted architectural writers and theorists, such as Kevin Lynch,[1] diagrams made by architect Kevin Bacon,[2] or even main points discussed in Vitruvius' Ten Books of Architecture,[3] there is no consensus about the perfect list of what makes a successful city. These lists establish a prototype of an ideal city, and cities that don't fit into this ideal are considered bad examples of urbanism. One of the most common examples of these cities is Los Angeles, which breaks every normal rule. According to most, Los Angeles is an urban disaster, but looking through a different lens, it is its own ecology.[4] Dallas, according to urban historian Harvey Graff in his extended analysis in The Dallas Myth, is an example of a city that does not work. He states that Dallas is a "city with no history" and that the way Dallas has been planned has perpetuated the idea that it is an unsuccessful city.[5] He is correct to an extent. Dallas does not fit into the ideal described by Bacon or the concept of imageability set by Lynch. It does not employ Jane Jacobs' style of effective building or demonstrate more recent ideas of ecological urbanism.[6] This, however, does not mean that Dallas is inherently a "bad" city. To truly analyze Dallas as it relates to the ideas of urbanism, the discourse surrounding what a successful city is at the time Dallas was designed will be discussed. George Kessler, the landscape architect who created the initial plan for Dallas, developed his own city prototype.[7] He took ideal city characteristics from popular ideas about urbanism at the time, and

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1. Lynch, The Image of the City.
2. Bacon, Design of Cities.
3. Vitruvius and Morgan, Vitruvius: The Ten Books on Architecture.
4. Banham, Los Angeles: The Architecture of Four Ecologies.

5. Graff, The Dallas Myth: The Making and Unmaking of an American City.
6. Jacobs, The Death and Life of Great American Cities.
7. Kessler, City Plan for Dallas.

then altered the prototype to fit certain cities, such as El Paso and Kansas City. From that, Kessler's prototype will be examined by comparing Kansas City and Dallas. Lastly, Dallas will be analyzed using the discourse from today to map how Kessler's choices in the design have changed and how the city relates to other large cities in an urban way. Contrary to what Graff believed, the choices Kessler made for Dallas were not all bad, and most were positive at the time. As the city continued to grow, however, and ideas about urbanism changed, his ideas remained prevalent in the city, holding it back from growing into a more urban environment. He used subtraction, shifts in scale, and insufficient mediation to create the city plan for Dallas, which grew to be problematic, causing the city to struggle with identity and become the city without a center that it is today.

METHODOLOGY

The project analyzes primary sources and compares secondary sources with my own conclusions. First, Kessler's prototype will be determined, and then compiling site visits with urban discourse will help me analyze Dallas. Research will involve examination of visual data, such as maps or city plans, as well as first-person experiences in those environments.

2.1 Close Reading

Kessler submitted a proposal to the parks board of Dallas for a city plan first in 1910 and subsequently in 1920. Throughout my research I will be using it as a primary source, gathering my own information and analyzing the visuals within it. The idea is to view Dallas through its own lens instead of through another more contemporary one in terms of success. Kessler's ideal city will be found through a review of the Kessler plan and images in both the Dallas and Kansas City plans. Common themes in both will lead to the composited prototype that Kessler created. I will be looking at how his ideal is altered within Dallas through the choices that he implemented in the plan and how those ideas evolved over time into problems that Dallas faces today.

2.2 Site Visits

It would be extremely difficult to discuss how a city functions without visiting that city. While on paper a city could be planned perfectly, how citizens interact with that city every day could prove challenging. As a result, my analysis of Kessler's plans also relied on visiting Dallas and Kansas City to compare the two at first hand. In Dallas, Turtle Creek Parkway and Kessler Park were key sites; in Kansas City, North Terrace Park and Penn Valley Park were most important. Pairing my previous knowledge of plans and visuals and experiencing the city three dimensionally allowed me think more deeply about Kessler's ideal.

DISCOURSE

The discourse around urbanism has changed since Kessler designed the 1910 original city plan. To understand why Dallas has become so problematic, it is important to look at both the past and present discourse surrounding the topic.

3.1 Urbanism in 1900–1920

In the early 1900s the idea of urbanism was still heavily impacted by the industrial revolution. Cities were concerned with how to incorporate cars into the urban fabric, and mostly focused on how roads should be inserted or formed within the city. The City Beautiful was also important during this time, as planners tried to combat the "paralyzing combination of stresses: the high tide of immigration… coincided with the burst of new technologies."[8]

3.1.1 An Ideal City   Up until 1920, there were certain ideas circulating about how to form the ideal city. With the urban population explosion, many planners were seeking a way to maximize the uses of infrastructure. There was also a desire to keep the rural feel that is so heavily associated with 19th century America. The City Beautiful movement was popular through the 1910s because of this desire to pair nature with the city. It was an "attempt to refashion cities into beautiful, functional entities."[9] Essentially, citizens and city board members desired their cities to be functional and aesthetically appealing to promote more balance in the daily lives of citizens. The problem is that many City Beautiful actions also happened on the level of city infrastructure. It was not on a human level; rather, it focused on roads and large-scale landscape architecture. There was a focus "on creating grand public spaces: civic centers, boulevards, and parkways,"[10] all of which

8. Fishman, "American Planning Tradition," 1-29.
9. Wilson, The City Beautiful Movement.
10. Fishman, "American Planning Tradition, 1-29.

were too large to really connect with the individual.

Elbert Peets, an influential architect and educator, published American Vitruvius in 1922, the culmination of his decades of work teaching. In this handbook and textbook he focused on the relationship between built and unbuilt space in cities. While he was discussing patterns in Europe, it was also clear how these lessons could apply to the United States. He discussed how streets could potentially align with the rest of the city grid and how they would allow for public space to form afterwards.[11] While not necessarily an advocate for green space being incorporated into the city plan, he was focused on urban density and the city becoming less populated as the distance from the center increased.

These models of the ideal city discuss the idea of public space without showing how it would connect with the pedestrian. It was assumed that public space would function inherently as an area the community would flock to. They each neglect, however, to plan the city on a human scale. Everything is discussed in terms of streets or intersections, making it evident that vehicles were the biggest priority; public space is mentioned, but the individual is not. The city becomes about outside appearances and ease of use rather than the citizens having a connection to the place. Although it would be aesthetically pleasing or have a positive impact on the quality of the city, public space should be discussed in its relationship to those who use it rather than how it fits into the larger plan.

3.2 Urbanism in 1950-1970

Critiquing the large-scale, solely functional design that happened after the City Beautiful movement, architectural theorists in the 1950s desired more of a purpose in the city. The dialogue had shifted to favor the individual. In the 1930s-1950s cities "combined a poorly understood caricature of modern design with a top-down authoritarianism" which became known as "urban renewal."[12] Afterwards, the foundations of contemporary ideas were laid in the latter half of the 20th century, and over a period of about 30 years those ideas grew together into the form of urbanism that is common today. Cities have been studied in terms of their local character and how successfully they have been planned. In addition to checklists that have been made to discuss how cities should be laid out and interact with their surroundings, a sense of place is introduced as making a city successful.

3.2.1 The Identity of a City   Kevin Lynch is one person who has made a perfect city checklist. He focuses on the idea of imageability in a city and on that city having a certain identity. How successful a city is can be determined by "studying [the] mental image of that city which is held by its citizens."[13] The five points that are supposed to make up imageability are paths, edges, districts, nodes, and landmarks. These highlight the sense of place that one feels within a city. While one could theoretically look at a map to find each of these points, he walked through cities and asked residents questions about how he could get to different places. This idea of walkability highlights the shift in scale. His ideas were focused on the individual person and navigability of the cities, which is a very important aspect of contemporary urbanism.

Edmund Bacon is another architect whose ideas are still largely followed today. He focuses on connecting spaces throughout the city, and using armatures to link the city.[14] While he does not expressly mention Lynch's idea of imageability, Bacon does look at different ways of diagramming a city. Those that are most easily diagrammed do contain aspects similar to Lynch's research. Public space is often used in the diagrams as a way to find anchor points along the armature, but it is large-scale.

Jane Jacobs, author of several books including The Death and Life of Great American Cities (1992), was equally as influential during this time. She fought against urban renewal, knowing that such developments were destroying urban environments.[15] She "provided what urban planning needed most in an era of decentralization...she provided a justification for the city."[16] Jacobs allowed certain key points to show which areas are urban centers. She suggested a mix of old and new buildings, a sense of enclosure on the street, and consideration of how different neighborhoods interact in dense environments.[17]

All three of these ideal city models look at public space on a more accessible scale. They look at how people are expected to fit into these spaces and are altered depending on how people interact with the city plan. The problem is, however, that they still attempt to come up with a blanket "fix" for cities; they imply that if cities have a certain percentage of these ideas in the plan, they will automatically be successful. A city should not be categorized by success or failure based on external factors. It is safe to say that Dallas does not adhere to Kevin Lynch's ideas of imageability, nor

11. Peets and Hedgemann, The American Vitruvius.
12. Fishman, "American Planning Tradition, 1-29.
13. Lynch, The Image of the City.
14. Bacon, Design of Cities.
15. Jacobs, The Death and Life of Great American Cities.

16. Fishman, "American Planning Tradition," 1-29.
17. Jacobs, The Death and Life of Great American Cities.

can it be easily mapped through connective city tissue like in Bacon's ideal, but this does not mean that it is unsuccessful. To reasonably analyze Dallas, it must be compared to the internal factor of its own plan. Kessler had his own prototype, which was a compilation of the ideas of the early 1900s. Dallas will be compared to this prototype and the intent behind it, as well as to Kansas City, which used the same prototype.

3.3 Urbanism in 2000-2020

One hundred years after the original city plan for Dallas, urbanism has cycled back to some similar ideas that were present in the early 20th century. Infrastructure is being investigated as a way to bring more than one service to residents. Walkability is a common buzzword in the discussion of successful urban centers, along with sustainability and mixed-use.

3.3.1 An Evolving City   Our ideas about the values and physical forms implemented in the ideal city continue to change. Mohsen Mostafavi's "Why Ecological Urbanism? Why now?" (2010) emphasizes "the interrelationship of organisms and the environment,"[18] built or otherwise, and how this process can adapt or evolve over time to function as its own ecology, which challenges the earlier prototypes established in the 20th century. Although normally applied to natural environments, there is an argument that cities should develop naturally. Rather than be superficial or thought of as the built environment—imposing and taxing on nature—cities should work in the context they have developed. Each should have different challenges associated with the site and be designed as a cohesive environment containing site, citizens, and infrastructure.

3.4 Urbanism in Dallas

Dallas was originally designed by George Kessler. Although it started in 1841, it was not formally planned until the 1910s. Kessler designed many cities. Dallas, El Paso, Kansas City and Denver are among the cities on this list. Being a landscape architect allowed him to see both the big picture and small picture when planning an urban environment. Some ideas are present in multiple cities, and these ideas seem to be the basis of his ideal. To fully analyze this concept, the ideal will be discussed in general. How it is employed in Dallas will be contrasted with how it is employed in Kansas City.

3.4.1 The Kessler Ideal   In any Kessler plan, bands of density around the city can be seen. The rings closest the center form the inner core of the city. The inner core increases in density as time goes on. Kessler knew that cities continue to expand, so he built space into the plan to accommodate expansion. In Figure
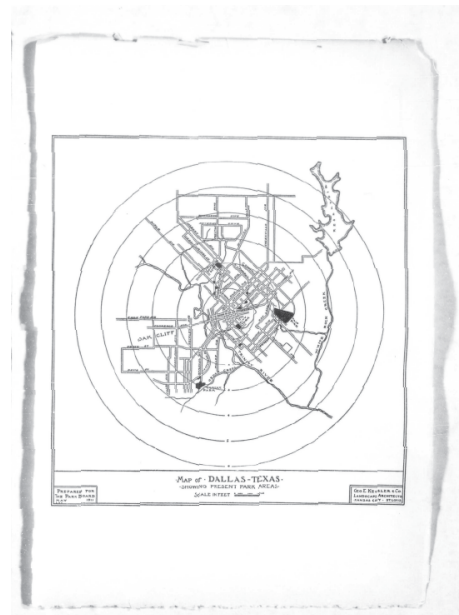
Figure. 3.1: Present Parks Map of Dallas (Source: Kessler[19])

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18. Mostafavi, "Why Ecological Urbanism? Why Now?," 12–51.
19. Kessler, A City Plan for Dallas.

3.1, the rings surrounding the city are diagrammed. From the center of the radial pattern, Dallas is positioned so that the downtown area is central.

Large boulevards for efficient connections are the second point in Kessler's plans. He designed several maps for parks and streets for the cities. Each one contained proposals for street widening and street extensions. This can be linked back to Peets' highlighting the formation of logical branches off a plaza as well as to the grandeur of boulevards in the City Beautiful movement. He wanted to avoid awkward connections of streets, so he altered the function of the typical old plaza into the new, larger intersection.

Nature spanning out from the city center was also present in his plans. This is most likely from the City Beautiful Movement.[20] Having nature radiating outwards through parkways or planned landscaping not only helps connect the rings of density, but also highlights the importance of the center core, as seemingly the origin of each branch. Many of the cities Kessler designed were situated near rivers or creeks, and this use of nature also helped facilitate the difference between urban and rural fabric.

3.4.2 An Adapted City The Kessler plan may have worked well at the time of implementation, but as the city progressed, it caused problems for the city.[21] The ideas that are circulating about urbanism today are not aligned with the ideas Kessler had when forming his plan for Dallas. Several terms that are associated with urbanism today are: walkability, mixed-use, and sustainability. Each point almost counters the initial ideas Kessler had when designing Dallas. He designed to help the city grow, since it was relatively small when the city plan was put in place.[22] Planning for growth, however, becomes difficult when the patterns of that growth are unable to adapt over the time that it spans. In other words, while Kessler may have been successful for a short period of time, the ideas that Dallas needed space to expand, that districts should not intersect with each other, and that industry would be a major contributor to the growth of Dallas moving forward were not suitable as a long-term city plan.

One of the first ideas Kessler incorporated into his plan was that Dallas needed space to expand. Originally, it was a small settlement, but Kessler saw the area develop rapidly and realized that if the city were to become successful, space needed to be built into the city plan. Kessler employed this idea mainly

by "redesigning an existing city."[23] He did not want to redo everything that had been built, but by redesigning things like roadways and major arterials, he could add space to the city. Additionally, he could connect outlying areas to the city, which would leave open space to develop later. Urban design was just starting to focus on the automobile and the City Beautiful movement. At the inception of the design, the city did not need to be walkable. Today, however, walkability is a major factor in deciding how successful a city is. The problem is, when sprawl is essentially built into a city, that model is difficult to change. Once Dallas started expanding, it continued to expand. While the city may have densified slightly, there was no way it could become dense enough to be inherently walkable after the traffic patterns were introduced to the area. It becomes almost impossible to take away something once it is introduced to an area.

The second main theme in Kessler's plan was that districts should not intersect with one another. He stated multiple times that the business district should not leach into the residential district, that the district involving industry should be placed so that it does not intrude on others, and that rails or thoroughfares can be established or extended to assure that districts will not get mixed up.[24] Having the use separated for each district created specific zones, and it was difficult to try to fit mixed-use neighborhoods together. Within his plan were residential districts, manufacturing districts, and business districts. Kessler did not foresee any future need to break away from this model; there would be no need to build new infrastructure to meet the needs of one area if it was already existing in another. In fact, instilling this form of separation between the districts made breaking down those divisions very hard. One of the tenets of urbanism today, however, is the idea of mixed-use areas. It is important for people to live, work, and spend leisure time all in one area. This allows for connections between neighbors, puts more people on the street, and promotes the feelings of a community.[25]

The third point in Kessler's plan is not as clear. Through his design choices, however, it is clear he assumed industry to be the most important district to establish. He felt industry would help Dallas develop further in the future. He proposed moving the Trinity River and dredging the bottom so that the depth would be suitable for cargo ships. He wanted to set up rail lines that would interact with these ships at levees. He wanted certain manufacturing districts to be placed

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20. Wilson, The City Beautiful Movement.
21. Kessler, A City Plan for Dallas.
22. Kessler, A City Plan for Dallas.
23. Fairbanks, For the City as a Whole.
24. Head, The Kessler City Plan.

25. Kessler, A City Plan for Dallas.

in the right areas so that they would have access to the new Trinity Canal. These choices placed industry at the forefront of development in Dallas. Again, this presents a problem when viewed from the third point in urbanism today, sustainability. Cities do not necessarily have to be green, but they should be able to function with their surroundings more easily. They can exist and act in a multifaceted way to help both residents and be more of an environmentally friendly system.[26]

To compare Dallas and another plan that was based on Kessler's prototype, Kansas City will be studied. In Kansas City, the park board had specific goals they wanted Kessler to achieve. One goal was to keep the natural topography as much as possible; they did not want to flatten the city out. The other goal was to focus on creating density in the inner core of the city before proceeding to the outer rings. These two goals affected two of the points in a Kessler prototype city. Obviously, the rings of density would be skewed. Rather than leaving space to expand gradually, Kessler was instructed to assume that the inner core would be developed as much as possible before the city was to spread. This resulted in a more compact city center. The city viewed expansion as something that would happen after a center was fully established, and this resulted in the city having a unique sense of place and identity. The surrounding city was aware of the inner core's role

in the system, rather than each inner and outer core being relatively equal at the beginning. In Figure 3.2, the density of Kansas City's center is very evident compared to the smaller houses to the east. City blocks are close together and dark, with a clear grid in between them.

The other point is the large boulevards that could not be as present in the plan. Because of the topography and the city's desire for it to remain mostly natural, it was difficult for Kessler to expand the street sizes as in his other plans. Rather than having one main street that dominates the grid, the grid becomes more even and balanced. There are streets that work together to form urban spaces rather than the street being used as a means of efficiency to get somewhere else. The prototype is effective in Kansas City because it was slightly altered to meet the needs of the place. The city had goals in mind, which resulted in the plan for the new city forming around its identity. In Dallas, the prototype was not as effective.

ANALYSIS

In Dallas, Kessler was not given any set guidelines. There were challenges presented by the Trinity River, but the city did not have a list of set expectations. As a result of this, Kessler did not have a framework to

Figure. 3.2: Figure Ground Map of Kansas City (Source: Samantha Oliphint)

26. Jacobs, *The Death and Life of Great American Cities.*

fit with his prototype. Instead, he used subtraction, shifts in scale, and insufficient mediation to create the city plan for Dallas. This, rather than becoming an adaption of his original prototype, effectively changed the ideal. Dallas struggled to find an identity and hence became a city without a center.

4.1 Subtraction

Subtraction, or rather the lack of addition, can be seen in Dallas today. There is not a planned, cohesive city center. When designing the plan for Dallas, several people disputed over the inner core. There were different city grids and the downtown area was not one urban fabric. In Kessler's ideal, he employed rings of density around a core, but rather than attempting to unify the core, Kessler chose to focus primarily on the outer rings of the city. Essentially the core was left alone except for superficial alterations. Some street extensions or widenings were planned, as well as certain interior parks, but there was not a focus on this part of the city. This choice to focus on the exterior portion of the ideal rather than the interior is one of the main reasons Dallas is struggling today. Kessler made the city plan for Dallas with certain gaps so that the city could have space to expand, but when the city expanded with no real path or intent—especially in the urban core—it became difficult to address issues of sprawl.

Some could say that leaving the original city core was a good, conscious decision and that it should have given Dallas an even stronger sense of identity. While this could have happened, the choices Kessler made to expand the areas outside of the city caused decentralization of the core. This made the identity within the city even weaker. When people left the city center to move toward the outer zones, the originality of the core began to vanish. It allowed newer companies to move in and newer buildings to become the focus. In Figure 4.1, the center of the city is difficult to distinguish because the density in the surrounding areas is almost as high. The only differentiation is the stark difference of grids. Had Kessler chosen not to subtract the center of his prototype, the city would appear much more cohesive because he would have been designing with the city, not around it. Again, this is not inherently negative; growth of a city center over time is positive, and it would make sense to have density spreading to the surrounding areas. When it happens rapidly, however, and with no clear goal or framework around the city center, it causes the surrounding areas to struggle with finding identity as well.

4.2 Shifts in Scale

The choices Kessler made also caused a huge, premature shift in scale of the city center. Dallas was

Figure. 4.1: Figure Ground Map of Dallas (Source: Samantha Oliphint)

extremely small compared to other cities that were undergoing planning to this extent. Because of this, the city was not as prepared for the results of the choices Kessler made; it was too small to carry out the planning decisions successfully. One of the main things that was implemented from the plan was to connect Dallas to the Oak Cliff area. To do this, Kessler expanded the outer rings of density that were common in his prototype. This pushed the older core into the position of a metropolitan center. While it was a smaller metropolitan area than DFW is today, for the time it was still the beginnings of a collection of several towns. The city had not grown organically to this point, so it was difficult to make it a clear center. In other words, Kessler took a city center that needed more planning and placed it in the center of an even larger city. There was no clear identity or purpose behind Dallas becoming the center of the area at this stage in its development. Most of the time, it would make sense to plan the city center and develop the outer rings naturally over time, but Kessler did the opposite. As a result, Dallas today does not have a center or its own identity. The identity of Dallas is formed by the cities around it rather than by the internal dynamic of its downtown. Figure 4.2 shows the overview of Kessler's plan for Dallas. The downtown area is just east of the river. In the plan it is much more centrally located than it would be if Oak Cliff were not incorporated into the plan.

Another example of this shift in scale involves the roadways Kessler proposed. Most noted is one that would span 200 feet.[28] Though it was not implemented, the proposed roadway is emblematic of how Kessler took a developing area and gave it the treatment of the huge urban centers on the East Coast.[29] Each aspect of the city that he magnified placed Dallas further and further into a realm of urbanity that it was not ready for.

4.3 Insufficient Mediation

The last problem with Kessler's plan for Dallas was that it did not mediate the connections between the inner and outer rings of the city. In the inner core of the city, Kessler proposed street connections and extensions. He did the same in the outer core, but the only way he connected the two was by using major thoroughfares. In some ways, this was similar to the City Beautiful ideas at the time: creating grand boulevards. As Kessler was planning Dallas with some of these ideas, however, he did not place as much emphasis on the smaller connections. The insufficient smaller connections between the Dallas city center and the outlying sprawl caused more people to use the efficient thoroughfares. This in turn led to more traffic and more need for the highways that disrupt connections in Dallas today. Not only are the interior and exterior rings not sufficiently connected, but the smaller level of connections within the city is also lacking.

Figure. 4.2: General Plan for the City of Dallas (Source: Kessler[27])

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27. Mostafavi, "Why Ecological Urbanism? Why Now?"
28. Kessler, A City Plan for Dallas.
29. Kessler, A City Plan for Dallas.

Kessler desired zones within the city that did not overlap, but he did not do anything other than extend roads to link sections. As a result of these poor connections, Dallas is a fragmented example of urbanity.[30] Figure 4.3 shows the proposed street extensions; compared to the untouched streets, he did not propose that many connections. He attempted to stitch together the parts of Dallas that had developed separately, but he did so by using roads, completely forgetting that the feeling of the spaces would remain unchanged.

4.4 Implementation

The ideas that informed Kessler's original plan continued to affect Dallas even though not all of them were implemented. Turtle Creek Parkway and Kessler Park were big pieces in his plan that were carried out. Additionally, some street extension proposals in the core were carried out by 1928.[32] Even though so little of the original plan was implemented, the positioning of the pieces that were actualized still had the intended effects on the city. Both the parkway and the park bring nature to the plan, which is positive. They also, however, are located outside the city center. This makes it clear that he promoted the idea of growth outwards. There was no incentive for the city to grow within the downtown area, because it still was not functional. As a result, expanding into the outer rings of the plan

occurred and urban sprawl became an issue. Figure 4.4 shows Turtle Creek Parkway and Kessler park moving outwards from the inner core. Little to no green space was added to the existing parks in the city center.

The street connections succeeded in making it easier for cars to access the city. This was positive for the time period in which Dallas was growing, but it soon led to an abundance of cars in the city and a need for even more roadways. None of Kessler's ideas were negative in the time period they were proposed. The problem with the Kessler plan was that after the initial plan was carried out, it did not leave much room for continual redesign. Kessler was specific that he did not want to "build a new city, but to rebuild an existing city."[33] He realized that starting from scratch was not a viable option, and at the time the plan was established, the city was small enough that he could in a sense redesign it. As the city kept growing, however, redesign became increasingly difficult. Leaving space for the city only worked for so long until the issue of urban sprawl came into play. While each district was expanding they remained separate, and these separations led to the city being difficult to navigate. Although industry was important to the growth of Dallas, rail lines soon turned into roadways. Roadways turned into highways surrounding Dallas, which then became dividers of the city and are largely out of scale in the center of an urban environment.
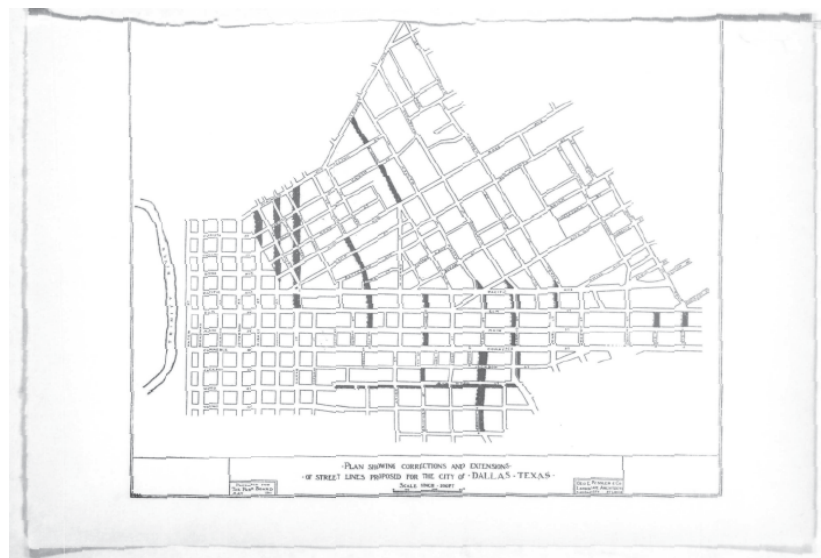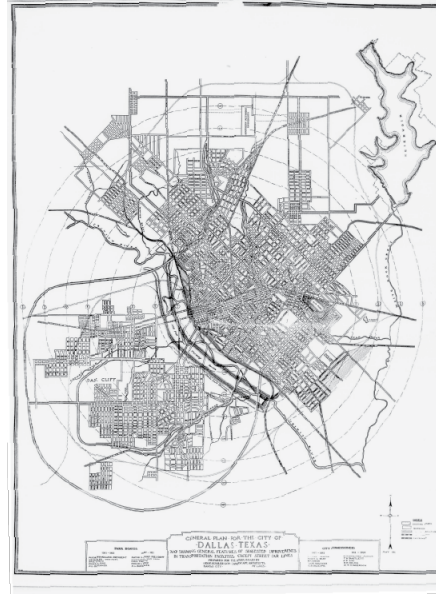

Figure. 4.3: Planned Street Connections and Extensions (Source: Kessler[31])

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30. Fairbanks, For the City as a Whole.
31. Graff, The Dallas Myth.
32. Kessler, A City Plan for Dallas.
33. Head, The Kessler City Plan for Dallas.

Figure. 4.4: Map of Parks and Boulevards (Source: Kessler[34])

CONCLUSION

Dallas should not be classified as successful or unsuccessful. It does not conform to urban ideas through the 1910s, 1960s, or the early 2000s. To analyze Dallas, one needs to look at the original prototype used to design the city. The city, however, has been so far altered from Kessler's ideal that his intent has not materialized. Rather, the city is a collection of vague ideas and notions distant from the prototype. The intent behind Dallas shifted from something meant to make a city functioning and beautiful to something that was just meant to connect portions of the existing city together. The original Kessler Plan for Dallas was a superficial addition that did not connect with the original identity of the city. As a result, the city's identity is made up by its location at the center of other cities rather than being the original point of urban growth. The subtraction, shifting scales, and lack of sufficient connectivity in the Kessler Plan caused Dallas to grow into an amalgamation of areas rather than a city with a central urban fabric.

Graff was not correct in his assumption that Dallas was automatically an unsuccessful city.[35] Compared to its own prototype, it is true that Dallas is unsuccessful in carrying out the original intent of Kessler's ideal. In terms of recent ideas of urbanism, however, a city is an ecology. It can continuously adapt and be altered. This exercise is important in studying how urban planning can affect a place over time. Even though not that much of Kessler's plan was implemented, the intent can be read clearly through how the early city developed. Cities are not good or bad, but they should relate to and interact with the people who live there. Because they chose not to contribute input when Kessler was designing the plan, the citizens of Dallas were not able to find a sense of place or connect with their history once the plan was adopted. Rather than reestablishing this connection after the plan was completed, the city remains lost almost one hundred years later because of the choices Kessler made. Now that ecological urbanism has been introduced into the discourse, Dallas has a huge amount of potential. Since ecological urbanism is similar to the City Beautiful movement in terms of infrastructure and the desire to provide multifaceted services to the public, the missing points of Kessler's prototype could finally be implemented. With a few tweaks to include urban ideas and link the two models, a cohesive city that relates to Dallas' history could finally be designed. The moment in urbanism today is an amazing opportunity to link the past with the present and create a definite identity in Dallas.

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34. Fairbanks, For the City as a Whole.
35. Graff, The Dallas Myth.

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