University of Arkansas, Fayetteville ScholarWorks@UARK

Theses and Dissertations

7-2020

Visualizing Interdisciplinary Collaborations within Exercise Science: A Pilot Study

Elizabeth Bjornsen University of Arkansas, Fayetteville

Follow this and additional works at: https://scholarworks.uark.edu/etd

Part of the Curriculum and Instruction Commons, Exercise Science Commons, and the Higher Education Commons

Citation

Bjornsen, E. (2020). Visualizing Interdisciplinary Collaborations within Exercise Science: A Pilot Study. *Theses and Dissertations* Retrieved from https://scholarworks.uark.edu/etd/3725

This Thesis is brought to you for free and open access by ScholarWorks@UARK. It has been accepted for inclusion in Theses and Dissertations by an authorized administrator of ScholarWorks@UARK. For more information, please contact ccmiddle@uark.edu.

Visualizing Interdisciplinary Collaborations within Exercise Science: A Pilot Study

A thesis in partial fulfillment of the requirements for the degree of Master of Science in Kinesiology

by

Elizabeth Bjornsen Taylor University Bachelor of Science in Exercise Science, 2019

> July 2020 University of Arkansas

Kaitlin Gallagher, Ph.D. Thesis Director

Matthew Ganio, Ph.D. Committee Member Elizabeth Keiffer, Ph.D. Committee Member

Abstract

Exercise science is a growing field with sub-disciplines exploring various aspects of physical activity. Diverse perspectives allow the field to answer complex research questions, but little is known about the collaborative nature of exercise science today. Research practices have implications on undergraduate curriculum, likely incorporating experiential knowledge into course subject matter and providing diverse experiences for students entering the workforce. Therefore, the purpose of the pilot study is to visualize and quantify interdisciplinary collaborations within exercise science. Journal citation analysis and an adaptation of social networking theory were utilized to examine collaborative practices of exercise science faculty at the University of Arkansas during the 2018 calendar year. The model was replicated with exercise science faculty from a benchmark institution, School X, to assess feasibility. 70 articles were analyzed at the University of Arkansas (n=22) and School X (n=48). Total collaborations for the University of Arkansas and School X were 127 and 247 respectively. Collaborations occurred across 12 sub-disciplines at the University of Arkansas, with 13 sub-discipline collaborations occurring at School X. The pilot study presents a feasible method to study interdisciplinary collaborations within exercise science. Study findings support occurrence of interdisciplinary collaborations across the field, with collaboration trends specific to subdisciplines. Research practices have curricular implications and educators must provide diverse experiences to prepare students to meet expectations of future employers. The visualization methodology would provide universities with a collaborative research environment the ability to market program strengths.

Keywords: Exercise science, interdisciplinary collaborations, sub-disciplines, curriculum

Table of Contents

Introduction	1
Review of Literature	3
History of Exercise Science	3
Sub-disciplines of Exercise Science	7
Exercise Science Careers	8
Importance of Interdisciplinary Collaboration in Research	11
Importance of Interdisciplinary Collaboration in Education	12
Social Networking Theory	15
Methods	
Search Methodology	
Exclusion Criteria	
Article Analysis	19
Visualization	
A Visual Model	20
Metrics	20
Adjustment for Unequal Faculty Size	21
Results	24
University of Arkansas	24
School X	
Program Characteristics	
Replicating Visualizations	
Discussion	
Expansion of Exercise Science	
Limitations	
Feasibility Assessment	
Conclusion	
References	
Appendix A	42
Appendix B	
Appendix C	45
Appendix D	47

ppendix E50

Introduction

According to the American College of Sports Medicine (ACSM), exercise science is defined as the "study of various aspects of physical activity, exercise, sport, and athletic performance that have the common characteristic of physical movement and the adaptations that occur as a result of participation in physical activity and regular exercise" (Potteiger, 2014). By that definition, exercise science is a broad field and can explore physical activity from different viewpoints. Consequently, multiple sub-disciplines have developed and allow the field to answer complex research questions. Health-related problems continue to increase in complexity and there is one opinion that the field must choose between sub-disciplinary isolation and interdisciplinary collaboration to meet societal needs (Knudson, 2016). Research practices vary by sub-discipline, but little is known about the collaborative nature of exercise science today. Therefore, the purpose of the pilot study is to visualize and quantify interdisciplinary collaborations within exercise science. The study will utilize an adaptation of the social networking theory to examine the collaborative nature of exercise science faculty at the University of Arkansas. The model will then be replicated with a benchmark institution's exercise science faculty to observe the model's adaptability towards an outside sample. Primary outcomes of the pilot study will be a visualization of the collaborative network of exercise science faculty members and development of a standard operating procedure for the model's decision-making process. Two visualizations will be expected, one depicting interdisciplinary collaborations within the university's exercise science program and the second based on the benchmark institution's program. A secondary outcome is the feasibility of reproducing the data collection on a wider scale and providing written tutorials that would allow other programs to replicate the visualizations for personal use. The visualization can be used at a departmental level to identify strengths and weaknesses of a department collectively or assist individuals in understanding personal collaboration tendencies. A robust model would also be applicable to disciplines outside of exercise science and potentially allow a standardized measure of collaboration. Marketing applications are also possible, allowing departments to provide information to incoming faculty members or students.

Review of Literature

Exercise science is a broad discipline and includes multiple sub-disciplines concerned with physical activity. Available careers within the field are growing, as a 12.1% growth for bachelor-degree graduates in the workplace was observed between 2017 and 2018 ("Kinesiology & Exercise Science"). With the increasing popularity of recognized sub-disciplines, exercise science graduates have multiple career pathways from which to choose. Exercise science largely prepares students for allied health professions, a trend that has increased in recent years (Brusseau, 2018). As health-related problems continue to increase in complexity, the field must choose between deeper specialization and collaborative integration to meet societal needs (Knudson, 2016). The choice will be apparent first in research, but also in undergraduate curriculum. Therefore, a brief examination of the historical development of the field, as well as the specialization versus integration debate, is necessary to understand students' current and future needs post-graduation.

History of Exercise Science

Fascination with health and human movement dates back to ancient times. The majority of the era's consensus regarding medical practice and early presuppositions of human physiology can be attributed to pure human observation. Perhaps the earliest positions on wellness stem from Hippocrates (460-370 BC), who wrote *Regimen in Health*, identifying exercise as a means to promote health of all ages (Tipton, 2003). While the advice given may today seem frivolous and unsupported, the ideas were revolutionary to the period. Galen, an early Roman physician (129-200 AD), built upon Hippocrates' work, continuing to highlight exercise as beneficial to one's health (Tipton, 2003). Galen further expanded the current practice by concerning himself with human anatomy, working to comprehend the function of body organs and methods to

maintain wellness (Tipton, 2003). A Persian physician, Flavious Philostratos (170-244 AD), later added to Galen's physiological thoughts, claiming that professional athletic training could be an independent science (Newburgh, 1949). The findings of Hippocrates, Galen and other ancient physicians laid the foundation for later periods, concentrating heavily on human physiology. Each of these early physicians sought to understand biological processes, primarily utilizing pure observation and experimental theory (Tipton, 2003). It was during this period that exercise began to be recognized as synonymous with health, a thought that would influence teaching and circulating knowledge during the middle ages.

Scientific developments in medieval times decreased in comparison to ancient times (Nigg & Herzog, 2006). However, the period notably witnessed the growth of medical schools and universities, where enrolling was considered a noble profession (Tipton, 2003). Coursework continued to build upon the foundational thoughts penned by ancient physicians yet had significant advances by individuals of the day. The *Canon of Medicine*, written by Avicenna (980-1037 AD), a Persian physician, may have provided the most noteworthy advancement (Ivy, 2007). The work outlines the importance of separate body organs and understood that intensity and dose of exercise bouts elicits specific responses and became a standard text in medical schools (Tipton, 2006). Other attempts to further the work of Hippocrates and Galen were found during the Renaissance, where human anatomy was a conceptual focus (Nigg & Herzog, 2006). Anatomical knowledge, coupled with philosophical reasoning, opened the door further for the future development of exercise science. Jean Fernel, a French physician, wrote *Medicina* in 1554, where the term "physiology" was first coined (Tipton, 2003). Physiology furthered the quest for knowledge as medical research became commonplace.

During the seventeenth century, various scientists became dedicated to answering the most pressing physiology questions of the day. Robert Boyle (1627-1691) and Robert Hooke (1635-1703) worked together to understand respiration (Foster, 1970; Potteiger, 2014; Tipton, 2003). Both individuals developed cardiorespiratory experiments, exploring the relationship between heart rate and exercise intensity with an Oxford physician, Richard Lower (1631-1693) (Foster, 1970; Tipton, 2003). Another Oxford physician, John Mayrow (1641-1679), built upon his predecessors' work. Mayrow focused his attention on the relationship between exercise and health. Foundational components of energy expenditure became Mayrow's focus, noticing that an animal's core body temperature rose with exercise (Tipton, 2006). However, his most influential discoveries were within muscle physiology, specifically identifying muscle fiber components and muscular contraction (Potteiger, 2014; Tipton, 2006). Regardless, the most notable advancement of the era was observed in the deepening conceptual complexity. The stage was set for the Enlightenment period, where conceptual theory was then advanced through empirical methodology.

Improved technology became a catalyst for exploring complex questions and provided the capability to quantify former theoretical concepts. The Enlightenment period boasted many advancements within physiology, notably observed in the first measurements of pulse and blood pressure (Potteiger, 2014; Tipton, 2003). Early mathematical formulas to understand the body's response to exercise also circulated during this period, further expanding the scope of physiology. The work of Stephen Hales (1677-1761), a clergyman, provided the background for the first experiments in cardiac output by Daniel Bernoulli (1700-1782) (Potteiger, 2014; Tipton, 2003). Each foundational experiment broadened the scope of understanding within physiology and further prepared the path for greater expansion within the field. As common knowledge of exercise physiology grew, efforts increased to promote physical activity during the nineteenth century. Early theories on the health benefits of exercise now had scientific support. Longevity was promoted widely, especially with the formation of the American Physiological Society in 1837 (Alcott & Graham, 1937). During this time, the term "physical education" began to circulate throughout Europe and America (Potteiger, 2014). Books were published with calisthenics and gymnastics style exercises in the 1870s and exercise physiology was finally recognized as a separate, scientific discipline (Tipton, 2003). Medical concepts and exercise physiology became commonplace in the university setting towards the end of the nineteenth century. Universities created physical education programs as a separate field of study available (Ivy, 2007). Additional interest in physical education was possibly endorsed by the emergence of professional sports teams. Athletic training grew in popularity, largely from human competitive nature, desiring to excel in sports competitions (Potteiger, 2014). The athletic application of science greatly expanded the reach of physiology, opening doors for future subdisciplines to emerge.

Specialized organizations began to form in the twentieth century, which built upon the foundational components of exercise physiology. Notably, the American College of Sports Medicine (ACSM) was founded in 1955 and remains the governing body of exercise science today (Potteiger, 2014). Other organizations, such as the National Athletic Training Association (NATA) and the International Society of Biomechanics (ISB) were founded in 1950 and 1973 respectively (Potteiger, 2014). Sports psychology also emerged following the increased emphasis on athletics and physical education. Consequently, the Association for Applied Sport Psychology was founded in 1986 (Potteiger, 2014). Each of these groups and associations illustrates the wide range of applications possible under the large umbrella of exercise science. Nonetheless, the

additional societies formed further solidifies the separation of exercise science from physical education and the subsequent recognition of the field's sub-disciplines. Not only are the specialized areas helpful to the expansion of the field, but it allows today's researchers to solve wide-scale and complex problems.

Sub-disciplines of Exercise Science

While there are numerous applications rooted in exercise science, the ACSM currently recognizes seven sub-disciplines. The organization formally recognizes exercise physiology, clinical exercise physiology, biomechanics, nutrition, psychology, athletic training and sports medicine, and motor behavior as being within the field's scope (Massengale & Swanson, 1997; Potteiger, 2014). Most of the sub-disciplines can be applied either to a general population that promotes health and wellness or to an athletic population focused on improved performance. Clinicians and researchers generally specialize in one of the two populations.

As the field continues to adapt, some elements must be recognized to further the success of exercise science. The presence of multiple sub-disciplines allows for researchers to become recognized area experts. A logical consequence is the ability of researchers to answer questions of increased complexity. However, as the field continues to expand its knowledge in separate specialty areas, the undergraduate exercise science degree should match the growth of the field. As researchers in exercise science programs nationwide are responsible for the education of future researchers, faculty should critically evaluate whether a broad education will best suit undergraduate students entering the workforce or if a specialty-specific education will best meet students' needs. Both choices have resulting benefits and disadvantages. Little has been written on the emerging issue that may become more apparent in future years. Therefore, exercise scientists must begin to question whether a broad degree will prepare students for specialized career paths.

Exercise Science Careers

Numerous career paths can be pursued with an undergraduate degree in exercise science. Literature has documented the increasing number of students who indicated future careers in allied health (Brusseau, 2018). Students in an Introduction to Exercise Science course at the University of Arkansas were surveyed for future career aspirations in Spring 2020. With a 94.7% (90 students) response rate, 98.8% indicated a profession that required additional schooling (A. Human, personal communication, January 17, 2020). Common clinical careers for exercise science students include physical therapy, occupational therapy, athletic training, and medicine (Gledhill & Jamnik, 2009). Each specialty requires coursework specific to future aspirations, including industry occupations as well. Exercise science can be considered a preparatory degree but presents additional challenges when considering how to best serve students with a wide net of ambitions.

Careers within exercise science are broad, preparing students for both clinical and industry occupations. Examples of clinical jobs settings include hospitals, clinics, and out-patient rehabilitation settings (Gledhill & Jamnik, 2009). Graduates may be required to pursue additional schooling and certification in order to pursue clinical occupations. A list of common jobs include: exercise physiologist, cardiac rehabilitation specialist, athletic trainer, dietician, medical doctor, chiropractor, nurse, nurse practitioner, and respiratory therapist (Gledhill & Jamnik, 2009). However, there are also opportunities to pursue non-clinical jobs. Examples of industry occupations generally fit into the wellness and fitness category, working in corporate wellness, community wellness, or strength and conditioning (Potteiger, 2014). Additional opportunities exist for students who desire an advanced degree. Students who continue with a master's or doctorate education will be prepared for a career in biomechanics, motor control, neuroscience, or research (Potteiger, 2014). Many career opportunities exist for exercise science graduates both in clinical and industry settings. As exercise science programs serve students with numerous career paths, programs may need to evaluate the ability to prepare all types of graduates.

Some schools have attempted to address the breadth within exercise science by implementing a European degree model. Such institutions have restructured degree coursework and provided integration opportunities with career-specific professionals. One Australian institution, Griffith University, employed drastic changes to the exercise science degree to match the growth of the field. Griffith University integrated early coursework to showcase the various career pathways available within exercise science (Reddan & Harrison, 2010). In providing early exposure to the workforce, students have ample time to explore future employment opportunities and narrow coursework to better suit needs.

Typically, students are unaware of specific career pathways until the later years of undergraduate education, limiting time to pursue path-specific learning. Griffith University recognized the need to make the most of the educational experience and provided students with additional electives to match skills desired by both clinical and industry employers (Reddan & Harrison, 2010). University administration assessed the importance of subsequent changes and cited the position of McKay and Marshall, who believed the undergraduate degree should possess "a greater focus on outcomes in terms of attributes, skills and knowledge required, driven by industry demand, [providing] a focus which is likely to result in the shaping of curricula that is more likely to produce graduates more closely aligned to the needs of industry"(2007). The reasoning for the university's drastic changes is rooted in a greater vision, one that recognizes the need for higher education to be student-focused. Students have high expectations for employability after receiving an undergraduate degree (Reddan & Harrison, 2010). Therefore, Griffith University took a step further to create a specific course that combines industry professionals with a focus on the job search process, including interviewing skills and resume building activities (Reddan & Harrison, 2010). Qualitative feedback was positive and allowed greater integration between required knowledge and real-world applications.

Other universities employ different measures to bridge the gap between book-knowledge and the workplace. Cooperative opportunities are common in Canada, Europe, and Oceania. Such universities provide the opportunity to better prepare graduates for the workplace, above what curricular knowledge alone can provide (Reddan & Harrison, 2010). While requirements differ between institutions, generally, students have repeated opportunities throughout the degree timeline to learn from clinical and industry professionals. American schools provide internship opportunities as a part of the degree; however, it is rare to have more than one internship placement. It should be understood that exercise science is a broad field with many available career paths, making a single, cookie-cutter degree unable to teach all necessary skills specific to clinical and industry needs (Fleming & Ferkins, 2005). Recently, the University of Arkansas' Chancellor distributed a memorandum to faculty and staff regarding future aspirations for students' education. The Chancellor noted the need for faculty to bring diverse backgrounds into the classroom, expanding opportunities for students to gain inter-disciplinary experience from a broadened curriculum (Steinmetz, 2020). Encouraging faculty to extend knowledge circles and pursue interdisciplinary collaborations will benefit students and preparedness for the diverse skill-sets employers desire. The vision is applicable for the university, but also reflects the

growth of exercise science and its need for increased interdisciplinary collaboration in research and education.

Importance of Interdisciplinary Collaboration in Research

Few publications explore the field's expansion issue, with the exception of opinion pieces. One individual, Duane Knudson, a biomechanist at Texas State University, continues to explore research challenges within exercise science. One of the most notable concerns for the field is the specialization versus integration debate (Knudson, 2016). Knudson recognizes the increasing number of sub-disciplines, largely observed via the presence of specialized journals. For example, although biomechanics is a recognized sub-discipline of exercise science, the area can specialize further, an example of which would be the Gait and Posture journal (Knudson, 2016). Within these smaller specialty areas, discipline-specific protocols for writing and data collections have also emerged (Knudson, 2016). While such practices can advance the specialty area, it can alienate researchers in other sub-disciplines. Knudson recognizes such issues and identifies additional negatives of greater specialization. Area specialization can limit contact with other exercise science professionals and perhaps decrease the visibility of ground-breaking research by publishing to specialized journals (Knudson, 2016). Additionally, the connection of exercise science researchers may be further limited in conferences attended. Abstracts and publications may better match specialty journals and specific conferences, reducing knowledge of other area specialists still under exercise science.

Perhaps one antidote to the increasing isolation is observed in the grant requirements of federally funded bodies. Many large grants today look for increased collaboration to answer large-scope questions (Knudson, 2016). Federal funding institutions, such as the National Science Foundation, cites "convergence research" as an emerging trend. Convergence research provides new opportunity to solve challenging problems for the betterment of society via integration across multiple disciplines (*Convergence Research at NSF*). Disciplines have separate knowledge bases and therefore, require assistance from other discipline professionals to solve problems holistically. Naturally, there are challenges to pursuing convergence research regularly. Physical location of collaborative partners and general feasibility are legitimate concerns, especially as many faculty members have productivity requirements (Knudson, 2016). While such concerns should be recognized, a collaborative environment may allow research teams to answer research questions that benefit a greater audience.

Importance of Interdisciplinary Collaboration in Education

Exercise science research is broad topically and has potential to expand its reach to solve complex research questions. The field possesses deep roots in observatory skills and exercise physiology but has branched into specialty disciplines that require independent knowledge bases and skillsets. In higher education, faculty members often provide mentorship to younger faculty and graduate students, transferring specific knowledge and guiding the mentee's future directions (Pyne, 2018). These mentees will soon educate undergraduate students who will become tomorrow's educators. Educators often teach in a way that is reflective of previous instructors and experiences (Kaufman, 2003). Therefore, a researcher's collaborative practices will likely also be observed in the classroom. Researchers who collaborate across disciplines may incorporate knowledge from outside disciplines in lecture content. Alternatively, researchers may present knowledge only pertinent to the researcher's identifying area of expertise, which may prevent exposure to other aspects of the discipline.

While all exercise science sub-disciplines have specialized knowledge bases and research practices, one example of drawing from other disciplines is observed in biomechanics.

Biomechanics is an integrative field by nature, reflected in its historical development. The area is influenced largely by other subfields, often outside exercise science. Without an interdisciplinary education, individuals interested in biomechanics jobs may find the positions are unattainable post-graduation. Therefore, a brief summary of the sub-discipline's later historical development and the influence of other fields may better highlight the skills needed for a future biomechanics career and why increased reach across disciplines would be useful for future students.

The development of biomechanics remains rooted in the broad expansion of the exercise field as a whole. However, while the current practice of biomechanics today draws from medical theory advancement that propelled exercise science as a whole, the majority of disciplinary growth is found in the interest of observing humans in motion. Growth within the field was accelerated in the twentieth century, as like-minded individuals gathered for the first biomechanics conference in 1967 and with the later formation of the International Society of Biomechanics (ISB) in 1973 (Nigg & Herzog, 2006; Potteiger, 2014). The ability to share and challenge individuals with similar interests allows for collaboration among professionals and for field standards to be assessed. Biomechanics today remains a multi-disciplinary field and has infiltrated exercise science programs around the globe, through introductory undergraduate coursework and professional disciplines.

A basic understanding of multiple sub-disciplines is required to succeed as a biomechanist. Biomechanics draws largely from engineering, anatomy, and technology, with the core components of physiology and exercise science bearing the foundation. Engineering principles are necessary for biomechanists to understand statics and dynamics principles. Knowledge of standard calculus equations used in engineering is also helpful, as the mathematical operations are being run in the background of motion capture processing software. Possessing a basic understanding of engineering principles is necessary for biomechanists, who must take the mechanical concepts one step further to apply to human motion to increase performance, prevent injury, and assist with rehabilitation.

Without a thorough understanding of anatomical structure and function, applications of engineering concepts are limited. Early scientists were fascinated with human anatomy and worked to understand human motion throughout history (Reddan & Harrison, 2010; Reddan & Rauchle, 2012). Structure and function of the human body are interrelated, making both concepts worthy of inspection. Biomechanists will likely specialize in gait analysis or a specific joint area during a professional career. Nonetheless, it is beneficial to comprehend governing principles of bones, muscle and tissue as stress and strain principles can be applied to any area of the body.

As the biomechanics field continues to progress, technology will continue to improve the ability to describe human movement. Today, biomechanists must remain current with technological advances and possess the ability to troubleshoot problems that occur with complex equipment. Motion capture systems utilize multiple cameras to capture movement in thousands of frames per second, allowing biomechanists to visualize motion more reliably. Additional software is required to process the video files collected, requiring knowledge of coding and advanced computer skills. File sizes are also increasing, requiring knowledge of working with big data and accompanying challenges. As the biomechanics continues to grow, these specialized skills require a choice to be made. Biomechanics relies heavily on knowledge from other fields, increasing the ability to solve complex research problems. However, as noted by Knudson (2016), the increase in technological complexity may further alienate biomechanics as a discipline or catapult the field into a more collaborative environment. Either choice will create

two vastly different cultures for the field going forward and influence the skills needed to succeed as a biomechanist.

Regardless of the research environment biomechanics will choose going forward, there are certain skills that a biomechanist must possess to succeed professionally. The ability to navigate computer software, new technology, and troubleshooting will remain a necessary component of a biomechanist's job. Equipment is expensive and the product chosen will elicit specific strengths and weaknesses, requiring a thorough knowledge of products on the market. Additionally, the biomechanist must possess strong interpersonal skills and clearly communicate the technical aspects in meaningful ways to clinicians and industry partners. Data collected may have either medical or performance applications and it is necessary to interpret the findings in ways specific to the population of interest. It is also important to understand the current trend of collecting big data sets. The practice can have positive and negative results; however, it is the biomechanist's job to interpret what is truly meaningful. With the understanding that biomechanics requires a multidisciplinary knowledge base, it is necessary to examine the state of biomechanists' research collaborations, as well as other sub-disciplines across exercise science. Understanding the nature and frequency of interdisciplinary collaboration will provide information on the current state of the field.

Social Networking Theory

One method of understanding the interdisciplinary nature of exercise science is to utilize an adaptation of social networking theory. Social networking applications range in complexity, yet all are rooted in the idea that relationships between people exist and can be studied (Kadushin, 2004). Generally, a network includes objects that are then depicted via relationships in a map-style visualization (Kadushin, 2004). A relationship can be described as being unidirectional or reciprocal (Kadushin, 2004). Either status provides an additional layer of information specific to the relationship. While social networking has been studied by social scientists, other fields can utilize the foundational ideology. The methodology provides a means to describe relational ties in specific populations.

Marketing research has utilized social networking ideology to explore and evaluate the direction of the field as a whole (Baumgartner & Pieters, 2003). Journal citation analysis was used in conjunction with social networking to characterize the state of the marketing field. Derek Price, an early proponent of the social network theory, believed the "pattern of bibliographic references indicate[d] the nature of the scientific research front" (De Solla Price, 1965). Attributes of the authors themselves, such as professional discipline and identifying institution, can be examined. This provides a built-in network to observe relationships between researchers, disciplines, or institutions. While many applications of journal citation analysis are possible, marketing research utilized the approach to describe interdisciplinary knowledge utilized by marketing researchers and publishing behaviors of marketing journals (Baumgartner & Pieters, 2003; Biehl et al., 2006; Goldman, 1979). In using journal citation analysis, social networks can be identified and provide insight into a sample population. Baumgartner and Pieters (2003) utilized this method to identify changes in marketing journals' influence over a thirty year period. Trends for the rise and fall of marketing sub-disciplines were also observed and provided insight into the development of the marketing field (Baumgartner & Pieters, 2003). Therefore, in using an adaptation of the social network theory, it is possible to understand the current nature of exercise science and its interdisciplinary collaborations.

The need for interdisciplinary collaborations will vary by sub-field and up until now has only been an opinionated debate. It would greatly benefit exercise science to have a visual and quantifiable measure of what is truly is occurring through the examination of research. Logically, a faculty member's research will be reflected in the individual's pedagogical practice. Therefore, undergraduate coursework may reflect the faculty's specialty area and will either incorporate information from a variety of sub-disciplines or project knowledge of one sub-discipline. Therefore, to continue questioning the best future pathway for exercise science, a quantifiable measure of collaboration must be created. Exercise science will progress with either isolated subdisciplines or choose to utilize interdisciplinary collaborations to explore challenging problems. Although biomechanics remains a sound example of why interdisciplinary collaboration is necessary, other sub-disciplines have different knowledge bases and research practices that require similar collaborations. Reserachers may choose to collaborate with fellow faculty members of the same sub-discipline or with faculty members of a different specialty. Other reserachers may collaborate within the same unversity, but choose faculty members outside their department to fill knowledge gaps. Collaborations can also occur outside the faculty's home instution, such as with a previous mentor or colleague from another institution. Some subdisciplines may also utilize clinical and industry connections as research collaborators. Tendencies and types of collaboration are likely specific to the sub-discipline; therefore, it is beneficial to examine all ACSM recognized sub-disciplines. Potential exists to quantify and visualize the current collaborative practices of all sub-disciplines using an adaptation of the social networking theory and journal citation analysis.

Methods

Search Methodology

A complete list of the exercise science faculty members at the University of Arkansas was compiled from the university website, with additional confirmation from the department administration. Physical education/pedagogy faculty members, which belonged to the education program within the department, were also included. Faculty members were employed at the University of Arkansas for the full 2018 calendar year for inclusion. Faculty member names were used to conduct a systematic review of all peer-reviewed journal articles published within the one-year timespan. The search was conducted using EBSCO with the following databases included: Academic Search Complete, CINAHL Complete, ERIC, Health Source, MEDLINE Complete, PsycINFO, and SPORTDiscus. A follow-up search was conducted via Google Scholar using the author name and year range. Search accuracy for the sample was confirmed with an annual review, submitted by program faculty for the 2018 calendar year. All articles for each faculty member were downloaded to RefWorks citation manager. Duplicates were deleted in RefWorks and exported as a .csv file to create a single database with all authors employed at the university and their collaborative partners.

Exclusion Criteria

Directionality of the collaboration was recorded from the perspective of the University of Arkansas faculty members, providing a focused network of collaborators. Frequency of collaboration can further characterize the relationship between authors (Hanneman & Riddle, 2005). The collaboration frequency was observed by author, discipline, and location. While relationships can be bi-directional, reciprocity was not examined. The relationships were considered from the viewpoint of the University of Arkansas faculty member and information about the external connections of collaborative partners outside the program were not explored. Therefore, a faculty member must be listed as corresponding author to maintain directionality assumptions. In addition, conference proceedings and book chapters were not included as collaborations are still visible in published works and would cause unnecessary duplication. Articles without a designated corresponding author were excluded to retain integrity of directionality.

Article Analysis

All articles were examined for author information via EBSCO and Google Scholar. Author affiliation and sub-discipline were recorded using the provided information on the article. The seven, exercise science sub-disciplines recognized by ACSM were collapsed into six areas, combining exercise physiology and clinical exercise physiology into a single physiology subdiscipline. Experts may debate the boundaries between disciplines, however, no distinction within physiology were made to reduce error and to improve readability in the resulting visualization. Eight additional areas including academic, academic/clinical, clinical, industry, psychology, physical education/pedagogy, student and post doc collaborations were added to provide additional detail for collaboration practices (Appendix A). Students were further separated into undergraduate and graduate categories, with further specification noted for students internal and external to the exercise science program. New categories were created to better reflect job-oriented perspectives. More detailed information regarding represented subareas were collected; however, final visualized disciplines were collapsed into recognized categories to best illustrate clarity and organization.

Follow-up analysis was also used to confirm the author's disciplinary specialty via institution webpage and accessible research profiles. All author information was coded

separately by two analysts with the same available categories. Conflicting sub-disciplines and affiliations defaulted to a third analyst. Inter-rater reliability for the outside institution was assessed with a Cohen's kappa reliability measure (SAS, Cary, NC).

Visualization

Data were visualized through Tableau (version 2019.4; Seattle, WA) using two layovers. The first layer represents the individual authors and the names of collaborators and their subdisciplines. A geographical map of the exercise science program at the University of Arkansas accounts for the second layover. Descriptive statistics regarding frequency and proportions of sub-disciplinary collaborations were also visualized.

A Visual Model

As the collected data organization was tailored to model the University of Arkansas' exercise science faculty specifically, the model was replicated with a separate sample. Any model requires validation outside of the original training dataset to avoid over-fitting (Shmueli et al., 2020); therefore, the model was replicated with the exercise science program at School X, which ranks within the top 50 doctoral programs according to the National Academy of Kinesiology (Ulrich & Feltz, 2016). School X is also a benchmark, SEC institution for the University of Arkansas. The additional step provides information on application to other universities.

Metrics

Total collaborations are the sum of co-authors on individual papers and can be expressed to a faculty member, or summed together to provide total collaborations within a sub-discipline or department. For example, a faculty member with three co-authors on a single paper will have three collaborations. Collaborations were not limited to unique relationships, meaning that frequent co-authors will be counted for each instance of collaboration. Collaborations from individual faculty members were then summed into sub-discipline totals. The secondary metric was a percentage, illustrating total collaborations with respect to co-authors' sub-disciplines (Table 1). Sub-discipline collaboration percentage was calculated using (1) with an example calculation from sport psychology's collaborations with clinical psychologists in (2):

Sub Discpline Collaborations (%) =
$$\frac{Total subdiscipline collaborations}{Total collaborations} * 100\%$$
 (1)

Sport Psychology Collaborations (%) = $\frac{8}{15}$ * 100% = 53.33% (2)

Table 1. Example Calculation for Sport Psychology Collaborations by Sub-Discipline.Collaborator's Sub-DisciplineSub-Discipline Collaboration
Percentage (%)Psychology853.33

Psychology	8	53.33	
Graduate Students	4	26.67	
Sport Psychology	2	13.33	
Clinical/Academic	1	6.67	
Total	15	100.00	

Adjustment for Unequal Faculty Size

Sub-disciplines did not always contain the same number of faculty. For example, a program may have five physiologists and a single motor control faculty member. Therefore, total collaborations were normalized to better compare across sub-disciplines and institutions. Normalizing provides a means to compare collaborations when faculty size within specific subdisciplines is variable (Table 2). Normalized collaborations, with an expected unit of collaborations per faculty member, were calculated using (3) with an example calculation from physiology's academic collaborations shown in (4):

Normalized Collaborations =
$$\frac{\text{Total subdiscipline collaborations}}{\text{Total faculty members within subdiscipline}}$$
 (3)

Normalized Collaborations $=\frac{21}{4}=5.25$ collaborations per faculty member (4)

Sub-discipline collaboration percentages calculated from original total collaborations will remain

unchanged for the normalized values.

collaborators' sub-disciplines.		
Collaborators' Sub-Disciplines	Total Collaborations	Normalized Total Collaborations
Academic	21	5.25
Academic/Clinical	1	0.25
Clinical	1	0.25
External Graduate Student	2	0.50
External Undergraduate Student	1	0.25
Graduate Student	71	17.75
Industry	11	2.75
Motor Control	0	0.00
Physical Activity	0	0.00
Physical Education/Pedagogy	0	0.00
Physiology	19	4.75
Post Doc	2	0.50
Undergraduate Student	7	1.75
Total	136	34.00

Table 2. Example Calculation for Normalized Total Collaborations within Physiology. The total number of collaborations by physiology faculty members (n=4) were categorized by collaborators' sub-disciplines.

Outcomes of the Pilot Study

The primary outcomes of this project were visualizations depicting the collaborative network of program faculty members. One visualization depicted interdisciplinary collaborations within the University of Arkansas' exercise science program and the process was replicated with School X's exercise science program. School X's collaboration network will not be included to retain anonymity. Multiple decisions regarding data structure and the resulting visual display were made post data collection. Reasoning was based on the need for a complete data set to graphically arrange authors and the location of sub-disciplines nodes.

Total collaborations and associated percentages of total collaborations, were included to provide a means of comparison between two exercise science programs. The metrics were created via Tableau and visualize collaborative trends between sub-disciplines. Therefore, as the visualization methodology was exploratory, the feasibility of reproducing the process with a different sample was assessed with the additional school.

Results

University of Arkansas

39 articles were collected from 12 exercise science faculty members at the University of Arkansas who published within the 2018 calendar year. Article inclusion was assessed with a self-submitted, annual faculty review. Exclusion criteria resulted in 22 articles (Figure 1) and 127 total collaborations (Figure 2). Corresponding authors represented six sub-disciplines physiology, sport psychology, physical activity, physical education/pedagogy, biomechanics and graduate students. Collaborating authors represented 12 sub-disciplines - physiology, sport psychology, physical activity, physical education/pedagogy, biomechanics, industry, psychology, academic, undergraduate students, academic/clinical, clinical and graduate students.



Fig. 1. Article exclusion process for the University of Arkansas' exercise science department faculty members.

Articles with Arkansas' physiology faculty members as corresponding authors contained 69.3% of total program collaborations (Figure 3A), followed by sport psychology faculty (11.8%). Physical activity faculty accounted for 8.7% of collaborations. There were 2 articles with graduate students as corresponding authors, which provided 6.3% of all program

collaborations. Physical education/pedagogy faculty and biomechanists had 2.4% and 1.6% of total collaborations respectively.

When normalized to account for faculty size (Figure 3B), sport psychology faculty (n=1) averaged for 30.2% of total collaborations, followed by physiologists (n=6) with 29.5%. Physical activity (n=1) produced 22.1% of faculty collaborations. Graduate students (n=2) represented 8.1%, with physical education/pedagogy (n=1) and biomechanists (n=1) averaging 6.0% and 4.0% respectively.

The six sub-disciplines represented were examined individually to observe withindiscipline trends (Figure 3A, Figure 3B). 56.8% of physiologists' collaborations (n=88) were with graduate students and 26.1% were with other physiologists. The remaining 17.1% of total collaborations occurred across seven recognized sub-disciplines. Sport psychologists collaborated with clinical psychologists for 53.3% of total collaborations (n=15). Graduate students represented 26.7% of total collaborations. 13.3% of total collaborations were with other sport psychologist co-authors. Academic/clinical collaborations accounted for the remaining 6.67%. Physical activity faculty members collaborated with other physical activity specialists for 63.6% of all collaborations (n=11), with clinical psychologists, graduate students, biomechanists and physiologists each accounting for 9.1%. Two graduate students were listed as corresponding authors, including other graduate students (62.5%) and physiologists (37.5%) as co-authors (n=8). Physical education/pedagogy faculty (n=1) co-authored with another physical education/pedagogy faculty member and two graduate students. Biomechanists collaborated solely with undergraduate students during the time period (n=2). Geographically, the University of Arkansas pursued collaborations at 24 unique locations, across six countries (Appendix E) from academic institutions (n=18), clinical (n=4), and industry sites (n=2).

School X

Eighty-eight articles were collected from School X within the same 2018 calendar year. After exclusions, 48 articles (Figure 4) and 247 total collaborations remained (Figure 5). Corresponding authors represented six sub-disciplines - biomechanics, physiology, motor control, post docs, graduate students, physical education/pedagogy. Collaborating authors represented 13 sub-disciplines - academics, academic/clinical, clinical, external graduate students, external undergraduate students, graduate students, industry, motor control, physical activity, physical education/pedagogy, physiology, post docs and undergraduate students. Interrater reliability for author sub-discipline was assessed with Cohen's Kappa. Raters received .2204 (95%CI .1459 to .2949), categorized as fair agreement (McHugh, 2012).



Fig. 2. A collaboration network for the University of Arkansas faculty members. Size of node indicates number of collaborations, with color representing sub-discipline categories.



A B Fig. 3. A. University of Arkansas faculty members' identifying sub-discipline shown by total collaborations. Color layovers represent the collaborators' sub-disciplines. B. Figure shown with total collaborations, normalized to account for unequal faculty size.





Fig. 4. Article exclusion process for School X's faculty members.

Physiology faculty members represented 55.1% of program collaborations, followed by 24.7% from biomechanists (Figure 5A). Motor control faculty members and post doctorate students represented 9.3% and 6.9% of total collaborations, respectively. Physical education/pedagogy faculty members accounted for 2.4% and graduate students 1.6%. When weighted by faculty member (Figure 5B), biomechanists (n=1) observed 50.4% of total collaborations. Physiologists (n=4) and motor control faculty (n=2) accounted for 28.1% and 9.5% respectively. Post doctorate students (n=2), physical education/pedagogy faculty (n=3) and graduate students (n=1) represented the remaining 12.0%.

52.2% of all physiology co-authors (n=136) involved graduate students. Academic collaborations were observed 15.4% of the time, followed by 14.0% and 8.1% of physiology and

industry co-authors. Nine additional sub-disciplines were involved, representing the remaining 10.3%. Biomechanists collaborated with graduate students 65.5% of total counts (n=61), followed by clinicians (26.2%). 8.3% of co-authors were undergraduate students. Motor control faculty included graduate students in 43.5% of collaborations (n=23), with academic faculty and physiologists representing 21.7% and 17.4% of all co-authors. Other areas of motor control collaborations include undergraduate students, motor control and physical activity faculty. Post-doctorate students collaborated with other graduate students in 29.4% of all occasions (n=17), with other areas including academics, physiologists, external graduate students, motor control and academic/clinical connections. Physical education/pedagogy faculty collaborations (n=6) were evenly split at 33.3% between graduate students, other physical education/pedagogy faculty and post doctorate students. Graduate students partnered with physiologists on 50.0% of occurrences (n=4), with the remaining 50.0% including physical activity faculty and industry members.

Geographically, School X's collaborators represented 16 unique locations across 2 countries, including academic institutional sites (n=8), clinical (n=5), and industry sites (n=3).

Program Characteristics

Both programs from the University of Arkansas and School X shared collaborative practices. Graduate students at the University of Arkansas and School X were included as co-authors 47.9% and 51.8% of the time. Faculty size for both programs were also similar. While both programs share the highest faculty size for physiology, each school has differing program make-ups. The University of Arkansas represented physiology, sport psychology, physical activity, physical education/pedagogy and biomechanics. School X includes biomechanics, physiology, motor control, and physical education/pedagogy faculty members. Post doctorate

individuals (n=2) were involved in research at School X, whereas that was not observed at the University of Arkansas during the assessed time frame. Neither school represented all ACSM sub-disciplines, with no faculty member focusing on specific athletic training or nutrition research. Within a prominent sub-discipline, physiologists at both schools shared the same top four collaborators' sub-disciplines, including graduate students, other physiologists, academics and industry members. From a geographical perspective, the University of Arkansas had more international connections in comparison to School X. Arkansas also observed more distinct affiliations (n=24) than School X (n=16). Additionally, total collaborations as a program differed, with the University of Arkansas tallying 127 and School X observing 247 co-authors during the 2018 calendar year. Faculty size for University of Arkansas (n=12) and School X (n=13) were similar, although possessed differing program focuses (Table 3).

Faculty Sub-Discipline	University of Arkansas	School X	
Biomechanics	1	1	—
Graduate Students	2	1	
Motor Control	0	2	
Physical Activity	1	0	
Physical Education/Pedagogy	1	3	
Physiology	6	4	
Post Doctorate Students	0	2	
Sport Psychology	1	0	
Total	12	13	—

Table 3. Faculty Sub-Discipline Representation by School Program.

Replicating Visualizations

Data collection processes are provided for replication purposes (Appendix B, Appendix C). Python code with instructions are also included (Appendix D) to allow other individuals, departments and institutions to visualize collaborative practices via Tableau software.



.

33

Discussion

This pilot study examined 70 articles across two exercise science programs published during the 2018 calendar year. Study findings support occurrence of interdisciplinary collaborations across the field, with co-authorship trends specific to sub-disciplines. Multiple sub-disciplines under exercise science were represented, including areas not officially recognized by the ACSM (Potteiger, 2014). Pilot study methodology provides a feasible approach to study exercise science trends on a larger scale.

Expansion of Exercise Science

This pilot study highlights physiology's continued influence within exercise science. Physiology faculty account for the largest research drivers within both exercise science programs. Physiology is considered a foundational component of the exercise science field and is therefore unsurprising to be reflected in program personnel (Tipton, 2003). However, when total collaborations were normalized to account for faculty size, a more balanced effort across faculty sub-disciplines was observed for the University of Arkansas whereas School X observed the highest output from biomechanics.

Two faculty sub-disciplines did not fall under the categories currently recognized by ACSM (Potteiger, 2014). Physical activity, a combination of health promotion and measurement of physical activity levels is an emerging area, currently identified by the National Institute of Health as a research priority (*Physical Activity*, 2020). Another area that was present in both programs was physical education/pedagogy, a foundational area to the history of exercise science and is still studied today (Potteiger, 2014). In general, the highest percentage of collaborators' sub-disciplines were not within the corresponding faculty members' identifying sub-discipline. The trend highlights that faculty members are reaching out to foster interdisciplinary research, expanding upon one's personal expertise. Additionally, both schools frequently incorporated graduate students on research projects and had collaborations both inside and outside exercise science circles. Reaching outside exercise science brings differing perspectives, allowing researchers to partner with clinicians and industry professionals to solve complex research problems (Appendix A). Such external collaborations are beneficial for researchers' agendas and can provide application examples within the classroom.

The number of students pursuing a degree in exercise science is increasing (Brusseau, 2018). Educators must match the growth, evaluating whether a broad degree will prepare students with diverse interests. Interdisciplinary collaborations were observed across exercise science sub-disciplines included in the study and diverse ideas and perspectives are likely filtering into the classroom. Mentorship practices are also affected, as students often employ similar practices as mentors (Pyne, 2018). Therefore, graduate students will likely assume similar collaboration tendencies as previous mentors, carrying practices over into faculty appointments as independent researchers and educators. Interdisciplinary research experiences not only strengthen the creativity of research output but provide students with broad skillsets desired by future employers. Exercise science programs that regularly include graduate students in research should market the strength to incoming students, highlighting the emphasis placed on preparation for professional appointments.

While intentions behind the interdisciplinary collaborations are unknown, grant funding requirements may be pushing researchers to overcome challenges associated with collaborations outside of one's field (Knudson, 2016). Connections with previous academic mentors or professional partners may also carry over into research practices. Expertise originating outside specific sub-disciplines brings unique perspectives and broadens the ability to answer complex

research questions. The pilot study observed that researchers, regardless of specific subdisciplines, are looking outside identifying subject areas to propel research agendas. The sentiment reflects the call for exercise science professionals to choose interdisciplinary collaboration over area isolation within research (Knudson, 2016), with the likelihood of subject matter being incorporated into curricular programming. While the occurrence of interdisciplinary collaborations was observed across sub-disciplines, the reasoning behind collaborative practices needs further study.

Limitations

Difficulties arise in categorizing individuals correctly, as reflected with a fair inter-rater reliability. Choosing a small number of predetermined categories promotes clarity yet may fail to correctly identify emerging sub-disciplines. Allowing user-defined categories would improve categorization validity but may increase confusion on associated sub-disciplines. Future studies should employ a user-defined categorization method, with pre-defined bins to reduce excessive categorization. Difficulties also arise when corresponding authors are not indicated on accessible journal articles. This may be sub-discipline specific but provides no objective way to indicate directionality. Information from excluded articles was lost and highlights the need for self-reported information in the future.

Faculty output also varied by sub-discipline, requiring a greater sample size to better identify research practices between sub-disciplines. Observed trends reflect a narrow time period and small sample of exercise science programs across the United States. Future studies should gather longitudinal data to better understand exercise science practices at a single institution. Multiple programs should be surveyed to understand collaborative practices as a field.

Feasibility Assessment

A primary outcome of the pilot study was a feasibility assessment of process replication. The initial modeling process was created with the University of Arkansas exercise science program and replicated with School X. Data collection and python code remained the same for School X and can be replicated with other programs. The greatest consideration will be to utilize user-defined categories to promote visual clarity and improve sub-discipline accuracy. Basic knowledge of Python and computer skills are necessary to replicate the process. The majority of time is spent data cleaning, requiring great attention to detail.

Conclusion

This pilot study presents a feasible method of studying interdisciplinary collaborations within exercise science. Interdisciplinary research practices will likely have implications for curricular content and mentorship of graduate students. With the rise of exercise science graduates in the workforce, educators must provide experiences to prepare students to meet desired skill sets of future employers. Universities that boast an integrative research environment could use the visualization as a marketing tool, as well as provide a department with a current representation of program strengths and weaknesses.

References

- Alcott, W., & Graham, S. (1937). The Centenary of the First American Physiological Society Founded at Boston. https://search.proquest.com/openview/cdeba5dcb17bba22e684c01c01ef4202/1?cbl=1816 629&pq-origsite=gscholar
- Baumgartner, H., & Pieters, R. (2003). The Structural Influence of Marketing Journals: A Citation Analysis of the Discipline and its Subareas over Time. *Journal of Marketing*, 67(2), 123–139. https://doi.org/10.1509/jmkg.67.2.123.18610
- Bell, B., Crebert, G., Partrick, C.-J., & Cragnolini, V. (2003). *Educating Australian Leisure Graduates: Contexts for Developing Generic Skills*.
- Biehl, M., Kim, H., & Wade, M. (2006). Relationships among the academic business disciplines: A multi-method citation analysis. *Omega*, 34(4), 359–371. https://doi.org/10.1016/j.omega.2004.12.002
- Brusseau, T. A. (2018). The Benefits and Challenges of Kinesiology as a Pre-Allied Health Degree. *Kinesiology Review*, 7(4), 300–304.
- *Convergence Research at NSF*. (n.d.). National Science Foundation. Retrieved January 21, 2020, from https://www.nsf.gov/od/oia/convergence/index.jsp
- De Solla Price, D. (1965). *Networks of Scientific Papers*. https://www.academia.edu/12796334/Derek_J._deSolla_Price_Networks_of_Scientific_P apers_The_pattern_of_bibliographic_references_indicates_the_nature_of_the_scientific_ research_front_Science_149_3683_510-515_July_30_1965
- Fleming, J., & Ferkins, L. (2005). Enhancing Student Employability: A New Zealand Case Study of Cooperative Education in Sport. 8.
- Foster, S. (1970). Lectures on the History of Physiology During the Sixteenth, Seventeenth, and *Eigteenth Centuries*.
- Gledhill, N., & Jamnik, V. R. (2009). Careers opportunities for Exercise Science/Kinesiology Graduates. 2(1).
- Goldman, A. (1979). Publishing Activity in Marketing as an Indicator of Its Structure and Disciplinary Boundaries. *Journal of Marketing Research*, 16(4), 485–494. JSTOR. https://doi.org/10.2307/3150809
- Hanneman, R., & Riddle, M. (2005). *Introduction to soical network methods*. https://faculty.ucr.edu/~hanneman/nettext/C11_Cliques.html
- Ivy, J. L. (2007). Exercise Physiology: A Brief History and Recommendations Regarding Content Requirements for the Kinesiology Major. *Quest*, 59(1), 34–41. https://doi.org/10.1080/00336297.2007.10483534

Kadushin, C. (2004). Introduction to Social Network Theory. Charles Kadushin.

- Kapoor, A. (2018, October 2). *Social Network Analysis in Python*. DataCamp Community. https://www.datacamp.com/community/tutorials/social-network-analysis-python
- Kaufman, D. (2003). *Applying educational theory in practice*. https://www.bmj.com/content/326/7382/213
- *Kinesiology & Exercise Science* | *Data USA*. (n.d.). Retrieved January 7, 2020, from https://datausa.io/profile/cip/kinesiology-exercise-science
- Knudson, D. (2016). Future Trends in the Kinesiology Sciences. *Quest*, 68(3), 348–360. https://doi.org/10.1080/00336297.2016.1184171
- Massengale, J. D., & Swanson, R. A. (1997). The history of exercise and sport science (J. D. Massengale & R. A. Swanson, Eds.; 1996-98961-000). Human Kinetics Publishers.
- McHugh, M. L. (2012). Interrater reliability: The kappa statistic. *Biochemia Medica*, *22*(3), 276–282.
- McKay, J., & Marshall, P. H. (2007). Repositioning Information Systems Degrees to meet Contemporary Business Challenges: Including Supply-driven and Demand-driven Processes and Practices. EJ. https://eprints.utas.edu.au/4807/
- Newburgh, L. (1949). *Physiology of heat regulation and the science of clothing*. https://www.cabdirect.org/cabdirect/abstract/19512200908
- Nigg, B., & Herzog, W. (2006). *Biomechanics of the Musculo-skeletal System* (3rd ed.). John Wiley & Sons.
- *Physical Activity*. (2020). National Institute of Health. https://prevention.nih.gov/research-priorities/physical-activity
- Potteiger, J. (2014). *ACSM's Introduction to Exercise Science* (2nd ed.). Lippincot Williams and Wilkins.
- Pyne, D. (2018). The Benefits of Mentoring for Researchers and Sports Scientists—Who Do I Help? *International Journal of Sports Physiology & Performance*, 13(9), 1113–1113.
- Reddan, G., & Harrison, G. (2010a). *Restructuring the Bachelor of Exercise Science degree to meet industry needs.* 16.
- Reddan, G., & Harrison, G. (2010b). *Restructuring the Bachelor of Exercise Science degree to meet industry needs.* 16.
- Reddan, G., & Rauchle, M. (2012). Student Perceptions of the Value of Career Development Learning to a Work-Integrated Learning Course in Exercise Science. *Australian Journal* of Career Development, 21(1), 38–48. https://doi.org/10.1177/103841621202100106

- Shmueli, G., Bruce, P., Gedeck, P., & Patel, N. (2020). *Data Mining for Business Analytics: Concepts, Techniques and Applications in Python.* John Wiley & Sons, Inc.
- Steinmetz, J. (2020). 2020: Focus on the Future | The Office of the Chancellor | University of Arkansas. https://chancellor.uark.edu/focus-on-the-future/index.php

Tipton, C. M. (2003). Exercise Physiology. Newnes.

- Tipton, C. M. (2006). ACSM's Advanced Exercise Physiology. Lippincott Williams & Wilkins.
- Ulrich, B. D., & Feltz, D. L. (2016). The National Academy of Kinesiology 2015 Review and Evaluation of Doctoral Programs in Kinesiology. *Kinesiology Review*, 5(2), 101–118. https://doi.org/10.1123/kr.2016-0004

Appendix

Appendix A

Glossary of Recognized Sub-Disciplines

ACSM Exercise Science Sub-Disciplines (Potteiger, 2014)

<u>Athletic Training</u>: "prevention, treatment and rehabilitation of sport and athletic injury" <u>Biomechanics</u>: "mechanical aspects of movement in disease, injury, sport and athletic performance"

<u>Motor Control</u>: "control of body movement in healthy and diseased conditions and improvement of sport and athletic performance"

<u>Nutrition</u>: "nutritional aspects of disease prevention and improvement of sport and athletic performance"

<u>Physiology</u>: "physiologic responses to physical activity, exercise, sport and athletic competition"

<u>Sport Psychology</u>: behavioral and mental aspects of exercise, sport and athletic performance

Additional Recognized Sub-Disciplines

Academic: a non-exercise science, university faculty member

Academic/Clinical: an individual with dual academic and clinical associations

Clinical: a practicing, medical professional

<u>Industry</u>: an individual not employed at a university, but within the private sector under company management

<u>Physical Activity</u>: an exercise science faculty member with a focus on health promotion and physical activity measurement

Appendix A (Cont'd)

Psychology: a practicing, clinical psychologist

<u>Post Doc</u>: a post-doctorate student employed under an exercise science faculty member at time of publication

Student Groups:

<u>Undergraduate Student</u>: an undergraduate, exercise science student at time of publication

External Undergraduate Student: an undergraduate student from another discipline at

time of publication

External Graduate Student: a graduate student from another discipline at time of

publication

Internal Graduate Student: a graduate, exercise science student at time of publication

Appendix B

	A	В	С	D	E	F	G	н	1	J	к	L	М
1	Title Primary	Corresponding Author	Node Name	Collaborati	ng Authors								
2	A radiographic investigatio	Gallagher, Kaitlin M.	Gallagher,Kaitlin M.	Douglas, Eth	han C.;Galla	gher,Kaitlin	M.						
3	Accelerometer-Derived Act	Howie, Erin K.	Howie, Erin K.	Howie,Erin	K.;Smith,A	nne L.;McVe	igh,Joanne <i>i</i>	A.;Straker,Le	on				
4	Are the Neck Positions and	Gallagher, Kaitlin M.	Gallagher,Kaitlin M.	Douglas, Eth	han C.;Galla	gher,Kaitlin	М.						
5	Cardiac hypertrophy in sar	Washington, Tyrone A.	Washington, Tyrone A.	Perry,Richa	ard A.;Brown	n,Lemuel A.;	Haynie, Wes	ley S.;Brow	n,Jacob L.;R	osa-Caldwel	l,Megan;Lee	,David E.;Gr	eene, N
6	Comparison of Exercise Per	Gray, Michelle	Gray, Michelle	Stone, Matt	hew S.;Gler	n,Jordan M	.;Vincenzo,J	ennifer L.;G	ray,Michell	e			
7	Correlates of physical activ	Howie, Erin K.	Howie, Erin K.	Howie,Erin	K.;McVeigh	,Joanne A.;\	Winkler, Elisa	abeth A. H.;I	lealy,Genev	vieve N.;Buck	cs,Romola S.	;Eastwood,F	Peter R.
8	Evaluating the Suitability o	Elbin, R. J.	Elbin,R. J.	Fazio-Sumr	ock,V.;Ande	erson, M. N.;	DAmico,N. F	R.;Said,A.;Gr	oseel,A.;Sch	hatz,Philip;L	ipinski,D.;W	/omble,M.	
9	Gastrointestinal Bleeding F	Kavouras, Stavros A.	Kavouras, Stavros A.	Adams, J. D.	;Kavouras,S	stavros A.;Jo	hnson,Evan	C.;Ganio,M	atthew S.;G	ray, Michelle	e;McDermot	t,Brendon P	'.;McKe
10	Hydration status influence	Ganio, Matthew S.	Ganio, Matthew S.	Caldwell,Aa	aron R.;Tuck	er, Matthew	/ A.;Burchfie	ld,J.;Moyer	,Nicole E.;S	atterfield,Al	fZ.;Six,Ashle	y;McDermo	ott,Bren
11	Longitudinal comparison c	Gray, Michelle	Gray, Michelle	Gray, Miche	elle;Powers,	Melissa;Boy	d,Larissa;Ga	rver,Kayla					
12	Obesity, but not hypohydr	Ganio, Matthew S.	Ganio, Matthew S.	Caldwell,Aa	aron R.;Buro	hfield,J.;Mo	oyen,Nicole	E.;Tucker,M	atthew A.;B	utts,Cory L.;	Elbin,R. J.;G	ianio,Matth	ew S.
13	Observation of Women Soc	Paulsen, Kathleen M.	Paulsen, Kathleen M.	Paulsen,Kat	thleen M.;B	utts,Cory L.;	McDermott	Brendon P					
14	Postsynaptic cutaneous va	Ganio, Matthew S.	Ganio, Matthew S.	Tucker, Mat	thew A.;Cal	dwell,Aaron	R.;Butts,Co	ry L.;Robin	son,Forrest	B.;Kavouras	Stavros A.;N	/cDermott,B	Brendoi
15	Prolonged standing increas	Ganio, Matthew S.	Ganio, Matthew S.	Caldwell,Aa	aron R.;Gall	agher,Kaitlir	n M.;Harris,I	Benjamin T.	Rosa-Caldw	ell,Megan;P	ayne, Marcu	s;Daniels,Br	yce T.;G
16	Promoting Physical Activit	Howie, Erin K.	Howie, Erin K.	Howie,Erin	K.;Daniels,	Bryce T.;Gua	gliano,Justi	n M.					
17	Prospective Changes in Ves	Elbin,R. J.	Elbin,R. J.	Elbin,R. J.;S	ufrinko,Alio	ia M.;Ander:	rson,M. N.;S	chatz, Philip	;Covassin,T	racey;Much	a,Anne;Colli	ns, Michael \	W.;Kon
18	Protein imbalance in the d	Greene, Nicholas P.	Greene, Nicholas P.	Brown,Jaco	b L.;Lee,Da	vid E.;Rosa-(Caldwell, Me	gan;Brown,	Lemuel A.;P	erry,Richaro	d A.;Haynie,	Wesley S.;Hu	useman,
19	Renal stress and kidney inju	McDermott, Brendon P.	McDermott,Brendon P	McDermot	t,Brendon P	.;Smith,Cod	ly R.;Butts,C	ory L.;Caldv	vell,Aaron R	t.;Lee,Elaine	C.;Vingren,J	akob L.;Mur	noz,Col
20	Spot Sample Urine Specific	Ganio, Matthew S.	Ganio, Matthew S.	Tucker, Mat	thew A.;But	ts,Cory L.;S	atterfield,Al	fZ.;Six,Ashl	ey;Johnson,	Evan C.;Gan	io,Matthew	S.	
21	Transcriptomic analysis of	Greene, Nicholas P.	Greene, Nicholas P.	Blackwell,T	homas A.;C	ervenka,Igor	r;Khatri,Bhu	wan;Brown	,Jacob L.;Ro	sa-Caldwell	,Megan;Lee,	David E.;Per	ry,Rich
22	Effect of a Cooling Kit on Pl	Smith,Cody R.	Smith,Cody R.	Smith,Cody	/R.;Butts,Co	ory L.;Adam	s,J. D.;Tucke	r,Matthew	A.;Moyen,N	icole E.;Gani	io,Matthew	S.;McDermo	ott,Brer
23													
24													

RefWorks excel format needed to begin Python code.

Title Primary: Article title exported from RefWorks

Corresponding Author: Corresponding author identified on the associated paper.

Node Name: Necessary duplication of Corresponding Author column for Python code.

Collaborating Authors: All collaborating authors on a respective paper. Note these are in a single cell, separated by a semicolon with no added space.

Appendix C

A	В	с	D	E	F	G	н		1	К	L	M	N	0	Р	Q	R	S	Т	U
1 Dummy	Sort Title Primary respon	nding Au	Secondary	Raw Name	Node Name	uthor Text Join	thor Add Edgth	or Relations	ailed Sub Disc	psed Sub Disc	iating Sub Disci	o Sub Disciplin	Affiliation	Path ID	Path Order	Latitude	Longitude	LineX	LineY	CircleY
2	0 Gastrointestin Kavo	ıras,Stav	Adams, J. D.	Adams, J. D.	Graduate Stud	'Kavouras,Stav (G_asymmetric K	avouras,Stav (Graduate Stu	d Graduate Stu	d Physiology	Graduate Stud	University of /	University of Arkansas>University of Arkansas	2	36.0687	-94.1748	-4.03001945	3.64318033	3.64318033
3	1 Gastrointestin Kavoi	ıras,Stav	Adams, J. D.	Kavouras,Stav	Kavouras,Stav	'Kavouras,Stav	G_asymmetric K	avouras,Stav I	Physiology	Physiology	Physiology	Graduate Stud	University of A	University of Arkansas>University of Arkansas	1	36.0687	-94.1748	1.29450538	3.02274416	3.02274416
4	0 Evaluating the Elbin,	R. J.	Anderson,M.	Anderson,M.	I Graduate Stud	'Elbin,R. J.','Gra (G_asymmetric E	lbin,R. J>Gt	Graduate Stu	d Graduate Stu	d Sport Psychol	Graduate Stud	University of (University of Arkansas>University of Georgia	2	33.948	-83.3773	-4.03001945	3.64318033	3.64318033
5	1 Evaluating the Elbin,	R. J.	Anderson,M.	l Elbin,R. J.	Elbin,R. J.	'Elbin,R. J.','Gra	G_asymmetric E	lbin,R. J>Gt	Sport Psychol	k Sport Psychol	Sport Psychol	Graduate Stud	University of A	University of Arkansas>University of Georgia	1	36.0687	-94.1748	0.04603173	-1.32022779	-1.32022779
6	0 Prospective CF Elbin,	R. J.	Anderson,M.	Anderson,M.	I Graduate Stud	'Elbin,R. J.','Gra	G_asymmetric E	lbin,R. J>Gt	Graduate Stu	d Graduate Stu	d Sport Psychol	Graduate Stud	University of (University of Arkansas>University of Georgia	2	33.948	-83.3773	-4.03001945	3.64318033	3.64318033
7	1 Prospective CF Elbin,	R.J.	Anderson,M.	l Elbin,R. J.	Elbin,R. J.	'Elbin,R. J.','Gra	G_asymmetric E	lbin,R. J>Gt	Sport Psychol	k Sport Psychol	Sport Psychol	Graduate Stud	University of /	University of Arkansas>University of Georgia	1	36.0687	-94.1748	0.04603173	-1.32022779	-1.32022779
8	0 Gastrointestin Kavor	ıras,Stav	Armstrong,L. I	E Armstrong,L.	E Armstrong,L. I	Kavouras,Stav	G_asymmetric K	avouras,Stav I	Physiology	Physiology	Physiology	Physiology	University of (University of Arkansas>University of Connecticut	2	41.8077	-72.254	6.49050641	3.46312304	3.46312304
9	1 Gastrointestin Kavoi	ıras,Stav	Armstrong,L.	E Kavouras,Stav	Kavouras,Stav	'Kavouras,Stav	G_asymmetric K	avouras,Stav I	Physiology	Physiology	Physiology	Physiology	University of A	University of Arkansas>University of Connecticut	1	36.0687	-94.1748	1.29450538	3.02274416	3.02274416
10	0 Transcriptomic Green	e,Nichol	Blackwell,Tho	Blackwell,Tho	Graduate Stud	'Greene,Nichol	G_asymmetric G	ireene,Nichol	Graduate Stu	d Graduate Stu	d Physiology	Graduate Stud	University of A	University of Arkansas>University of Arkansas	2	36.0687	-94.1748	-4.03001945	3.64318033	3.64318033
11	1 Transcriptomic Green	e,Nichol	Blackwell,Tho	Greene,Nicho	Greene,Nichol	'Greene,Nichol	G_asymmetric G	ireene,Nichol I	Physiology	Physiology	Physiology	Graduate Stud	University of A	University of Arkansas>University of Arkansas	1	36.0687	-94.1748	3.2	-0.15544652	-0.15544652
12	0 Transcriptomic Green	e,Nichol	Bottje,Walter	Bottje,Walter	Bottje,Walter	Greene,Nichol	G_asymmetric G	ireene,Nichol I	Poultry Scien	o Academic	Physiology	Academic	University of A	University of Arkansas>University of Arkansas	2	36.0687	-94.1748	6.47225018	5.66138884	5.66138884
13	1 Transcriptomic Green	e,Nichol	Bottje,Walter	Greene,Nicho	Greene,Nichol	'Greene,Nichol	G_asymmetric G	ireene,Nichol I	Physiology	Physiology	Physiology	Academic	University of A	University of Arkansas>University of Arkansas	1	36.0687	-94.1748	3.2	-0.15544652	-0.15544652
14	0 Longitudinal or Gray,	Michelle	Boyd,Larissa	Boyd,Larissa	Boyd,Larissa	'Gray,Michelle	G_asymmetric G	iray,Michelle I	Physical Activ	ri Physical Activ	i Physiology	Physical Activi	University of (University of Arkansas>University of Central Okla	1 2	35.6575	-97.4709	-5.47538051	-6.02683487	-6.02683487
15	1 Longitudinal o Gray,	Michelle	Boyd,Larissa	Gray, Michelle	Gray, Michelle	'Gray,Michelle (G_asymmetric G	iray,Michelle I	Physiology	Physiology	Physiology	Physical Activi	University of A	University of Arkansas>University of Central Okla	1 1	36.0687	-94.1748	0.16141849	0.76720561	0.76720561
16	0 Cardiac hypert Wash	ington,T	Brown,Jacob L	Brown,Jacob L	Graduate Stud	Washington,T	G_asymmetric W	Vashington,T	Graduate Stu	d Graduate Stu	d Physiology	Graduate Stud	University of A	University of Arkansas>University of Arkansas	2	36.0687	-94.1748	-4.03001945	3.64318033	3.64318033
17	1 Cardiac hypert Wash	ington,T	Brown,Jacob L	Washington,T	Washington,T	"Washington,T (G_asymmetric W	Vashington, T	Physiology	Physiology	Physiology	Graduate Stud	University of A	University of Arkansas>University of Arkansas	1	36.0687	-94.1748	-2.43468723	2.65346378	2.65346378
18	0 Protein imbala Greer	e,Nichol	Brown,Jacob L	Brown,Jacob L	Graduate Stud	'Greene,Nichol	G_asymmetric G	ireene,Nichol	Graduate Stu	d Graduate Stu	d Physiology	Graduate Stud	University of A	University of Arkansas>University of Arkansas	2	36.0687	-94.1748	-4.03001945	3.64318033	3.64318033
19	1 Protein imbala Green	e,Nichol	Brown,Jacob L	Greene,Nicho	Greene,Nichol	'Greene,Nichol	G_asymmetric G	ireene,Nichol I	Physiology	Physiology	Physiology	Graduate Stud	University of A	University of Arkansas>University of Arkansas	1	36.0687	-94.1748	3.2	-0.15544652	-0.15544652
20	0 Transcriptomic Green	e,Nichol	Brown,Jacob L	Brown,Jacob L	Graduate Stud	Greene,Nichol	G_asymmetric G	ireene,Nichol	Graduate Stu	d Graduate Stu	d Physiology	Graduate Stud	University of A	University of Arkansas>University of Arkansas	2	36.0687	-94.1748	-4.03001945	3.64318033	3.64318033
21	1 Transcriptomic Green	e,Nichol	Brown,Jacob L	Greene,Nicho	Greene,Nichol	'Greene,Nichol	G_asymmetric G	ireene,Nichol I	Physiology	Physiology	Physiology	Graduate Stud	University of A	University of Arkansas>University of Arkansas	1	36.0687	-94.1748	3.2	-0.15544652	-0.15544652
22	0 Cardiac hypert Wash	ington,T	Brown,Lemue	Brown,Lemue	Graduate Stud	Washington,T	G_asymmetric W	Vashington,T	Graduate Stu	d Graduate Stu	d Physiology	Graduate Stud	University of A	University of Arkansas>University of Arkansas	2	36.0687	-94.1748	-4.03001945	3.64318033	3.64318033
23	1 Cardiac hypert Wash	ington,T	Brown,Lemue	Washington,T	Washington,T	"Washington,T (G_asymmetric W	Vashington, T	Physiology	Physiology	Physiology	Graduate Stud	University of A	University of Arkansas>University of Arkansas	1	36.0687	-94.1748	-2.43468723	2.65346378	2.65346378
24	0 Protein imbala Greer	e,Nichol	Brown,Lemue	Brown,Lemue	Graduate Stud	'Greene,Nichol	G_asymmetrix G	ireene,Nichol	Graduate Stu	d Graduate Stu	d Physiology	Graduate Stud	University of A	University of Arkansas>University of Arkansas	2	36.0687	-94.1748	-4.03001945	3.64318033	3.64318033
25	1 Protein imbala Greer	e,Nichol	Brown,Lemue	Greene,Nicho	Greene,Nichol	'Greene,Nichol	G_asymmetrix G	ireene,Nichol I	Physiology	Physiology	Physiology	Graduate Stud	University of A	University of Arkansas>University of Arkansas	1	36.0687	-94.1748	3.2	-0.15544652	-0.15544652
26	0 Transcriptomic Green	e,Nichol	Brown,Lemue	Brown,Lemue	Graduate Stud	'Greene,Nichol	G_asymmetric G	ireene,Nichol	Graduate Stu	d Graduate Stu	d Physiology	Graduate Stud	University of A	University of Arkansas>University of Arkansas	2	36.0687	-94.1748	-4.03001945	3.64318033	3.64318033
27	1 Transcriptomic Green	e,Nichol	Brown,Lemue	Greene,Nicho	Greene,Nichol	'Greene,Nichol	G_asymmetric G	ireene,Nichol I	Physiology	Physiology	Physiology	Graduate Stud	University of /	University of Arkansas>University of Arkansas	1	36.0687	-94.1748	3.2	-0.15544652	-0.15544652
28	0 Correlates of p Howie	e,Erin K.	Bucks,Romola	Bucks,Romola	Bucks,Romola	"Howie,Erin K."	G_asymmetric H	lowie,Erin K I	Psychology	Psychology	Physical Activ	Psychology	Univeristy of \	University of Arkansas>Univeristy of Western Aus	2	-31.9801	115.8179	-5.29029053	5.7273982	5.7273982
29	1 Correlates of p Howie	e,Erin K.	Bucks,Romola	Howie,Erin K.	Howie,Erin K.	"Howie,Erin K."	G_asymmetrix H	lowie,Erin K I	Physical Activ	ri Physical Activ	Physical Activ	Psychology	University of /	University of Arkansas>Univeristy of Western Aus	1	36.0687	-94.1748	-0.22246154	4.4	4.4

Sample excel workbook prepped for Tableau import.

Variable Name	Description
Dummy Sort	Two lines of information are required to represent a single relationship. The first line will be represented by a 0 and the second as a 1. 0's represent the collaborating author, while the 1's will always refer to the corresponding author for clarity. This method will be used in the python data preparation.
Title Primary	An associated journal article title will always be attached to the data if needed for future validation.
Corresponding Author	The corresponding author on a given collaboration. Duplicated information on both lines.
Secondary	The collaborating author on a given collaboration. Duplicated information on both lines.
Raw Name	Name of individual author. If 0, then collaborating author. If 1, then corresponding (see Dummy Sort).
Node Name	Same as Raw Name, unless listed as an undergraduate, graduate or post-doctorate student.

Appendix C (Cont'd)

Author Toxt Join	="""&(C2)&"",""&(F2)&""
Author Text John	*will always indicate directionality; therefore, corresponding author will be listed first
Author Add Edge	="G_asymmetric.add_edge("&G2&")"
Author Aud Euge	Edges for Python code
Author Relationship	=(C2)&">"&(F2)
Collapsed Sub-Discipline	Recognized author sub-disciplines
Detailed Sub-Discipline	More detailed information of sub-discipline/occupation prior to collapsing
Affiliation	Author's affiliation
Path ID	=(N3)&">"&(N2)
	Author affiliation connection
Path Order	Indicates order of geographical relationship. Collaborating authors (0's) are the receivers and will have
	a 2. Corresponding authors (1's) will have a 1 (see Dummy Sort).
Latitude	Affiliation latitude
Longitude	Affiliation longitude
LineX	Node placement on x-axis produced via Python.
LineY	Node placement on y-axis produced via Python.
CircleY	Duplication of LineY required for Tableau process.

Appendix D

import pandas as pd

Authors = pd.read_excel('File Location', sheet_name ="Sheet Name")

Authors

#Separate all collaborating authors into their own dummy columns. Note-There will be a lot of columns.

#Assuming all collaborating authors are in a single column.

Authors_Dummy = Authors.join(Authors['Collaborating Authors'].str.get_dummies(sep=';'))

Authors_Dummy

#After checking accuracy of dummy codes, drop the original 'Collaborating Authors' column

Authors_Dummy2 = Authors_Dummy.drop(columns=['Collaborating Authors'])

Authors_Dummy2

#MELT all dummy columns into a single data table.

#Keep in mind you will need to have all the columns that are not collaborating authors in the id_vars array

Authors_Combo = Authors_Dummy2.melt(id_vars=['Title Primary', 'Corresponding Author','UARK Corresponding Author'], var_name='Secondary')

Authors_Combo

#We only need the value = 1

Authors_Combo3=Authors_Combo[Authors_Combo['value']==1].drop(columns=['value'])

Authors_Combo3

Appendix D (Cont'd)

#Now that we have the data that we need

#Export Excel workbook

Authors_Combo3.to_excel('File Location', sheet_name ="Sheet Name")

#Open Excel and remove duplicate author relationships #=IF(Corresponding Author=Secondary,1,0) in new column #Delete 1's and Remove Column #Duplicate with Dummy Sort and add Node Name #Import Author Information

#Import Author Information

Author_Information = pd.read_excel("File Location', sheet_name ="Sheet Name") Author_Information

#Import new sheet with added nodes #make sure these are pasted with values to import correctly

Added_Nodes = pd.read_excel("File Location', sheet_name ="Sheet Name") Added Nodes

#Join Author Information to Nodes from above #Left join two data set

left_join_df = Added_Nodes.merge(Author_Information, how="left", on="Raw Name")
left_join_df.to_excel("File Location', sheet_name ="Sheet Name")
left_join_df

#Duplicate with Dummy Sort #Add text join for relationship component of node placement in new sheet #Remove duplicate entries in new sheet (add dummy column) #Add G_asymmetric.add_edge('A','B')

#Import updated Excel Sheet

import pandas as pd
Nodes1=pd.read_excel('File Location', sheet_name ="Sheet Name")

Nodes1

import networkx as nx
G_asymmetric=nx.DiGraph()

#Copy and paste all edges (ex. G_asymmetric.add_edge('Graduate Student','Graduate Student')

nx.spring_layout(G_asymmetric)

nx.draw networkx(G asymmetric)

Appendix D (Cont'd)

#Note: this export produces a .csv file and must be changed to .xlsx prior to reimport from networkx.drawing import layout layout.spring_layout(G_asymmetric) coord_dictionary=layout.spring_layout(G_asymmetric) pd.DataFrame.from_dict(coord_dictionary,orient='index').to_csv('File Location'.csv, header=None)

for k,v in coord_dictionary.items():

print(f'{k},{v[0]},{v[1]}')

#Scale coordinates to your preference #Import sheet

scaled_coordinates=pd.read_excel("File Location', sheet_name ="Sheet Name")
scaled_coordinates
#Import updated excel sheet

Updated=pd.read_excel("File Location', sheet_name ="Sheet Name") Updated

#Join discipline coordinates to sheet above #Left join two data sets #Name excel sheet to be exported

```
left_join3_df = Updated.merge(scaled_coordinates, how="left", on="Raw Name")
left_join3_df.to_excel("File Location', sheet_name ="Sheet Name")
left_join3_df
```

Adapted from the following sources:

Boothby, Kelly (2020). networkx/drawing/layout.py (version 3.8.2.).

https://github.com/networkx/networkx/blob/master/networkx/drawing/layout.py

Kapoor, A. (2018). Social Network Analysis in Python. DataCamp Community.

https://www.datacamp.com/community/tutorials/social-network-analysis-python

Appendix E



Appendix E1. Geographical representation of University of Arkansas' collaborations across North America.



Appendix E2. Geographical representation of University of Arkansas' collaborations worldwide.