RESEARCH AS INQUIRY:

A DISCIPLINE SPECIFIC APPROACH TO INFORMATION LITERACY

An Affordable Learning Georgia Continuous Improvement Grant

Acknowledgements

Special thanks are extended to Abraham Baldwin Agricultural College for aiding with implementing this grant and allowing faculty members to grow scholarly information in information literacy; and University System of Georgia for funding this project through the Affordable Learning Georgia Grant. Lastly, Scott Pierce for helping to coordinate with several departments.

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Introduction

The term information literacy has an ever-increasing definition that is being adapted daily as our lives are being inundated with more information. The Association of College and Research Libraries (ACRL) have worked tirelessly to help equip institutions of higher learning with tools to empower students to become experts at information literacy that is now necessary for success in their occupation, quality of life, and lifelong learning. The current standards have been adapted over and over to account for the dynamic nature of information and diverse needs of students (ACRL, 2015). Unfortunately, accrediting bodies that ensure standards of excellence are met by colleges that have not addressed the gaps and changes college libraries are facing with the resources necessary to ensure information literacy is adequately covered in the curriculum.

In most studies and publications on best practices, researchers recommend embedded librarians work with courses that have either a research objective or writing requirement. While this is ideal, college libraries are being faced with budget constraints and fewer professional staff members to meet the challenges. Some larger colleges are not experiencing this phenomenon as much as smaller institutions, but the hiring trends and budget allocations per full time student provides a grim view of support. Also, ideally you will see an embedded librarian with an undergraduate degree or second master's degree in the field where they are currently embedded. This best practice is becoming harder for smaller colleges to accomplish. Instead, we see librarians at smaller institutions supporting all programs and learning about new disciplines in short periods of time to support the college faculty and students.

The lack of resources both from a financial and personnel standpoint in our college's libraries has forced many faculty members to take on teaching information literacy in their courses without a great deal of support from a librarian much less actually having a librarian embedded in the course. This body of literature is to help support librarians and faculty that might not otherwise be able to incorporate information literacy into their curricula. Faculty are busy and work tirelessly with students to help them achieve context knowledge for the course. Dedicated faculty members are now responding to the critical needs of students to gain information literacy skills sometimes without more than a one-shot instruction from the college librarian. “However, it is the faculty members who design courses and who are best situated to communicate disciplinary values and the frameworks for critically evaluating the concepts, methods, and conclusions of those who engage disciplinary problems" (Stranger, 2010). It is imperative to have faculty involved in the college discourse on information literacy. Sometimes librarians forget that faculty are the content experts and are an important component in reaching students with information literacy. Without faculty buy-in, librarians must trust the students to seek out help with research and searching.

Librarians are well-equipped to help faculty with activity suggestions for classes. The issue with this is that most faculty do not think about the librarians when it comes to developing their course's curricula. The dialog between librarian and faculty must be one where the advocacy and coaching takes place. This can be difficult for librarians who are experiencing staff shortages and cuts in the university budget. "Librarians can be models for good teaching practice, while not being teachers themselves, in that they can use innovative and creative teaching methods to explore thresh-old concepts such as Information Has Value, which is a concept that can be interrelated with many disciplines and specific subjects" (Godbey, Wainscott, & Goodman, 2017).

Essentially, students need to leave college programming being able to function successfully in a community of practice. The community of practice might be a graduate program or a job situation. This has potential in influencing employers' view of hiring new graduates. Hireability has definitely become a concern for individuals looking at different programs and colleges. Ultimately information literate individuals make better citizens that are able to utilize information by locating, evaluating, and using information based on need. Information literacy is a foundational skill that benefits society as a whole. Lifelong learning is an intrinsically motivated force that supports real-world endeavors, employment activities, and educational pursuits (Currano, 2016). The process of discovering and evaluating the results suggests the goal courses should be to not just focus on critical thinking but also for students to have critical consciousness evolve over time. "Critical consciousness is critical thinking about the self (Wittebols, 2020).

Studies by Gross and Latham (2012) suggest undergraduate students are overly confident in their ability to find information and critically analyze how it is best applied. The process of search is vital to undergraduates obtaining information literacy skills (Gross & Latham, 2009). Understanding the standards and relevance of information literacy was very important for students when developing information literacy skills. “Within the hard sciences, good writers will clearly and concisely convey information, support their statements with data, incorporate credible outside sources as needed, and properly cite information from outside sources” (Thompson & Blankinship, 2015, p. 29) .

In 2000, the ACRL said that individuals that could perform the following tasks were *information literate*: decide how much information was needed, find the information, critically evaluate the sources, select information, use information effectively, and understand the issues surrounding the information (legal, ethics, economics, etc.). These standards were adopted in 2015 were to be more flexible and include broad ideologies established as overarching concepts. These ACRL standards included the following: “Research as Inquiry, Authority is Constructed and Contextual, Information Creation as a Process, Searching as Strategic Exploration, Information Has Value, and Scholarship as Conversation” (ACRL, 2015). These new standards prescribe a path for exploration instead of a step by step list. This lends itself to creating conversations between librarians and faculty on how to address learning in a more organic way that meets the needs of the discipline, course, and student. This holistic way of addressing information literacy in the classroom becomes a way of thinking.

While the ACRL has created a framework for information literacy, this project only addresses *Research as Inquiry*. Research as Inquiry depends upon asking dynamic questions that are complex and require constant revision. These questions lead to more questions and inquiry within the field. Ideas are converted to questions; questions change overtime and create more questions for discovery. The role faculty typically play in this process is one of guidance as the content expert. The faculty helps the student learn how to think within the context of the discipline and put together effective questions that can be answered. Really faculty spearhead the student’s creativity and imagination within a domain of knowledge.

Nature of Discipline Specific Information Literacy

Disciplines have shared values and concepts that students master so that they can become a participant within the community of practice. There are written guides for much of this shared knowledge. For example, citing sources in a common format is a practice that most disciplines formally accept. This is also tacit knowledge that is learned by mentorship and experiences that usually come from hands-on learning. “In order to produce information literate undergraduates in a given discipline, information literacy standards must be integrated with the values and processes of the discipline” (Winterman, Donovan, & Slough, 2011, p. 38). Information literacy infused into undergraduate curriculum helps the student be better prepared for participating in the community of practice. It is very difficult to view information literacy with generalizable lenses when the very nature of information literacy is contextual to the setting where the information is applied.

This does raise discourse between the generalizability and the discipline specific application of information literacy (Kuglitsch, 2015). Many librarians operate under the generalized list of information literacy components listed by ALA. While librarians have a graduate degree, most of the time they are asked to teach information literacy outside the scope of their educational background. Unless the librarian works with someone in the discipline’s community of practice, the librarian will only be able to speak the more common knowledge areas that apply to information literacy. Librarians are experts in information literacy, but they may not be content experts. Sometimes these gaps in understanding can marginalize faculty in disciplines that use terms associated with scientific literacy and numeracy.

Discipline specific information literacy transferability requires that outcomes for the curriculum be addressed. According to Kuglitsch (2015), if a librarian desires to provide information literacy instruction that goes beyond surface knowledge, the following concepts about a discipline must be understood, metadata, searching databases (designed for the discipline), format, authority, primary sources, information as a commodity, and lastly, the research problem. It is imperative that information literacy concepts are conceptualized for students in a way that incorporates them into the community of practice. Without a deep meaningful understanding of information literacy within the conceptual environment of the discipline, scientific settings can appear overly simplified. For example, a researcher with a PhD submitting an article for peer review will determine if the article is meaningful and valid, is an oversimplification. "Students may give too much credence to unfamiliar credentials because they sound impressive" (Kuglitsch, 2015, p. 463).

University System of Georgia

One reason information literacy incorporated into college curriculum has become more important in Georgia is due to the redesign of general education within the university system (https://www.usg.edu/redesigned_general_education). The University System of Georgia decided to create a redesign strategy that focused on student success and completion. Faculty, administrators, and industry leaders were questioned about what skills students needed at graduation to be competition for jobs and lifelong success. Critical thinking skills were one of the major considerations mentioned. Information literacy was noted as a part of the core elements redesign in mathematics, social science, science, and data fluency (Appendix A). This project was born out of the need for librarians and faculty to help support this initiative in a way that could be measured in the classroom with specific outcomes.

Abraham Baldwin Agricultural College

All of the faculty members participating in this grant are professors at Abraham Baldwin Agricultural College. It is important to include some information about the college to give the following chapters more context. The information in this project will best support small college librarians and faculty interested in implementing information literacy in the curriculum.

Founded in 1908 as the Second District Agricultural and Mechanical High School in rural Georgia, Abraham Baldwin Agricultural College (ABAC) has a long history of providing unique, hands-on learning opportunities for students. The institution is a member of the University System of Georgia (USG), which is governed by the Board of Regents (BOR), is designated as Georgia's Agricultural State

College and is fully accredited by the Southern Association of Colleges and Schools Commission on Colleges (SACSCOC) to grant associate and bachelor's degrees. The academic program offerings have expanded substantially since its founding and its 75-year tenure as an associate-degree granting institution, where initial offerings centered around agriculture, forestry, and home economics. The BOR granted ABAC status as a State College in 2006, allowing the College to offer bachelor's degrees. Over the past decade, the College has increased its academic programs to include 12 baccalaureate degrees and 4 associate degrees.

On January 1, 2018, the BOR approved the consolidation of ABAC and Bainbridge State College (BSC). The consolidation resulted in the expansion of ABAC's service area to 100 miles beyond the main campus in Tifton, extending its programmatic reach further into rural southwest Georgia via the instructional sites located in Bainbridge, Blakely, Donalsonville, and Moultrie. This consolidation has created a dynamic restructuring at the administrative level and in the classroom.

Table 1: ABAC enrollment by semester

Semester	**Total**	**Full Time**	**Full Time %**
Fall 2016	5943	3310	55.7%
Fall 2017	5140	2960	57.6%
Fall 2018	4291	2660	62.0%

In the Fall semester of 2018, 4,291 students enrolled at ABAC (see Table 1), 2,660 of whom werefull time. Although this represents a decrease from previous years, the percentage of full-time students has notably increased to 62%. The decline in students is attributed to the consolidation with BSC – as previous years' figures were adjusted to include BSC students, many of whom were enrolled in technical programs. They were removed from ABAC's rosters and transferred to the Technical College System of Georgia.

Table 2: ABAC Low Income and First-Gen Enrollment

Semester	**Pell**	**Pell %**	**1G**	**1G%**	**Pell+ 1G**	**Pell +1G%**
Fall 2016	1325	40.0%	981	29.6%	660	19.9%
Fall 2017	1258	42.5%	861	29.1%	597	20.2%
Fall 2018	1197	45.0%	808	30.4%	569	21.4%

Of those Fall 2018 students, 1,197 (45%) were eligible for the Pell grant per internal FAFSA data. Also, just over 30% of students reported they were first-generation students. A total of 569 students (21.4%) were both Pell-eligible AND first-generation. Please see Table 2 for a summary of low income and first-generation student enrollment. Student one-year retention is presented in Table 3 below. The statewide retention rate for full time students averages just under 76% over the last three years. Among State Colleges in Georgia, the rate drops to 61%. Overall, ABAC fares slightly better at 62%, on average, for the past three years. Among Pell-eligible students, the rate drops to 58%, and among first-generation students 59%. Among students who are both low income and first generation, the average retention rate drops to 57.6%. That is, **ABAC's students who are both low income and first generation are 4.4% off the pace with their peers at ABAC, and 18.4% behind the pace for their counterparts statewide.**

Table 3: Internal (Banner + FASFA) data

	All GA	State Colleges	All ABAC	ABAC Pell	ABAC1G	ABAC Pell + 1G
Fall 2014	76.0	61.5	60.9	56.4%	55.9%	**57.3%**
Fall 2015	76.0	61.5	64.1	60.0%	58.1%	**58.5%**
Fall 2016	75.7	60.0	60.7	57.5%	62.5%	**57.1%**

ABAC has 147 full-time and 45 part-time faculty, where 61% of full-time faculty hold terminal degrees. During fall 2018, 88% of courses were taught by full-time faculty. Table 4 shows ABAC's IPEDS-reported student/faculty ratio compared with other state colleges. **For the past three years, ABAC's student faculty ratio is lower than the state average.**

Table 4: Student-to-Faculty Ratios Across State Colleges in Georgia

Institution	**2016**	**2015**	**2014**
State College Average	21	26	23
Abraham Baldwin Agricultural College	**20**	**20**	**21**
College of Coastal Georgia	19	19	18
Dalton State College	21	30	29
East Georgia State College	24	28	28
Georgia Gwinnett College	18	18	19
Georgia Highlands College	21	20	21
Gordon State College	20	20	21
South Georgia State College	22	27	28

In addition to SACSCOC institutional accreditation, the A.S.N and B.S.N programs are accredited by the Accreditation Commission for Education in Nursing (ACEN). The B.S in Natural Resource Management, Forestry track is accredited by the Society of American Foresters (SAF). The B.S. Agricultural Education program is approved by the Georgia Professional Standards Commission as an Education Preparation Provider.

ABAC transitioned from a two-year program into a four-year program about ten years ago. Thecollege overall has worked tirelessly to provide programs that meet the needs of South Georgia. The agricultural community in the local area depend heavily on the excellent work many of the undergraduates do while attending ABAC. The following chapters will provide evidence of this fall. There is still more program growth needed, but ABAC focuses on what programs will best serve South Georgia with the biggest impact. **Over the past five years, ABAC has nearly tripled the number of bachelor's degrees conferred.** This is the largest area of growth for the College, as shown in Figure 1. ABAC began offeringjunior and senior level classes to 41 students enrolled in the new bachelor's degree programs in 2008.When the Fall 2018 term began, over 2,000 students were enrolled in the 12 bachelor's degree programs.The transition from an associate degree granting institution for 75 years to a bachelor's degree institution over the past decade has been extraordinary and has greatly impacted the type of academic and studentsupport services needed.

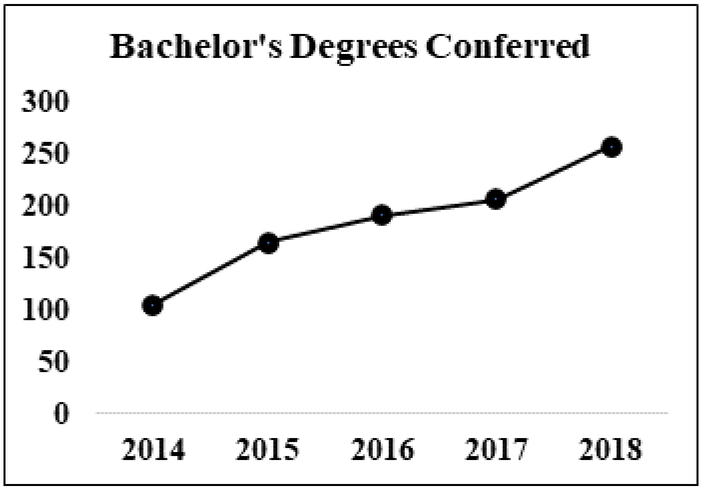

Figure 1: Bachelor's Degrees Conferred FY 14-18

Social Science

Social Science is a broad area that covers subjects such as psychology, history, and anthropology. Many of the courses for these programs have major writing requirements. This allows for faculty to evaluate how students find information, compare and evaluate information, and the student's ability to organize, apply, and communicate information within the context of the course. The ACRL has made a sandbox that addresses some of these specific disciplines.

An example would be standards for the psychology discipline. The ACRL's (2010) four information literacy competency standards for psychology are as follows:

1. determines the nature and extent of the information needed.
2. accesses needed information effectively and efficiently.
3. evaluates information and its sources critically and combines the selected information into a knowledge base.
4. uses information effectively to accomplish a specific purpose (Stanger, 2012).

Most information literacy standards for social science do not deviate far from these standards. Faculty are now tasked with finding ways to incorporate these elements into the curriculum.

Ultimately, *Research as Inquiry* provides learning experiences around information literacy that allows for seeking and reflecting on multiple perspectives during the information-gathering process (Godbey, Wainscott, & Goodman, 2017). This provides a useful tool for developing and strengthening collaborative work between the faculty and librarians focused on the process of exploring and engaging with critical information. A foundation component for this frame is the value of intellectual curiosity and problem-posing environments.

STEM

Most of the following chapters will focus on a science based discipline. While science-based disciplines differ greatly, they still follow some of the same patterns for information literacy discovery and fluency. Information literacy implementation in the sciences has uneven at best. Even in a single college, many times standards for information literacy within the curriculum can be very different in nature, quality, and format. Many times faculty will assign activities to force students to learn different information literacy skills in order to be completed. The following chapters will address chemistry, biology, and land management areas of information literacy implementation in the curriculum.

The ACRL Task Force on Information Literacy for Science and Technology established specific standards for information literacy within the context of science research that included information retrieval and recursive dynamic process for scientific discovery. The focus on the search process can help students learn and revise as they review search results. According to ACRL (2006) information literacy in relation to science, engineering, and technology is defined as “a set of abilities to identify the need for information, procure the information, evaluate the information and subsequently revise the strategy for obtaining the information, to use the information and to use it in an ethical and legal manner, and to engage in lifelong learning” (Currano, 2016, p. 4). This definition is important to keep in mind as the Information Literacy Frames are addressed in any curriculum.

Historically, many larger colleges and universities have had little difficulty fulfilling library resources for the American Chemical Society (ACS) course requirements. Large university libraries have extensive collection development budgets, and “librarians trained in chemistry or a related science, who are accustomed to teaching students the complexities of chemical information with its multitude of entry points” (Currano, 2016, p. 9). Smaller teaching colleges usually can hire one or two librarians that support multiple science related departments (Currano, 2016). The ACS has put forth a great deal of effort in disseminating information on the subject of information literacy in chemistry. There is probably no other science discipline that has more books and articles available for faculty and librarians to draw from.

A key component for chemistry students is learning how to find and review chemical literature. It is also how chemistry students learn about information literacy. Chemical information literacy is a searchable word found in publications. Information literacy is an interconnected topic that demonstrates an individual's understanding of how knowledge is used within a community of practice. Undergraduate students in STEM disciplines are offered the opportunity to participate in creating discipline specific knowledge. This creates an atmosphere where they have more responsibility to understand the contour and dynamic changing environment of information by using data and scholarship. In return, more emphasis is placed on teaching faculty to design a curriculum that fosters "engagement with core ideas about information and scholarship within their discipline" (Currano, 2016, p. 14). Librarians' role in support of this should come from their own knowledge domains, but in many cases, librarians from social science must find creative ways to enhance a cohesive curriculum and collaborate with faculty who speak a very different language.

Undergraduate biology majors have a unique opportunity to learn information literacy through scientific writing. These two skills help support them through upper-division and graduate school. Students should be able to synthesize scientific literature found in publications. Demonstrating how to utilize discipline specific information for the purpose of conducting research is essential not just for undergraduate biology majors but for all science-based disciplines. The opportunity for writing in science-based courses extends beyond research into labs, where reporting is an essential skill for all students in STEM.

Land Management as a field is very similar to Forestry and Wildlife Management. While this area of study is rooted in research, there is a lack of literature on this and other similar disciplines when it comes to information literacy. Due to the type of writing and research in this field of study, the focus is more on case studies, but the community of practice lends itself to research even at the undergraduate level. It is important to note that research papers are critical for all undergraduates due to the reporting nature of the profession. Many state and private organizations rely heavily on this skill to further knowledge and demonstrate areas of need.

Conclusion

As colleges across Georgia and the United State prepare students for life after undergraduate studies, key skills such as information literacy will play a major role in their success. Georgia is proactively addressing the skills students need for success. Information literacy is an integral part of the University System of Georgia Resign for the General Education Curriculum.

This project seeks to address information literacy in several disciplines' curriculum. Some of these disciplines have little literature support in information literacy and have solely been addressed by faculty experts in the field, while other disciplines like chemistry have a significant amount of published material to support their field in the area of information literacy. Other disciplines will need to be the focus of future projects as the University System of Georgia proceeds with the redesign implementation, however, this project provides a framework for moving forward.

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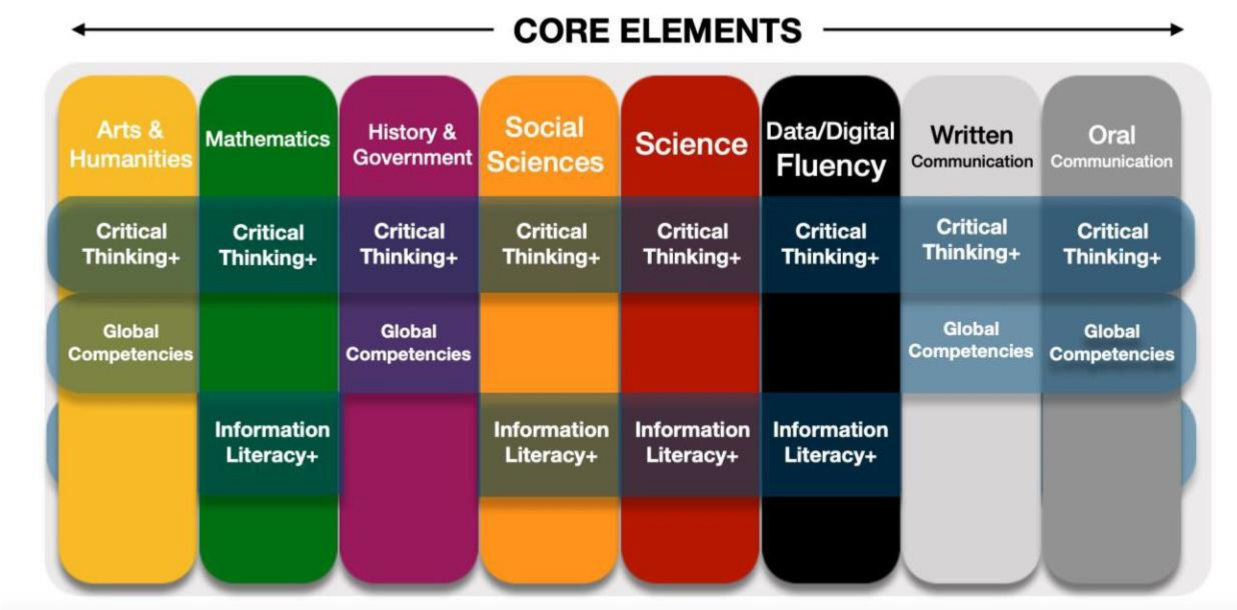
Appendix

Appendix A



(University System of Georgia, 2017).

Chapter 2: Information Literacy in Chemistry

By: Kennon Deal, Ph. D. and Scott Pierce, M.S.

Abraham Baldwin Agricultural College

I. Introduction

The chemical information landscape has changed drastically in the last 30 years. No longer do we sit in the library combing through stacks of old chemistry journals looking for the newest articles that fit our field. Now, most information is a guided computer search away at the comfort of our desk, or even on our own couch. It is now much simpler to find relevant information than it was even 15 years ago. Ever-evolving science and technology search engines replace Boolean operator searches within a generic main frame or long, finger-cracking nights at the card catalog. That saves time for many people, but I sometimes miss the feel of an *Analytical Chemistry* journal in my hand as I rifle through it.

The term 'information literacy' is directly related to the concept of 'computer literacy' and was put into common practice in the early 2000's although it is thought that it was originally coined in 1983 by Eileen Trauth of Boston University[1]. This has become such a large part of the curriculum, that many schools are incorporating literature searching as well as oral and written communication[2-4]. The *Journal of Chemical Education* designated an entire publication to this topic entitled: Special Issue: Chemical Information. *"Understanding how chemical information is published, discovered, and managed are key skills needed by students, educators, and researchers.[5]"*

Much of what is known and accessed about chemicals, structures, reactions, scientists, and prior art has been structured by the American Chemical Society (ACS). This group is the largest scientific organization in the world with over 150,000 members in 150 countries [6]. Through its 75 journals (including 12 open access), ACS has published over 1.3 million research articles, 35,000 book chapters and 1,000 reference standards. No other organization, in any discipline, has that kind of command over the literature, discoveries, and prior research. Finding that information can be a real challenge to new students. In this chapter, we will share our experiences in this ever-changing research field followed by what has been established as ‘normal practices.’

On the first day of my Instrumental Class, I go through the syllabus and lay out what I expect from my students. Inevitably, when I say, “You will be completing a research paper on a chemistry topic of your choosing,” a collective groan emanates from the class. I am pretty sure I did the same thing. Upper-level science courses often require a research paper. In my courses, I let students pick their own topic. I think it is more enjoyable (that term is relative!) to them if it is something they are interested in. When I was a student writing research papers, I picked topics based on what interested me at the time. For example, I wrote a research paper on Twin Row Peanuts as a college sophomore because a few days before the assignment, I remember driving down a country road and seeing a peanut field that looked different to me. This field had two rows of peanuts per row, and I was very intrigued (see image to the right)[7]. To research that, I used the local co-op, google, Galileo, and the library to discover many interesting journal articles about the topic as well as have useful discussions with scientists in the field. For my students, the only limitation imposed on their research assignment was that if you state it as fact, it must be cited from that journal, book, or website. Our library does a good job of obtaining multiple search platforms for the students to use. Galileo is readily accessible through the student’s IT account.

To write a good research paper will be time consuming, will take a lot of thought, will take a lot of planning, searching, organizing, writing, and citations. Oh, the dreaded works cited page! When it is finished though, it is something to be proud of. For an undergraduate, it is a necessary skill to have when a chemistry degree is completed. In fact, the Committee on Professional Training (CPT) from the American Chemical Society lists the following skills as those that students should be able to accomplish[8]:

- Efficiently locate chemical and physical properties of substances, including spectra.
- Efficiently locate references for the detection, characterization, or reactions, including syntheses, of desired compounds or classes of compounds.
- Be able to obtain information on a substance through a variety of searching strategies, including structure searching, and searching by molecular formula and name.
- Identify key references and use citation searching of articles to locate more current articles on the topic of interest.
- Complete a comprehensive subject search.
- Compile a complete bibliography of an author's publications.
- Locate recent review articles on a subject.
- Know the importance of patents and be able to search for patents on a subject.
- Use a bibliographic program to organize information and prepare a scientific paper.

Many ACS-approved Chemistry degree programs have a course dedicated to Chemical Literature. It is typically referred to as ChemLit by instructors and students. An example of a Chemical Literature syllabus has been included in the appendix. Most of that class, even 10 years ago, revolved around navigating the Chemical Abstract Service (CAS). Students learned how to locate topics of interest through a proprietary SciFinder database or hard copy in the library. The CAS contains every known article published, every chemical structure and patent, every author and every research result known to the field. Students also learned how to prepare abstracts for the service, and in so doing, how to "chase a topic to ground" (working backwards in time to the first mention of a structure, topic, discovery, or method).

Today, much of what an undergraduate student needs can be found online without the restrictions and cost of the CAS database. Authors are free to post their papers online after a prescribed period of time. Structures and identifying spectra are available for no cost from the National Institute of Standard and Technology via WebBook or through the National Library of Medicine's PubChem service[9,10]. Still, students must be guided through the literature to understand what they are looking at, why it is important and what they can (and cannot) say about it.

Students are more technologically advanced these days, more so than I was as an undergraduate. They tend to grasp the computer side of searching for topics and literature very well. They struggle with the content, however. Chemistry is not easy and there are a lot of technologies and terminologies used in the literature that confuses and frustrates them. While I do not expect my students to grasp every concept, I do expect them to be able to put together a well written research paper and to be able to explain any and all content that they include in a paper, poster, or presentation. At times, students will include a nice graph or table but not be able to explain the significance of it. The following sections will describe the common practices involved in chemical literature today for academia and the research fields of chemistry. It will be an overview of what is commonplace in today's publication as well as what is generally involved to get to a publication.

To help illustrate chemical information literacy in the classroom, I undertook a series of assignments in my CHEM 4305K (lab-based Instrumental Analysis) class. One research activity started with a general approach, asking the students what they knew about science journals. We started with a discussion about graduate school and what they thought it might be like. (Appendix Item 2) We then shifted into a discussion about information literacy, peer reviewed journals, what steps they would take to write a paper and where they would go to find information. Our next activity began the work of choosing a topic. (Appendix Item 3) I let the students work together on this. The only requirement was that it had to be within the subject area of chemistry. Our final activity was an invited speaker, our ABAC librarian, who gave a virtual information session on all the resources that are available from the library including online, in-library, and from the staff, personally. He also explained that interlibrary loans make it possible for us to obtain journals and books from other institutions as well as the many different techniques of acquiring articles that ABAC may not have a subscription for. The results of this assignment will be discussed in a later section. Below is a timeline I established for the research paper and presentations:

Timeline for Research Topic

- March 30th 2021 — Outline due
- April 8th 2021 — Rough Draft due
- April 22nd 2021 — Research Paper due
- April 27th 2021 — Poster Due
- May 6th 2021 — Presentation Due

II. Common Research Methods, Theories, and Approaches

Common chemistry experiments involve similar characteristics of any field of science that can be observed, analyzed, or collected. Examples include preliminary characterization concepts like absorbance/fluorescence, acidity/basicity, melting/boiling points, reactivity/toxicity, morphology, reduction/oxidation (RedOx) properties. More complex concepts like DNA analysis, reaction mechanisms, enzyme kinetics, surface interactions, photovoltaics or the quantum nature of particles branch off from and build on these primary characterizations into various areas of analysis and theoretical chemistry.

Chemistry research admits of a tremendous variety in research methods. These range from the simple "bench" projects to instrumental-centric projects to field sample collection to the purely computational. These can be simple and cheap or complex and expensive. Generally, chemists have no desire to re-invent, so they search and search to find out if others have done before what they are interested in. I have had many, many discussions about fantastic ideas for a compound or process only to find out that it was patented in 1900.

As an experiment is being designed, these characteristics are all used to formulate the initial literature search in various Primary Chemistry Literature journals such as the *Journal of the American Chemical Society* (*JACS), Nature Chemistry, Langmuir, Analytical Chemistry or Journal of Chromatography A*. Journals can be for a broad range of topics for a broad audience, or they can be written for a specific topic like *Lab on a Chip*, a journal designed for the study of microfluidics which is Kennon's area of research or the *Journal of Colloid and Interface Science* where Scott has published[11].

If an article has not been written about our research question of interest, then we can tune our research experiments to allow us to investigate our topic and possibly add to what others have discovered. These ideas are established and written in well-organized articles that provide the materials and methods being used such as where the chemicals were purchased and what concentrations were used, the experimental set-up which discusses the type of instrument and the parameters used for that instrument, the data that was collected along with a discussion of what the data tells the researcher and reader about that investigation. What is the take home message that was obtained from that set of experiments? The Future Work section lets others know where the investigator is headed with his/her next set of experiments. This information is extremely specific to allow for experimental replication so others can recreate an experiment to build on.

As a case in point, I will use one of Scott's projects as an example. As a grad student, he was doing forensic electron microscopy work on gunshot residue. He noticed that there were some new types of ammunition that used novel priming compounds. They did not use lead. Prior to that, all primers for metallic cartridges were known to use lead, barium, and antimony. These new compounds used strontium, potassium, aluminum, and calcium in various combinations. He wondered if they might deposit unique compounds on the skin of the person firing a gun. Since the physical chemistry of very high pressure and temperatures are known to be unique within a firearm cartridge, he supposed that these new ammunition types would also generate unique post-firing compounds based on their composition and morphology. With that kernel of an idea and with some literature familiarity in hand, he set about finding everything he could about gunshot residue detection. Over the course of a year, he gathered around 150 articles to read. In turn, that "first run" generated another 100 or so leads to other papers. When his literature survey was complete, he had gathered a solid bibliography of around 350 references and had read all of them. That depth of survey is standard practice in grad work. The investigator is responsible for finding every piece of information about the topic, materials, and methods at hand.

A clear pattern of experimentation emerged. Researchers would fire a gun with both known and unknown ammunition types, then collect samples from the hands of the person firing the gun plus samples a few feet forward of the gun's muzzle. These samples were analyzed for morphology and composition in a scanning electron microscope (SEM) with energy dispersive x-ray spectrophotometry (EDS). (This pioneer of this technique, Dr. Sam Basu, started the forensic program where Scott was working.) Using those same methods as a base, he and his advisor designed a series of experiments to answer the question: Were lead-free ammunition types likely to generate unique particles that firearms examiners could use in their work? Several commercial ammunition samples were purchased, test firings under controlled, indoor conditions were conducted, then each sample was analyzed. After about 300 hours of SEM time, a library of particle spectra (elemental composition of each particle) by ammunition type was amassed. It was now possible to say something statistically valid about the likelihood examiners would find a certain size, shape, and composition of particle on the hands of a person who shot these new ammunition types. The results were published in the Journal of Forensic Sciences[12]. The paper has been incorporated into the NIST Standard Practice for Gunshot Residue Analysis as well as many law enforcement forensic training manuals.

The approach he used is a common one: Start with a novel idea. Read the literature to see if it actually is novel. Read some more to find out how others would have tested the idea (what methods they used). Develop a new method and a series of experiments likely to answer the question, based on others' (proven) methods. Conduct experiments using both positive and negative controls to see if the method works. Once validated, conduct the research experiments.

The previous information has been largely presented from our own experiences and points of view. We would like to shift now to common approaches that are shared and generally agreed upon in the field of chemistry.

III. Recognition of Ideas and Data

The approaches to data collection can range from simple in-lab observations such as color change or temperature change to instrumental data collection such as chromatograms with HPLC that measure retention of a molecule on a column or how well a mixture of molecules can be separated. It could be remote collection of data such as what the Mars Rover is accomplishing now which is an engineering and technology masterpiece. Animals or humans could be involvedin the data collection process in the form of concentration of hormone production or simply as a physical response to a stimulus. This data could be analyzed and presented through the use of calibration curves or limits of detection (LOD) or as a means of the sensitivity capabilities of an instrument.

For example, constructing a calibration curve is a typical second year undergrad student project. It is standard Quantitative Analysis I material. This teaches the student about how to measure, how to combine measurements with a theory of data validity and how to apply these to quantify an unknown. If the student wants to know how much zinc is in hair, they would mix up a standard solution (a known and tested concentration) of zinc dissolved in hydrochloric acid. A series of dilutions would be made to reduce the concentration of zinc in acid in set increments over a range of 10x. So, a standard solution of 20% zinc would be diluted with more and more acid until a 2% solution is reached. Then, each one sample dilution is tested for absorbance of a knownlight frequency specific to zinc. The absorbance of light at that frequency is noted, along with each concentration. A curve is plotted. The curve is fitted with a linear equation ($y = mx + b$) with an error statement generated by the least squares fit R^2 value. (Any R^2 value under 0.99 is generally rejected, sending the student back to the bench.) The curve can be used to quantify unknown concentrations of zinc across this range based on the absorbance value.

Chemistry data are typically presented in *Systeme international* (SI) units (grams, liters, volts, etc…) so that all parties use a conventional system to allow comparisons to be made. With any measurement, there are errors associated with them so those need to be addressed. Typically, chemists use statistics in various forms to help us convey what limitations are encountered using Student's T tests, p-tests, confidence levels as well as identifying outliers using a Grubb's Test to see if a data point can be removed. These statistical tests allow us to compare two instruments to make sure each is reporting accurate, reproducible results. For example, a chemist wants to report how much UV light a molecule absorbs, (i.e. the absorbance of that molecule). It would be reported as 0.250 ± 0.035 to show that there is a limitation and an error associated with the results. No collected data is infinitely significant so there has to be a range in which that data can be accepted. All these experiments are driven by the Scientific Method which will be discussed in detail in a later section.

Qualitative data or sample characterizations can be quite valuable to chemists too. In some areas, characterization is a first step to further research. In other areas, characterization IS the research. For example, in developing new photovoltaic cells, researchers need to know compounds assemble on a surface. They answer questions such as: How big are the crystals formed on the surface? How far apart are they? What shape are they? What is their surface charge? How do they conduct electricity through them? How does that change when light is introduced? Answers to these questions allow researchers to accept or reject a compound or assembly.

IV. Student Identification of Ideas

As a chemistry student, learning to identify these ideas and their importance is a major task. Becoming a chemist is not just about performing an experiment and collecting data. It is about approaching a topic and designing an experiment that will provide relevant results that couldlead to bigger, more influential findings later. Early career students, such as those in freshmen Principles of Chemistry I and II courses, struggle to understand the underlying principles that leadto the design of a useful experiment. Professors at the University of Colorado established labs forfreshmen to address those issues. *"…we explore the idea of establishing information literacy at the beginning of our students' science education through the use of two general chemistry laboratory curriculum modules centered on experiment design.*[13]*"* The two modules are entitled *Exploring Scientific Literature* and *Design your own General Chemistry Laboratory Experiment.* Upper-level chemistry students, such as juniors in Research Methods, Quantitative Analysis, or

Instrumental Analysis courses, are required to work on chemical literacy concepts through a research topic assignment or via an in-lab assignment where they are required to design an experiment.

Undergraduate students should be able to conduct some parts of a Chemistry research project very early in their studies. In fact, some Course-Based Undergraduate Research Projects (CUREs) are predicated on the notion that "sooner is better" for students. The sooner they are involved, the more interested and prepared they tend to be[14]. Naturally, undergraduates need to have some basic understanding of chemistry principles, safety, and methods before they can truly understand how their work fits with the greater whole. As they develop knowledge and skills, their roles in research can expand. In large universities, a research team will be comprised of a faculty lead, a post-doctoral researcher or two, a few graduate students and several undergraduates. Everyone performs tasks according to their ability.

V. Difference Between Library Research and Lab Research

In chemistry, library research is undertaken to discover what others have done. It discusses the past tense…what has been discovered and when? What patents have been filed? What reactions will work for this or that? Lab research is about what might happen, and so is a future tense phenomenon: What is the compound like? What can be done with it? What would happen if…? Apart from the temporal delineation, library research almost never generates new knowledge for chemists. Almost all new knowledge is generated by a series of experiments designed to test or measure something. Library research is generally thought of as a literature review for chemists, a first step leading towards testing a new idea in the lab. The end result of a research project is a paper or presentation given to a peer audience. As such, the research completes the circle, filed away in a server for the next chemists to discover during an online search.

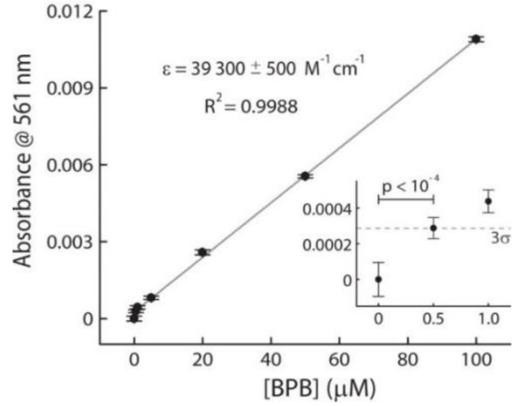
For example, perhaps a chemist wants to design an experiment using a molecule that can be detected by fluorescence. At first, the topic of interest itself may be searched such as the fluorescent properties of a molecule in general. Recent publications related to the research of interest are gathered and combed through to obtain any useful knowledge or findings. Experiments are searched to see if a particular set-up or type of analysis has already been performed. This is helpful not only to avoid duplicating experiments, but also to show what did *not* work for previous investigators. Lastly, if commercial applications are desired, a patent search is performed to see if any of the experiments led to successful creation of products or procedures. That would allow the researcher to fine tune their set-up to avoid any overlap or conflicts of interest as they prepareto commercialize their product or procedure. If one is looking to apply an older, established field to their research, then books that are specific to the material, are searched to find a more detailed explanation.

Once it is established that an experiment is novel, data can be collected in a variety of ways. Commonly, instrumentation is used to create some relationship between concentration, signal strength, response, and/or time. The actual data collection can be obtained through undergraduate researchers, graduate students, post docs or PIs. Collection can be obtained all in one setting or over a period of days or weeks. It can be collected manually through individual loading of the instruments or through automation with the help of auto samplers, electronic components that respond to feedback loops, and programmed ovens and detectors.

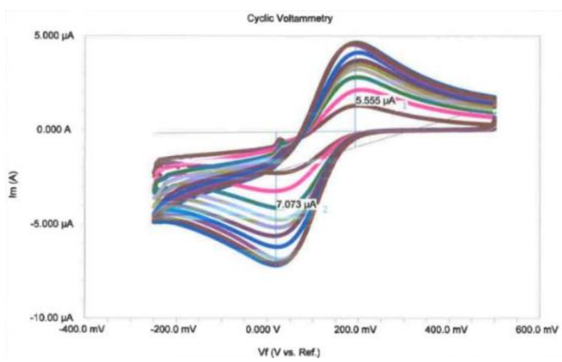
Raw data (directly from the detector) can contain noise (anything other than the signal of interest) from the environment that may hide the signal of interest so it must be modified. There are limits to the manipulation that can be done to data. For example, it is not ok to remove data points from an experiment just because it makes a calibration curve or limit of detection worse.

Once refined, that data is shared in the form of tables or graphs that provide a direct relationship to the question being asked. Some examples of chemistry instrumental data may be found below. Calibration curves (A.) are at the forefront of chemical literature as it shows how a detector increases its signal as the concentration of the analyte of interest increases[15]. Other examples are voltammograms (B.) for kinetics studies through oxidation and reduction as well aschromatograms (C.) for the separation of molecules in HPLC or GCMS[16]. Examples of each of these have been included from publications or from labs students complete at ABAC while in Quantitative or Instrumental Chemistry. Once the data has been collected, analyzed, and discussed,the research is conveyed through an article and published in a journal relevant to that particular subject area of research.

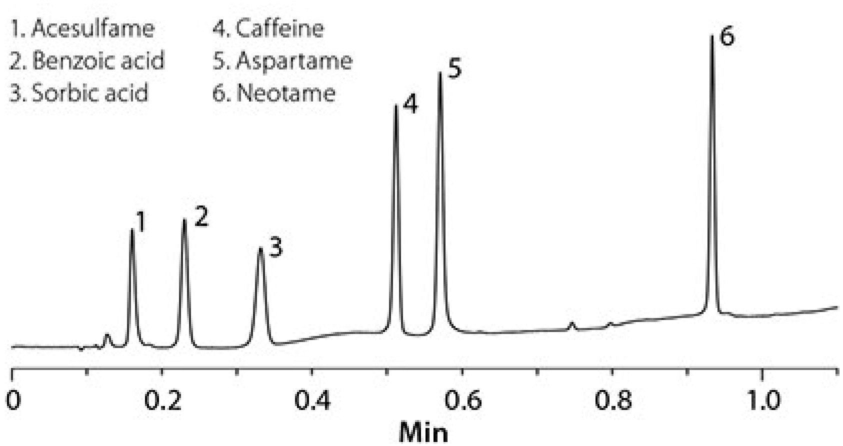
A. Calibration Curve that plots the concentration of Bromphenol Blue (BPB) vs Absorbance[15].



B. Cyclic Voltammogram plotting the kinetics and diffusion rate of a molecule during oxidation and reduction.



C. HPLC Chromatogram showing the simutaneous separation and detection of sweeteners, preservatives, and Caffeine in soft drinks[16].



The data, whether “good” or “bad” is always significant. It may not prove what you want it to but proving something wrong is still proof! In the labs, tasks are typically split betweenindividuals. Bench chemists are the machine to discoveries, but very rarely make them on their own. A typical bench chemist operates an instrument, series of related instruments, or otherwise collects data through predetermined operations. Generally, they would not be responsible for generating new ideas or conducting literature surveys. Their expertise is the technique and the instrument, as defined by others. With that said, they are an essential component in a research team. They are the ones who normally have their hands on the experiments the most and are able to report results and data most accurately. If a bench chemist conducted experiments leading to a publication, they are always cited as an author. If the bench chemist advised the research teambut did not conduct experiments, they would be listed in a journal article’s acknowledgement section. There are also technicians responsible for setting up electrical systems or advanced instruments, and there are writers that take rough drafts and turn them into publishable material. In chemistry, all effort toward a new research result is to be acknowledged. Sometimes, the sameperson wears all those hats. In other more established, larger labs, there may be different people for each task.

Increasingly, students are called upon to conduct library and lab research. Through guided coursework, they are exposed to literature searches, critiquing a peer reviewed article in which they are given an article in a field they may not be familiar with and are asked to answer several questions about the content, organization, and details of the research, planning an experiment, maintaining a laboratory notebook, creating data tables, calibration curves, chromatograms, creating and presenting a research poster and/or research talk, as well as writing several lab reports for various labs. One assignment that seems to work well is giving students a research article on a topic that they know nothing or very little about and having them critique it. It makes students think on a deeper level and demand they question everything they read. It also forces them to look up even more material that they are not familiar with which just strengthens their ability to search for topics.

VI. How Chemists Create and Share New Knowledge

As new knowledge is gained, the direction of research changes. Literary searches can set you in the right direction but inevitably, as you start to perform your own experiments, that direction will change and so will the questions you ask that you want to know the answers to. The Scientific Method points us in the right direction, providing a roadmap to new knowledge. As stated by the National Research Council, "*Although there is no universal agreement about teaching the nature of science, there is a strong consensus about characteristics of the scientific enterprise that should be understood by the educated citizen*[17]. As such, there are 4 traditional claims as established by and in science that are rationality, truth, objectivity, and realism[18]. These truths are the backbone of the scientific method and a quick search for a definition of the scientific method yields '*mathematical and experimental technique employed in the sciences. More specifically, it is the technique used in the construction and testing of a scientific hypothesis.'* The basic steps of the scientific method are listed, then described below.

<u>Steps of the Scientific Method</u>

1. Research question is established.
2. Create a hypothesis.
3. Set up and perform experiments.
4. Experiments and results provide 2 possible outcomes:

a. Hypothesis supported.

b. Hypothesis not supported.

5. Refine Hypothesis
6. Draw Conclusions
7. Report Results

First, an observation is made, and a research question is established as to why/how the observed phenomenon occurs. Second, a hypothesis is created that gives a reason why or how something occurs. A hypothesis is typically defined as an 'educated guess.' Next, experiments are designed and conducted that allows the hypothesis to be tested. The results either support the hypothesis meaning that the educated guess as to why or how something occurred is valid, or the results disprove the hypothesis and what was expected in the results did not occur. From these findings, the hypothesis and experiments can be refined to account for the new data and results and retested. This can continue until a relevant conclusion is established that satisfies the answer being pursued. Finally, the findings are reported in one of many ways ranging from a lab report up to a journal article.

There are variations to the method, but these common steps are always involved. As more information is gained from previous experiments, researchers adapt and develop more useful and specific experiments. Think of the previous research as steppingstones that create a path for new research to follow. Those scientists from other research groups and institutions may not be directly involved in an experiment, but they had a part in completing the work and getting it published so we give them credit where it is due. There are many ways to give credit. If someone is directly involved in the research, they are allowed authorship on a paper. First author is typically the individual that established the idea and did the majority of the work. The final author is the Primary Investigator (PI) which is the person that usually supplies the funding and workspace for the researcher. If contributions were made by individuals or companies but they did not directly work on the experiment, then acknowledgements are made for those. A company that supplied material for free or an individual that provided some new technique, for example, could be acknowledged. The institutions or agencies that provide the funding are also given credit. Some agencies such as the National Science Foundation (NSF) and others require the grant number to be displayed on any work in which they supplied monetary help. Finally, any previous literature that assisted in the development of the research is cited in the references.

Once the chemist's work is complete, the data collected and analyzed, the research results are disseminated to communities of interest. This normally takes the form of peer-reviewed journal articles. Depending on the importance or significance of the research, articles are typically published monthly for most journals, although some very specialized journals are published quarterly. Journals that cover a broad range of topics may publish weekly just to keep up with the pace of articles being submitted. Research articles that are considered groundbreaking may be listed as an editor's pick in that issue or they could be designated as a Rapid Communication online for immediate dissemination. All Journals are rated on what is called an Impact Factor (IF) or Journal Impact Factor (JIF) which is based on the number of citations from that journal in a designated time frame. The higher the JIF, the more 'important' a journal is considered within its field. *Nature* has an impact factor of 42.778, while *PNAS* has an impact factor of 9.412. Specific journals like *Analytical Chemistry* or *Lab on a Chip* have impact factors of 6.785 and 6.914, respectively. Anything above 3 is considered good for chemistry, while anything above and beyond 10 is considered excellent. JIF of 1 are not necessarily bad because the journals are typically very specific to their fields. For instance, the *Journal of Forensic Science* has an impact factor of around 1.4 but is the authoritative journal in the field. It is important for students to know that there is a hierarchy involved in available publications.

Below is a table of impact factor values from a variety or journal subject areas[19].

Journal	**Impact Factor**
Ca-A Cancer Journal for Clinicians	**292.278**
Science	**41.846**
Journal of Political Economy	**5.247**
Review of Financial Studies	**4.975**

VII. Experts and Research Teams in the Field of Chemistry

As a scientist remains in a sub-discipline within chemistry, publishes papers, attends talks, reviews others' papers and grant proposals, an expert in the field may emerge. There is not a certification or license process for experts in chemistry; they evolve. Various experts are established based on their years in the field and their amount of research performed. A good basis may be a citation list on their CV: How many first author papers do they have? How many publications? What about as a PI for other researchers? Have they given many talks at various conferences nationally or internationally? Have they been invited to provide articles or presentations for different journals or conferences? No matter the level of expertise, all contributions are considered significant. A typical expert in chemistry has authored 10 first author papers, 20-30 last author papers as the PI, has given 50+ conference presentations, may hold a few patents and serves as an editor for 2-3 journals in their field.

A typical research team will consist of one lead (the PI on a grant, a professor or other expert), a post-doctoral researcher or two, a few grad students, a few undergrad students and a technician or bench chemist. All may be involved in more than one project at a time, but in larger schools the post-docs and grad students work on one project at a time. Generally, research teams will meet once a week to discuss progress and get the lead's assistance during what is referred to as group meeting. The worst group meetings are always scheduled for Friday afternoon at 3:00 pm just to make sure lab members did not leave a little early to get the weekend started! All voices are heard at these meetings, the PI or research lead drives the project. It is their idea that generated the money, their name on the line, their space, their people, and their supplies to carry out the work. As such, they are ultimately responsible and garner the most credit.

VIII. Student Research Assignments in the Field of Chemistry

The research assignments provided give the students a chance to build a foundation that will help them become better scientists. As they grow as students, the assignments grow. It is a means for them to learn and develop as scientists. Some colleges involve only graduate students in the research while other colleges known as Primary Undergraduate Institutions, (PUI) rely exclusively on undergraduates to perform all the research and write up publications., we involve students in research projects from their first semester. Hope College in Michigan is a great example of a PUI[20].

The basics of chemical literature is a good starting point. Here are a few examples of how the assignments grow as students become more experienced. CHEM 1211/1212 (Principles of Chemistry I and II, the first two chemistry classes, usually taken by first year students) students are assigned a 1-page write up where they must describe a process they have observed but did not understand. They are to go find out why that process happens and turn it in for a grade. Another assignment that works well is assigning them a presentation. Most will dread it, but they will usually put the effort in to do a good job. Some students are just naturally comfortable being the center of attention, while others prefer doing all the work in a group setting and letting someone else present the material. For example, 3000- level (third year) biochemistry students must give a presentation to the class on a biochemical molecule of their choosing. This assignment requires them to have a better understanding of the fundamentals of science, how to search for and cite resources, and to be prepared. By the time students are in their fourth year, they should have a very good familiarity with chemical literature and scientific papers. With that in hand, they are ready to design and execute a small research project. The research assignment presented to CHEM4305 (fourth year) Instrumental class that was alluded to earlier is a great example of a success. Although they did meander about it at first, they eventually worked together to come up with a topic and put together a decently written research paper complete with poster and presentation. The project chosen by the students originally started by researching the graphene content in paintand how that kept vehicles clean. After reviewing articles, the project shifted to how graphene isused to remove salt from water using solar energy. To assess their work, a bi-modal evaluation strategy was employed. The instructor grades the posters and presentations and the students also graded each other, based on the following rubric.

This poster presentation is worth 100 Points. For each section below, choose the point value that you think the presenter(s) deserve(s).

Organization	21	22	23	24	25
Content	21	22	23	24	25
Explanation of Topic	21	22	23	24	25
Poster is Visually Appealing	11	12	13	14	15
Interaction with Audience	6	7	8	9	10

____Total________

Most of the time, the students grade harder than the professors do! There were a few areas that were lacking in both the paper and presentations, but the literary aspect of it was a solid B paper in that they provided a hypothesis, provided the literature to support their findings, demonstrated an understanding of the techniques used as well as what the graphs, tables, and illustrations meant, and were able to draw conclusions based on the authors' results and discussion. There were some deadline issues as well as some misplaced images and citations which cost them some points as well as a few issues with the poster presentation. Overall, the final product the students produced cab be considered a success. It was well written and well organized. Material submitted by the students for this research assignment has been included in the appendix as follows:

Research Paper:	Item 4
Poster:	Item 5
Power Point Presentation	Item 6

Once students get into graduate school, they have the classroom, laboratory, and literature basics that will allow them to join a research group. They may start out washing glassware, then they move up to preparing samples. A literature review is typically assigned to students for a new project being developed. Eventually, designing the experiments, operating the instruments, collecting data, and training new lab members becomes the everyday tasks. Finally, they write an article to be read by someone doing their first chemical literature search and the cycle continues!

IX. Conclusion

What is the importance of Chemical Literacy? Where is it headed in the next 20 years? We have seen major advancements in search capabilities as well as availability of information. New search systems such as Yewno which is a semantic language search engine are already on the market and available to use[21]. We believe the importance of chemical literacy can be explained as follows. It is no longer possible to be accepted to a graduate program on just academics. Multiple students with 4.0 GPAs have been denied acceptance to various programs. Today, programs are looking for students who have attended Research Experiences for Undergraduates (REUs), who have publications, who have attended conferences already[22]. That is a driving force for promoting and encouraging Chemical Literacy not only in freshman chemistry classes, but it stands to reason that an introduction in high school chemistry classes would be relevant as well.

X. References

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Appendix

Item 1

CHEM 2900 Principles of Chemistry Research BCHM 2910 Introduction to Biochemical Research

Course Description: This online course will allow students to explore many topics including career options for biochemists & chemists, scientific ethics, scientific research skills (Galileo, GSU library, and internet databases) computer skills (Excel, Word, RasMol/Protein Explorer), laboratory safety, resume writing, and scientific material presentation skills. This course allows you to work at your own pace, butthere are weekly deadlines for quizzes and assignments, as well as exams. Students may choose to complete all assignments before the end of the term.

Required Texts:

-- ACS Style Guide, Anne Coghill and Lorrin Garson, Eds, 3rd Edition, 2006, ISBN 978-0841239999 (***supplied electronically as pdf file***)

-- On Being A Scientist, 3rd Edition, National Academy of Sciences, et al, 2009, ISBN 0309119715 (***supplied electronically as pdf file***)

-- The Immortal Life of Henrietta Lacks, Rebecca Skloot, 2011, Broadway Paperbacks, ISBN 978-1-4000-5218-9 (***excerpt supplied electronically as pdf file***)

Required Computer Program: --Each student must have access to Microsoft WORD, Excel, and Powerpoint. Not "***open***" similar versions the real deal. You do not have to purchase them but you needto have access in some way to these computer programs.

Objectives: Students will

1. Examine the various careers for biochemists & chemists
2. Be introduced to various post-graduate options for BS chemists & BS Biochemists including how and when to apply
3. Gain chemistry-oriented research skills necessary for the profession
4. Gain chemistry-oriented computer skills necessary for the profession
5. Be introduced to proper laboratory safety including waste handling
6. Gain oral and written presentation skills for various venues

Learning Outcomes: Students will

1. Develop an understanding of the various career fields/option available
2. Write a resume/personal statement/CV
3. Execute a search of the chemical literature
4. Identify and avoid plagiarism, understand scientific ethics, and properly reference sources in standard journal formats
5. Use the correct format and voice for scientific writing
6. Demonstrate mastery in the use of Excel for data gathering, analysis, and statistics
7. Demonstrate mastery in the use of Word for writing technical reports including use of data tables, inserting figures, and the equation editor

8. Demonstrate mastery in the use of drawing software for chemical molecules and inserting theserenderings into Word reports
9. Read and interpret MSDS sheets
10. Properly label chemicals and materials handling outside of routine laboratory conditions
11. Classify and handle wastes
12. Appropriately use and care for routinely encountered laboratory equipment
13. Understand how to present scientific information to an audience of peers in both written and oralformat

GENERAL COURSE POLICIES

Academic Integrity: The integrity of the educational experience is diminished by cheating in class, plagiarizing, lying and employing other modes of deceit. None of these should be used as a strategy to obtain a false sense of success. I will not tolerate cheating in any form, and will punish transgressors tothe fullest extent possible (i.e., an F in the course).

Accommodations: If you have special needs, contact the Director of the Student Accessibility ResourceCenter for assistance at (912) 478-1566 or Video Phone: 225-9877 or email sarc@georgiasouthern.edu.

Exams: Exams will be given electronically via folio. There will be 4 take-home, open book, open note exams during the semester worth 25 points each. The exams will be timed and set for 1 submission only.Once you have begun an exam, you must finish it in the allotted time. You should not seek help or assistance from anyone when completing these exams. No makeup exams will be given and a score of “0” will be assigned for any missed exam.

Quizzes: Electronic quizzes in folio will cover assigned readings, self-study modules, and other assignedmaterials. The quiz scores will be averaged to give a final quiz grade. No makeup quizzes will be given.

Grading: A total of 1000 points are available for you to earn in this course. Final course grades will bedetermined by performance on these Components (assignments, quizzes and exams) as follows:

Components	**Points**
M1 Safety: Safety Assignment	100
M2: Scientific Ethics	50
M3 Info: Chemical Information	100
M4 Word: (Scientific Word)	75
M5 RasMol: (Visualizing Molecules)	75
M6 Careers: (Plan A and Plan B)	100 – 50 points each
M7 Resumes: (Resume and Personal Statement)	100 – 50 points each
M9 Excel: Excel Assignments	200 – 50 points each
Exams	100 – 25 points each
Quizzes (average of all quizzes)	100
Total	1000 points total

Grading Scale

A = 90%, B = 80%, C = 70%, D = 60%, F

Item 2.

Deal

CHEM 4305K

ALG Grant Activity

Peer Reviewed Journal Articles and Resources

"As a peer reviewer, your job is not to provide answers. You raise questions; the writer makes the choices. You act as a mirror, showing the writer how the draft looks to you and pointing out areas which need attention." - **S. Williams,** University of Hawaii at Manoa's Writing Program

The following activity will be a discussion in the classroom with students.

1. If someone asked you to think of chemistry graduate school, what picture would come to your imagination? Draw that picture. (Roughly)

2. What is your understanding of information literacy?

3. What is your understanding of a peer reviewed journal?

4. What steps do you think are required to write a peer reviewed article?

5.

a. If you had a research topic in mind, where would you go to find information?

b. What would you look for?

Item 3.

Research Paper

You will be writing a research paper this semester over a topic of your choice in the subject area of chemistry. That is a broad area so picking a topic will be the first major step.

1. Brainstorm.
    a. Make a list of several ideas, then do a quick search.
        i. A classroom discussion
        ii. A news story
        iii. A movie, tv show, or YouTube video.

2. Pick a topic that you are interested in.
    a. It will be hard to write a paper on science that you care nothing about.
    b. It will difficult to stay focused on science that you care nothing about.

3. Pick a topic that you may not know much about.
    a. If you are interested, but not well versed, your natural curiosity will drive you to learn more. (You are a science major for a reason. And not just because you want to go to a specific post graduate school.)

4. Niche topics are interesting, but sometimes there is not much information out there.
    a. Here is where it is tricky. If you find a super specific topic, it may be fantastically interesting, but there may be very little information about it.
    b. Your quick search in the brainstorm portion should help you with this.

5. Be flexible.
    a. Once you start, you may have to adapt your topic in order to handle the material or expand to get enough information.

Here is a link to a paper from Southwestern University in Georgetown, Texas. I have included a small excerpt from it that pertains to us.

https://www.southwestern.edu/live/files/4169-guide-for-writing-in-chemistry.pdf

Item 4.

The Importance of Graphene on Solar Desalination of Water

Angel Gibbons & Denny Dang

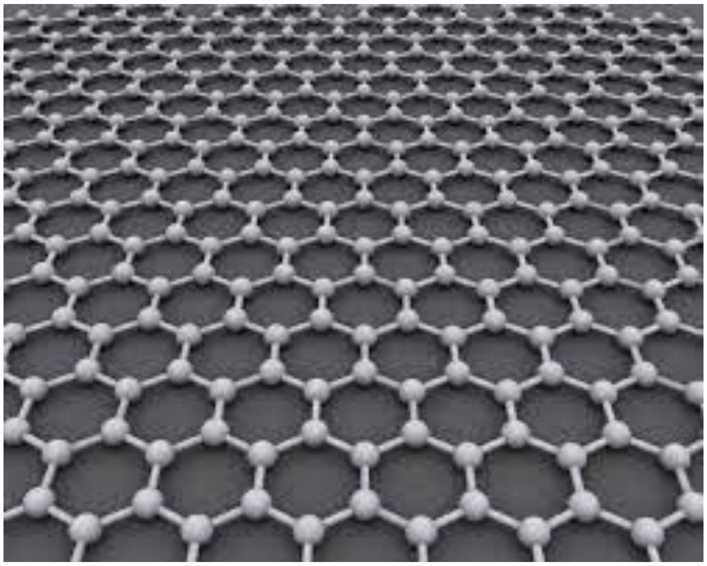
Chem 4305

Dr. Kennon Deal

Introduction

Graphite is a naturally occurring form of crystal carbon that is composed of single layers of graphene. Collins Brodie sparked the interest of the study of graphite when he discovered the layered nature of reduced graphite[2]. Hanns-Peter Boehm and his colleagues were the first scientists to discover single graphene sheets by using transmission electron microscopy and X-ray diffraction[2]. After their discovery, the term graphene was used in 1987 to describe single sheets of graphite[2]. Scientists knew that one atom thick graphene existed in graphite, but they were not able to separate it from graphite until 2004[3]. Two researchers Professor Andre Geim and Professor Kostya Novoselov from the University of Manchester separated graphene from graphite using adhesive tape[3]. This technique is referred to as micromechanical cleavage or scotch tape technique[3]. They used scotch tape to extract layers of graphene then the layers were added to silicon substrate for further analysis[3]. After extraction they used few-layer graphene (FGL) the scientists were able to demonstrate electronic properties by applying electric volts to the material[3].

When you talk about recent industrial advancements in technology the word carbon fiber may have been mentioned. Carbon fiber is a weave composed of carbon, nitrogen, and oxygen that ranges from 5-10 micrometers thick, carbon fiber often forms thin sheets that are stacked and formed to complex shapes. Carbon fiber is a highly sought after material when it comes to the many types of applications that it provides. Through the advancements in technology over the years the nitrogens and oxygens were able to be removed, this advancement allows for the creation of graphene which is composed of completely carbon atoms. Graphene is the thinnest material known to man[2]. Graphene is a two-dimensional allotrope of carbon consisting of a single layer of atoms arranged in a two-dimensional honeycomb lattice that resembles chicken



wire[2]. Each carbon in graphene is covalently linked to three other carbons[2]. Graphene is incredibly strong and is thought to be about 200 times stronger than steel. There are multiple structural features that contribute to the strength of graphene. Graphene exhibits sp^2 hybridization which causes delocalization of electrons flowing through positively charged carbon atoms[2]. This difference in charge creates a strong electrostatic attraction that holds graphene together. Graphene is only one carbon layer thick which allows it to be extremely flexible[2]. The flexibility without breaking the component of a graphene sheet is the main contributor to the strength of the compound[2]. Graphene is a heat and electrical conductor[4]. Graphene has the ability to act as an insulator or a semiconductor[4]. Bilayer graphene can act as an insulator which means it completely blocks electrons from flowing[4]. This is accomplished due to spontaneous symmetry breaking that is accomplished due to less electrons being present in the material and allowing them to behave in an orderly manner[4]. Band gap also contributes to whether graphene acts as an insulator or a semiconductor[4]. Graphene as a single layer has a small gap or no gap which allows it to be a semiconductor[4]. When a larger gap is present, normally in multilayer sheets of graphene, the compound acts as an insulator[4]. Graphene is a nonpolar compound that is thought to be hydrophobic[4].

Graphene oxide (GO) is a compound of hydrogen, carbon, and oxygen[7]. This compound can be obtained by treating graphene with strong oxidizers and acids[7]. The oxidized product is a yellow solid that retains the structure of graphene but is much larger and possesses irregular spacing[7]. GO is a hydrophilic compound which allows for water to insert itself in between sheets. The amount of water GO can absorb is dependent on the synthesis method used to make it as well as temperature of the environment[7]. Graphene oxide sheets have been used to prepare membranes, paper like materials, thin films, and composite materials[7]. Graphene oxides properties such as porosity and hydrophobicity can be modified for the purpose it is intended to serve. GO has been used in water distillation since the 1960s due to the versatility it can achieve based on how it is synthesized[7].

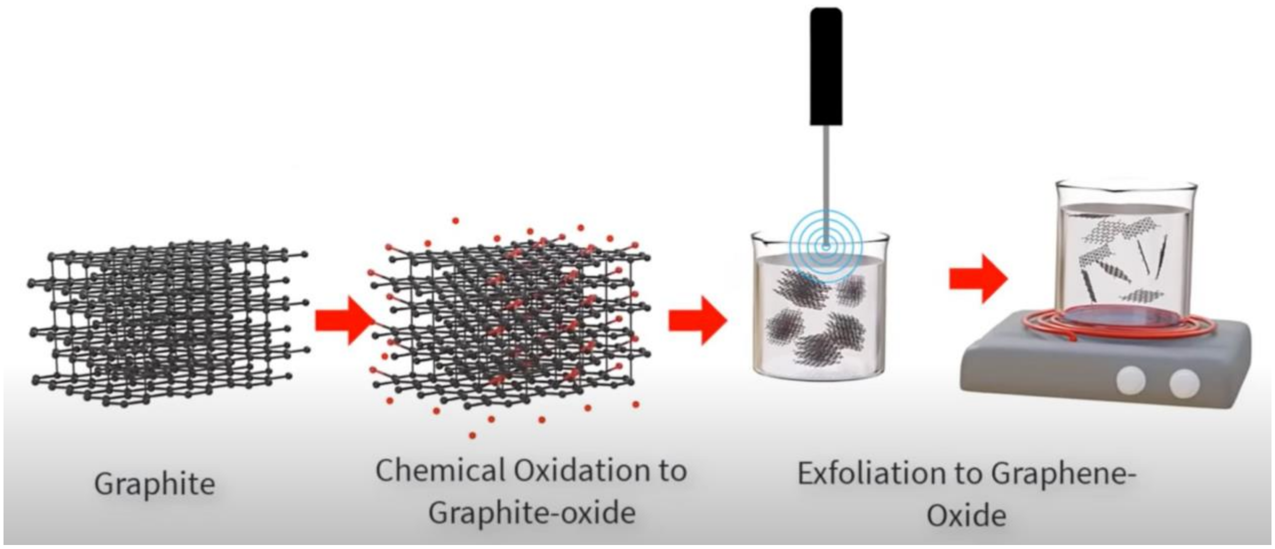


Figure 1: Hummers method in turning graphite into graphene oxide

Hummer's method was developed in 1958 and was presented as a faster, safer, and more efficient method of producing graphite oxide (GO)[6]. Before this method was developed the production of GO was a slow and hazardous process due to its use of sulfuric and nitric acid[6]. Hummer's method is the most widely used method to make graphite oxide because it is the fastest conventional method of producing GO that also maintains a high carbon to oxygen ratio[6].

Hummer's method is a chemical process used to separate graphite or graphene oxide through the addition of potassium permanganate to a solution of graphite, sodium nitrate, and sulfuric acid[6]. The chemical reaction in this method is the oxidation of graphite which is achieved by introducing molecules of oxygen to pure carbon graphene[6]. The reaction occurs between the graphene and the concentrated sulfuric acid, and the potassium permanganate and sodium nitrate act as the catalyst[6]. At maximum, this process can yield 118g of GO per 100g of graphite used. The ratio between carbon to oxygen varies between 1 to 2.1-2.9. On average the typical product is 47.06% carbon, 27.97% oxygen, 22.99% water and 1.98% ash with a carbon to oxygen ratio of 2.25[6].

In the recent studies of graphene, PTFE (polytetrafluoroethylene) membranes were modified with graphene in order to purify and desalinate water when exposed to solar radiation. Polytetrafluoroethylene (PTFE) is a synthetic fluoropolymer of tetrafluoroethylene. PTFE is a high molecular weight polymer containing carbon and fluorine[5]. An important feature of PTFE is that it is hydrophobic, which contributes to its versatile list of uses. PTFE is naturally hydrophobic due to it's low coefficient of friction, the coefficient of friction for PTFE is the third lowest of any known solid material[5]. PTFE is a thermoplastic that is solid at room temperature and has a relatively high melting point at about 600K, PTFE is used in the non-stick coating of pans and other cookware. PTFE is used as a lubricant and reduces friction, wear, and energy consumption of machinery. PTFE membranes are expanded PTFEs into a 3-D web-like porous structure[5]. This structure allows for particles to stick on the membrane surface due to its hydrophobic and nonstick nature. PTFE has been introduced as membrane filters in quantitative chemistry for its durability and it's aggressive approach to filtering out particulates[5].

With the prevalence of pollution and water shortages solar desalination is thought to be an effective solution to produce clean water without extra energy input[1]. Photothermal membrane distillation (PMD) uses polymer membrane along with a solar vapour generation system to improve the water collection ratio as well as the solar-water energy efficiency[1]. The membrane is a physical barrier to separate vapour molecules from water. The typical solar water efficiency in PMDs is typically at 45-53.8%[1].

Over the past five years scientists have continued to expand on graphene and solar energy in water desalination and have discovered different things. Ghamesi et al., developed a double layer structure of carbon foam and exfoliated graphite that efficiently localized solar energy and minimized heat losses. This demonstrated enhanced thermal efficiency under-one sun illumination. Ren et al., was able to achieve enhancement of broadband and omnidirectional absorption of sunlight using hierarchical graphene foam, which allows for a considerable elevation of temperature. Li et al., studied a foldable graphene oxide film-based solar desalination device. This device proved to have a two-dimensional water supply and suppressed thermal loss and could achieve an efficient solar desalination. The above-mentioned articles revealed that by localizing solar energy solar absorbing molecules can achieve efficient and fast evaporation response under one-sun elimination. For practical water treatment applications, a more efficient system of solar desalination is needed. There is nothing stopping the vaporized water from reentering the original brine decontaminating the water. A simpler way needs to be created to collect the condensed water before it enters the brine, this could be achieved by combining the properties of PTFE and graphene oxide to create a controlled filtration device.

Body

This paper worked to demonstrate that the immobilization of graphene oxide on a hydrophobic PTFE membrane surface can be used to construct a fast and efficient solar desalination system under one-sun illumination[5]. It was concluded that the surface of the GO film may be reduced rGO under direct sunlight due its color change after the membrane was repeated several times as seen in figure three. The PTFE membrane and the GO/PTFE membrane composite films showed great mechanical integrity without noticeable changes despite being continuously folded thirty times[5]. This component of flexibility and foldability is endured in the films and is very beneficial for the development of large scale solar distillation[5].

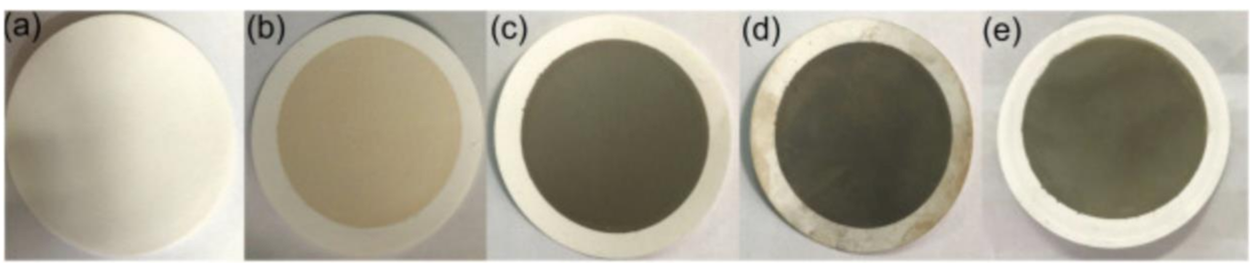


Figure 3: Photographs of (a) original PTFE membrane, (b) GO/PTFE membrane, (c) rGO/PTFE membrane, (d) pDA-rGO/PTFE membrane and (e) GO/PTFE membrane after several experiments[5]

The contact angle of each film was tested, the angle quantifies the wettability of each surface. The water contact angle for the original PTFE membrane was 117°C and significantly larger than the other membranes[5]. This indicates the PTFE membrane has the highest hydrophobicity, which was expected[5]. The pDA-rGO membrane possesses the smallest water contact angle which is 46°C[5]. This was due to the membrane becoming highly hydrophilic due to the hydrophilic catechol and amine functional groups of the pDA coating layer. The GO/PTFE membrane showed an initial contact angle at 57°C but after several experiments were run it was increased to 64°C. Showing that the GO/PTFE membrane is unstable and would most likely degrade over time with industrial usage[5].

In the experiment four evaporation systems were studied and their mass loss was recorded and displayed in figure 2. The membranes used were bare PTFE membrane, GO/PTFE membrane, rGO/PTFE membrane, and pDA-rGO/PTFE membrane[5]. Figure 2a shows the evaporated water mass loss for the four membranes without light[5]. The water evaporation in the GO/PTFE membrane was larger than the others indicating that the GO immobilized PTFE membrane can enhance the overall permeate flux[5]. The thermal conductivity of GO is lower than the PTFE membrane, contributing to the membranes having low thermal conductivity results in the reduction of temperature polarization and heat diffusion across the membrane, which further enhances the water evaporation flux[5].

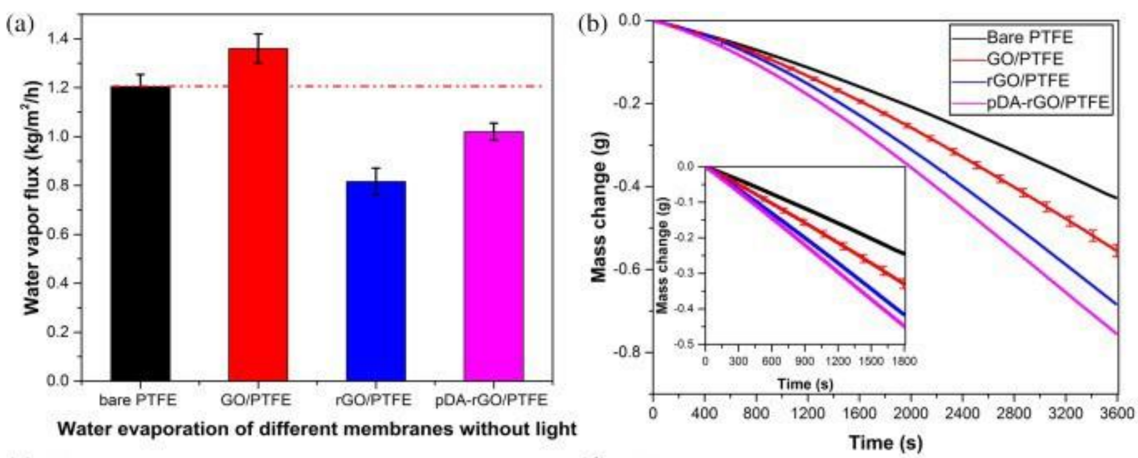


Figure 5: (a) The evaporated water vapor flux with bare/GO/rGO/pDA-rGO PTFE membranes without light. (b) The DI water evaporation mass loss with bare/GO/rGO/pDA-rGO PTFE membranes under one-sun illumination. The inset shows the stable water evaporation mass change after 30 min[5].

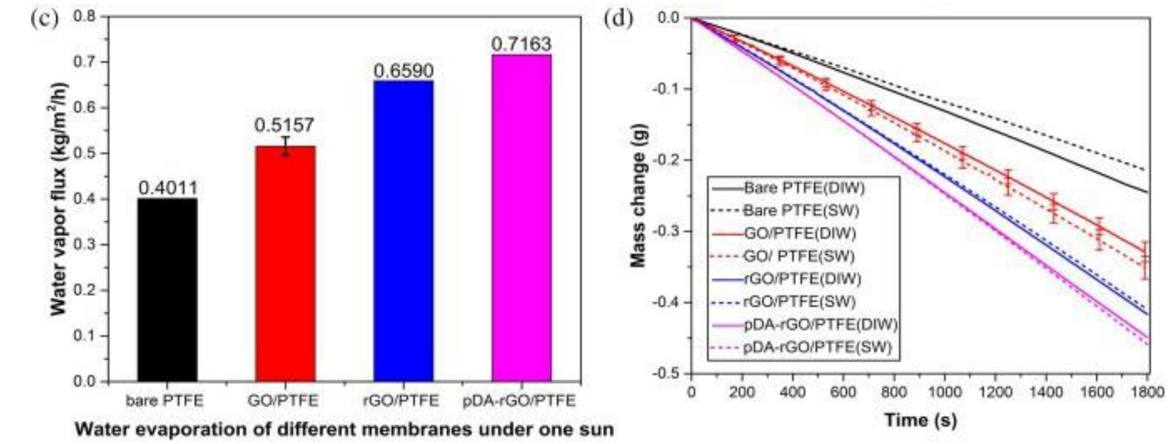


Figure 6:(c) The comparison of stable evaporated water vapor flux with bare/GO/rGO/pDA-rGO PTFE membranes under one sun. (d) The comparison of evaporation mass loss between DI water (DIW) and salt water (SW) with bare/GO/rGO/pDA-rGO PTFE membranes under one-sun illumination[5].

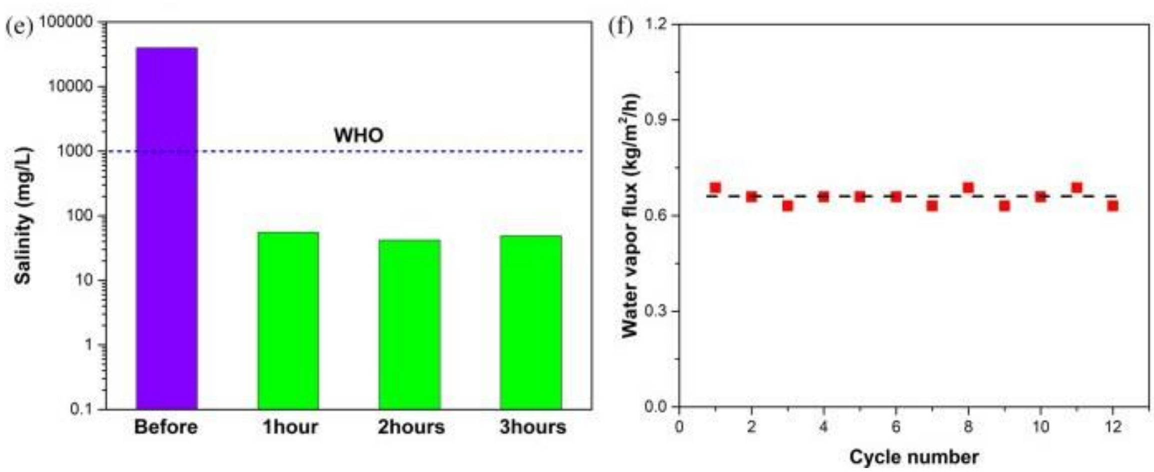


Figure 7: (e) Measured salinities of the 4% NaCl solution and desalinated water after different desalination time. The WHO standard for the available water was indicated by the dashed line. (f) The evaporation cycle performance of 4% NaCl solution with pDA-rGO/PTFE film under one-sun illumination[5].

Experimental

GO was prepared by using a modified version of Hummers method[5]. Natural flake graphite powder was exposed to a mixture of sodium nitrate, concentrated sulfuric acid and potassium permanganate for oxidation[5]. Three membranes were prepared GO, rGO and pDA-rGO. Surface morphology, hydrophobicity, and functional group of all three membranes were tested[5].

Figure two displays self-made apparatus where the water transmembrane evaporation was carried out. The apparatus contained three parts; the first piece was an upper transparent PPMA container where a certain volume of water was stored[5]. The second piece was a membrane part where the prepared graphene-base materials modified PTFE film was mounted, this was the site of water vapor penetration[5]. The third piece was a bottom support frame where the evaporation container was placed and the weight change of the whole system caused by water evaporation was monitored by an electronic analytical balance[5].

A solar simulator was used to generate the one-sun illumination beam. All three films were run through the apparatus in figure one. The evaporation of each membrane was tested with and without the presence of light to get an accurate evaluation of the performance of each film[5].

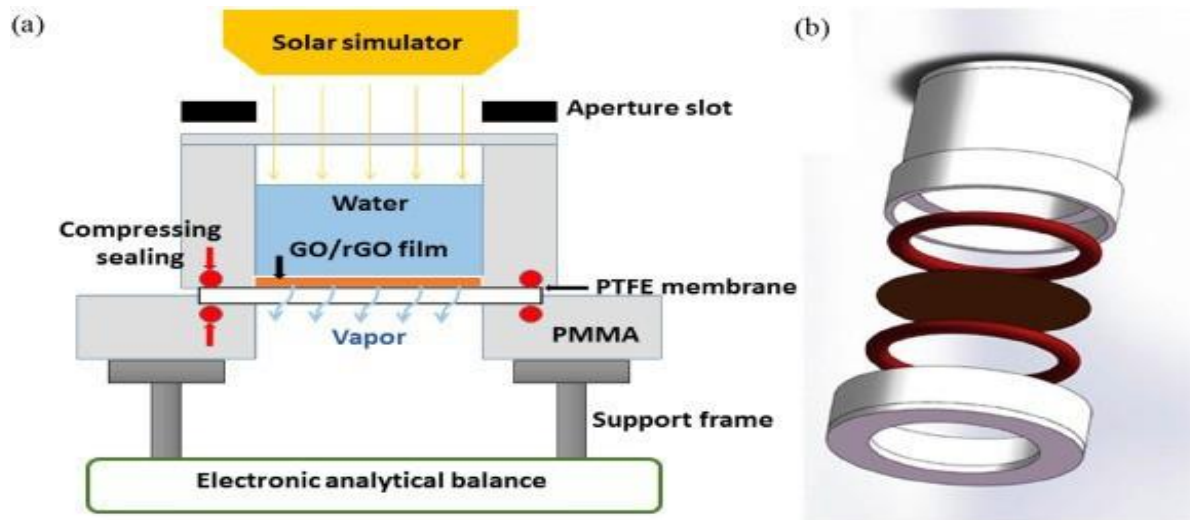


Figure 2: Schematics of water transmembrane evaporation experiments (a) The experimental apparatus with the solar simulator. (b) The set up for solar steam generation[5].

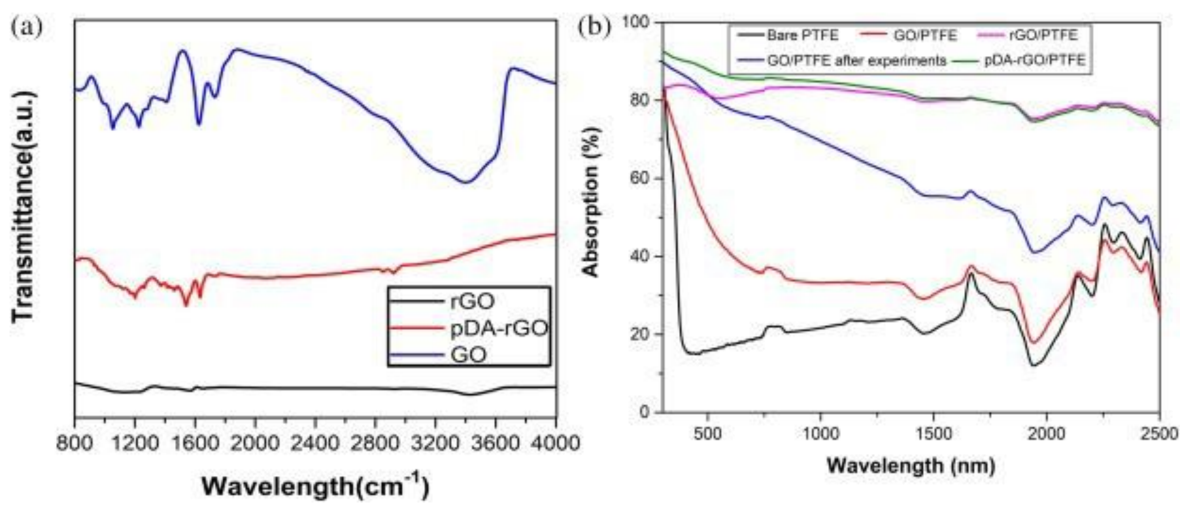


Figure 4: (a) Fourier transform infrared spectroscopy spectra of GO, rGO and pDA-rGO membranes. (b) The absorption spectra of different composite membranes in the wavelength range of 300 nm to 2500 nm[5].

Conclusion:

PTFE membranes are currently used to filter salt from the water in the process of photothermal solar distillation which is highly inefficient. Through the process of coating the PTFE with reduced graphene oxide the energy conversion of the solar radiation was improved approximately 79%. In the article written by Huang and his partners, Huang used several methods to synthesize Graphene oxide and then dispersed over a PTFE membrane. In this process they were to be able to make a coated filter that shared characteristics from each material. The filter had a high durability which would allow it to withstand industrialization, with the added filtration of Graphene oxide the membrane is able to separate up to 40,000 ppm NaCl concentration. With the ability to separate the such small concentrations and being able to improve by a substantial amount it would be correct to conclude that the experiment was successful and that it set the baseline for future experiments to be expand on.

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Item 6.

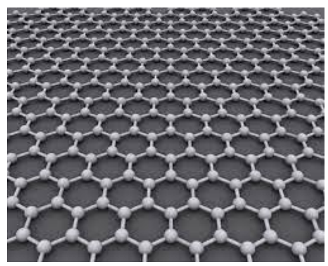
The Importance of Graphene Derivatives and PTFE Membranes on Solar Desalination of Water

Angel Gibbons
Denny Dang

What is Graphene

-Graphite is a naturally occurring crystal carbon that is composed of single layers of graphene.

- Graphene is a two -dimensional allotrope of carbon consisting of a single layer of atoms arranged in a two - dimensional honeycomb lattice that resembles chicken wire



Properties of graphene

- Graphene is incredibly strong and is thought to be about 200 times stronger than steel
- Graphene is only one carbon layer thick which allows it to be extremely flexible
- Graphene is a heat and electrical conductor
- Graphene has the ability to act as an insulator or a semiconductor
- Graphene has tightly bound bonds that can even prevent gas from diffusing through

Graphene oxide

-Graphene oxide (GO) is a compound of hydrogen, carbon, and oxygen

-The oxidized product is a yellow solid that retains the structure of graphene but is much larger and possesses irregular spacing

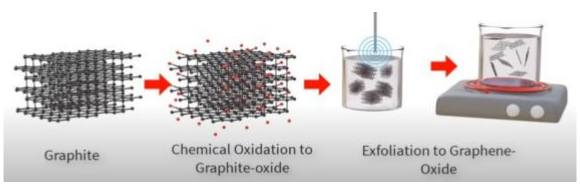
-Graphene oxides properties such as porosity and hydrophobicity can be modified for the purpose it is intended to serve

-GO has been used in water distillation since the 1960s due to the versatility it can achieve based on how it is synthesized

Hummer's method

-Hummer's method w as developed in 1958 and w as presented as a faster, saf er, and more efficient method of producing graphite oxide (GO)

-Hummer's method is a chemical process used to separate graphite or graphene oxide through the addition of potassium permanganate to a solution of graphite, sodium nitrate, and sulfuric acid



PTFE (polytetrafluoroethylene) membranes

-Synthetic fluoropolymer of tetrafluoroethylene

-PTFE is hydrophobic due to its low coefficient of friction

-PTFE is a thermoplastic that is solid at room temperature and has a relatively high melting point at about 600K

-PTFE membranes are expanded PTFEs into a 3 web-like porous structure whis is used in quantitative chemistry for its durability and it's aggressive approach to filtering out particulates

Graphene coated PTFE

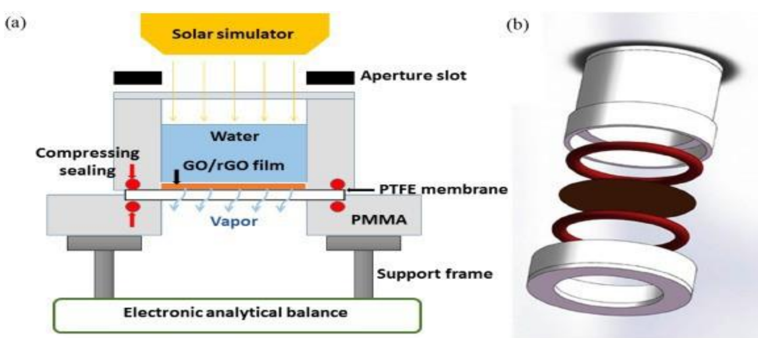
-Over the past five years scientists have continued to expand on graphene and solar energy in w ater desalination

-Double layer structure of carbon foam and exfoliated graphite that efficiently localized solar energy and minimized heat losses

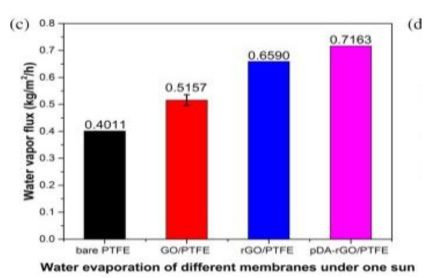
-Enhancement of broadband and omnidirectional absorption of sunlight using hierarchical graphene foam, w hich allow s for a considerable elevation of temperature

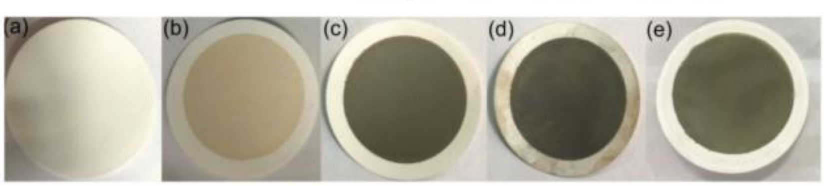
-A foldable graphene oxide film -based solar desalination device is developed to suppressed thermal loss and could achieve an efficient solar desalination

Experimental device



Results





Conclusion

-Several methods to synthesize Graphene oxide were developed and then dispersed over a PTFE membrane.

-In this process they were to be able to make a coated filter that shared characteristics from each material.

-The filter had a high durability which would allow it to withstand industrialization

-With the added filtration of Graphene oxide the membrane is able to separate up to 40,000 ppm NaCl concentration.

-Through the process of coating the PTFE with reduced graphene oxide the energy conversion of the solar radiation was improved approximately 79%.

Chapter 3: Natural Resources Management Research as Inquiry

Dr. Vanessa Lane

Abraham Baldwin Agricultural College

The Bachelor of Science degree in Natural Resources Management at Abraham Baldwin Agricultural College (ABAC) is focused on providing students with hands-on experiences in land, forestry, wildlife, and human management and undergraduate research opportunities. Students can choose among three separate tracts, including forestry, wildlife, and conservation law enforcement, to suit their interests and career goals. While each tract has nearly identical curriculum in freshmen and sophomore years, the tracts diverge in the junior and senior years to align with career needs and requirements of professional certifications. The Forestry tract in Natural Resources Management has full accreditation through the Society of American Foresters (SAF), and students are eligible to take the exam to become certified foresters at the completion of degree requirements. The Wildlife tract curriculum meets requirements of The Wildlife Society (TWS) Associate Wildlife Biologist certification, should students choose to apply upon graduation. No certification standards currently exist for the Conservation Law Enforcement tract, although the tract was developed with input and approval from Georgia game wardens, and students have been hired in Georgia, Florida, and Tennessee as game wardens from this program.

The three tracts also differ in the expectations for the senior capstone project, a required class in the Natural Resources Management (NRM) degree that is taken during a student's last semester prior to graduation. Forestry tract students are required through SAF standards to complete a timber management plan for a client (mostly private owners, although some state properties have been assessed in the past). Wildlife and Conservation Law Enforcement tract students are expected to complete research projects, including approval through the Institutional Animal Care and Use Committee and/or Institutional Review Board (for human research), development of hypotheses, study design, analysis, literature search, and the completion of a final report. While Forestry tract students are not conduct research per se, they are still required to research and cite sources to back up management recommendations. However, the majority of this chapter will be focusing on the true research projects conducted by Wildlife and Conservation Law Enforcement tract students. Student instructions for each capstone project type are given in Appendix A.

I. *What are common research methods, theories, or approaches in your discipline?*

The Bachelor of Science in Natural Resources Management at ABAC focuses on practical management of land, forestry, wildlife, and human management through the use of field-based, hands-on courses. Private forestry consulting companies, state natural resources agencies, and nongovernmental conservation organizations are the primary employers of our students. Undergraduate research projects are primarily focused on solving technical methodology problems, studying human dimensions of natural resources management, and improving institutional knowledge of organismal natural history, distribution, detection, and management to not only provide valuable experiences to students, but also improve working relationships with these private and state employers and cooperators.

This approach to providing practical and useful knowledge through the use of undergraduate research projects has several advantages and some drawbacks. Advantages include matching students with projects that suit their subject or employment interests, and providing foot-in-the-door experiences with actual employers. Two major drawbacks also occur. First, students may be unsure of their interests and thus may be assigned a project they may later find disinteresting, lowering investment in the final product. Secondly, conducting actual research that may eventually be used by private and state cooperators to inform management has its own consequences; expectations tend to be high, which may frighten insecure or academically weaker students, and data must be thoroughly critiqued by the instructor and advisors before sharing results with cooperators. In the former situation, replicating or continuing a previous experiment may be the safest options. In the latter, instructors and advisors must allocate enough time to evaluate research results beyond what is typically expected in an undergraduate project.

Generally, the responsibility of faculty undergraduate research facilitators is to maintain connections with people working in the field, including researchers or other experts such as land and wildlife managers, and maintain a current list of research questions and study topics for students to choose from. Undergraduates rarely have the world experience to understand the most pressing needs for information gathering, and while there is some value to replicating prior research projects, students have greater buy-in and investment in projects they know are improving the general knowledge of the field as a whole.

Faculty should also not expect any senior capstone course or project to be the end all, be all of information literacy education. Undergraduates, especially in underserved demographics and communities, often enter college with mediocre to poor writing and quantitative skills (Reid and Moore 2008, Long et al. 2009, Avendano et al. 2019). Expecting students to learn all of these skills, and develop, conduct, analyze, and report on a research project in one semester in a senior capstone course is simply unrealistic and will unlikely meet any learning objectives. As such, the various aspects of information literacy, such as identifying and using valid sources of information, should be incorporated, emphasized, and repeated throughout the entire undergraduate curriculum.

Curriculum mapping is a challenging but valuable exercise to ensure students are meeting learning objectives of the entire degree program, not just a single course. This does, however, require buy-in of most, if not all, of the professors in a degree program, including the creation and implementation of assignments to build students to an acceptable level of competency in various skills before senior capstone courses. An example of curriculum mapping for information literacy at the college level was outlined by Archambault and Masunaga (2015) at Loyola Marymount University, where the William H. Hannon Library and the university's Faculty Senate collaborated to embed information literacy concepts into individual course-level learning outcomes.

In the Natural Resources Management program at ABAC, information literacy has been incorporated throughout the entire four-year program, from a basic introduction of this concept to freshmen, to the full analysis, synthesis, and evaluation of data as seniors in the capstone course. A thorough review of information literacy activities and the academic year and degree tracts involved in ABAC's Natural Resources Management program are given in Table 1, but some of the more important exercises are summarized below.

As freshmen, students are introduced to information literacy through the creation of annotated bibliographies of peer-reviewed scientific journal articles. For nearly all students, this is their first time reading and summarizing scientific literature. As sophomores, wildlife and conservation law students must submit biological questions, which are later refined into hypotheses and incorporated into a research proposal which includes introduction, objectives, methods, budget, timetable, and literature cited sections. As juniors, students in all three tracts must write a comprehensive petition including a literature search to list a species of choice as threatened or endangered under the federal Endangered Species Act. Scattered throughout the NRM program are assignments that require students to find valid sources of information, typically in peer-reviewed literature, as well as improve scientific writing skills. A list of commonly used sources in the NRM program is given in Table 2.

Senior capstone projects themselves are typically highly diverse, requiring faculty to have a diverse skillset in organismal biology, land and forest management, statistical methods, and up-to-date knowledge of the current needs of the field. While we try to pair students with faculty who are most qualified to assist them with their project, in smaller colleges this can be challenging as often the instructor of record of the senior capstone course may also be the faculty who is most qualified in the subject material, creating a potential conflict of interest that other students (and faculty) may justifiably criticize when the project is evaluated. In ABAC's NRM program, if an advisor is the instructor of record for the senior capstone course, a new advisor is assigned for the duration of the class. Students must work with this new

Table 1. Timetable of abbreviated information literacy concept introductions, particularly the examination, evaluation, and use of peer-reviewed literature, to undergraduates in the Natural Resources Management bachelors degree program at Abraham Baldwin Agricultural College. Students can enroll in one of three tracts, including Wildlife, Conservation Law Enforcement, and Forestry.

Academic Year	Tracts Participating	Class Introduced	Activity
Freshman	Wildlife, Cons. Law	FRSC 1192: Wildlife Ecology and Management I	Annotated bibliography of ten separate peer-reviewed journal articles.
Sophomore	Wildlife, Cons. Law	FRSC 3135: Nongame Wildlife Conservation	Development of biological questions, refinement into hypotheses, creation of a research proposal with introduction, objectives, methods, budget, time table, and literature cited with 5 peer-reviewed sources.
	Forestry	FRSC 2255: Forest Mensuration	Comprehensive laboratory reports summarizing timber cruising inventories.
	Forestry	FRSC 2290: Timber Management	First timber management plan produced for a specific property either assigned or of the students' choosing.
Junior	Wildlife	Wildlife Measurements	10-12 minute oral presentation of an entire peer-reviewed journal article of an assigned statistical and/or measurement method in wildlife studies. Students must also create a research poster about this article.
	Cons. Law	ENGL 3010: Technical Writing	Covers creation of abstracts, reports, proposals/grants, research-based writing, and oral presentations.
	Cons. Law	ENGL 4010: Intro. To Professional Writing	Covers different writing/presentation needs by audience type, writing proposals/grants.
	All	FRSC 3130: Endangered Species Management	Formal petition to list an approved species as threatened or endangered under the federal Endangered Species Act. Requires a minimum of 10 peer-reviewed studies and is a comprehensive summary of population studies, current conservation challenges, and management efforts. 12-15 minute presentation describing their petition with the aim to convince the audience the listing is justified. Audience of peers votes on whether the petition is warranted.
	Wildlife, Forestry	FRSC 3300: Fire Ecology and Management	Evaluation of a fire incident case study, including descriptions of mistakes made and how to avoid future problems.
Senior	All	FRSC 4370: Natural Resources Recreation	Service project, topics vary greatly, but all must communicate with stakeholders, create time tables and budgets, write final reports, and give project presentations.
	All	FRSC 4630: Senior Project	Capstone course, development & implementation of research project for Wildlife/Cons Law, timber management plan for actual client for Forestry.

Table 2. Abbreviated list of frequently used sources, including peer-reviewed journals, in the Natural Resources Management program at Abraham Baldwin Agricultural College, their mission statements (if any), and additional notes.

Source	Mission Statements and Other Notes
Journal of Wildlife Management	The primary peer-reviewed journal of The Wildlife Society, the professional society that issues wildlife biologist certifications. Access to this journal is free for faculty and student members. Faculty members can issue free 6 month memberships to one person annually. The Author Guidelines, available online, is extremely thorough, therefore we use these formatting guidelines for most assignments, including senior capstones.
Wildlife Society Bulletin	A second peer-reviewed journal of The Wildlife Society. Typically contains studies that aren't as rigorous (i.e. smaller sample sizes, research notes, etc.) as JWM articles. WSB is a journal for wildlife practitioners that effectively integrates cutting edge science with management and conservation, but also covers important policy issues.
Southeastern Naturalist	Publishes natural history research related to all aspects of the biology and ecology of the organisms and environments of the southeastern portion of North America.
State Wildlife Action Plan	State-specific plans written by natural resources agencies and non-governmental cooperators which identify species, habitats, conservation risks, and management efforts of greatest need within each state. Reports are updated every ten years.
Journal of Forest Ecology and Management	Publishes scientific articles linking forest ecology with forest management, focusing on the application of biological, ecological and social knowledge to the management and conservation of plantations and natural forests.
Journal of Forestry	The mission of JOF is to advance the profession of forestry by keeping forest management professionals informed about significant developments and ideas in the many facets of forestry.
Timber Mart South	A database of timber finance information, updated regularly, used by foresters throughout the Southeast.

advisor for all draft reviews, while the instructor of record evaluates assignments and the final products.

In general, NRM senior capstone projects can be divided into two main groups: timber management plans for Forestry tract students, and research projects for Conservation Law Enforcement and Wildlife tract students. Timber management plans are required for Society of American Foresters accreditation for Forestry tract students. Undergraduate research projects for the remaining two tracts can be further divided into three main classifications: exploratory, observational, and experimental studies. Exploratory studies are often pilot studies where results may be uncertain or entirely unknown (i.e. a high chance of zeroes, such as no encounters with wildlife). Observational studies tend to be based on more thorough background information and may have established protocol or designs available (e.g. human attitude surveys, wildlife behavior studies). While exploratory and/or observational studies frequently lack one or more features of the three components of experimentation (controls, randomization of treatments, and replication), they are often cheaper, more realistic given logistical constraints of undergraduate research (i.e. lack of funding, travel restrictions, tight time frames, inability to control all variables, field conditions, etc.), and can still provide valuable information that is useful to cooperators, as long as limitations regarding study methodology and causality are understood and acknowledged (Shaffer and Johnson 2008).

II. How can you recognize these ideas when looking at materials produced in your field?

Faculty advisors must stay current on informational gaps present in their fields that undergraduate research may be able to answer, especially those gaps that are relevant to the immediate and local region. The elegance of undergraduate research is in its simplicity; often simple research questions may not be pursued by larger institutions, particularly among graduate student advisors, because those research questions may not be easily funded or the risk of no differences in experimental or observational groups is too high. The unfortunate bias among scientific journals of "no differences = no results" makes it difficult for these papers to get published (Korevaar et al. 2011, Dwan et al. 2013), thereby encouraging graduate students and their advisors from avoiding those subjects altogether. Equally unfortunate is that many of those questions, such as the presence or absence of species and their response/no response to management or habitat changes are often of keen interest to land managers and of real conservation value.

Additionally, undergraduates rarely take more than one introductory statistics course, therefore studies should be kept relatively simple unless they are given extensive mentoring by faculty or graduate students (if at a graduate school). This extensive monitoring is often not possible at smaller institutions with limited staffing and resources unless faculty are given the option for independent study credit. However, even with extensive mentoring most undergraduates simply go through the motions of using statistical software with no true understanding of study design, underlying statistical assumptions (or if they have been violated), or how to evaluate complex statistical results. Therefore, it is up to the faculty mentor to assist undergraduates develop appropriate study designs and identify relevant (and preferably simple) statistical tests. The goal of undergraduate capstone projects should not be complete, graduate-level understanding of every aspect of exploratory, observational, or experimental research, but should be a thorough and practical synthesis of those concepts. Mistakes will still inevitably be made even with faculty oversight but can be reduced with simple projects. However, having students identifying those mistakes and working through their solutions is an essential part of the learning process, and (relatively) low-impact undergraduate research is a safe place for those lessons to be learned.

Several common statistics are used throughout the Natural Resources Management curriculum. T-tests, including paired t-tests, and summary statistics such as means, modes, medians, standard deviations, confidence intervals, and standard errors are introduced as early as freshman and sophomore courses, such as in Quantitative Methods (FRSC 1180) and Forest Measurements and Mapping (FRSC 3140). More advanced statistical tests such as analysis of variance, occupancy analysis, detection probabilities, and nonparametric tests are introduced junior and senior courses, such as Techniques in Wildlife Management (FRSC 3363) and Wildlife Measurements (FRSC 4150). Therefore, students are exposed to and have used multiple statistical tests in courses prior to their senior capstone courses, but due to a relative lack of depth in that statistical knowledge as compared to graduate level courses not available at our undergraduate only institution, instructors aim to keep study design, methodology, and analysis relatively simple in senior capstones. Selected examples of completed senior capstone projects, their study type (exploratory, observational, or experimental), their title, and their reported statistics are given in Table 3. Additionally, due to ease of use and licensing expenses, we mostly limit data analysis software to Excel, SPSS, and sometimes R depending upon the expertise of faculty advisors.

Table 3. Selected senior capstone projects in the Natural Resources Management program at Abraham Baldwin Agricultural College, including the type of project (exploratory, observational, and/or experimental) and the statistics used in data analysis, if any.

Project Type	Project Title	Statistics/Results Reported
Exploratory	Population index map and impaled prey inventory of loggerhead shrikes in Tift County, GA	Census, entire county surveyed, total numbers presented
Exploratory	A new method for detecting fish hook ingestion in freshwater turtles	Simple totals, false positives tested via X-ray, false negatives not due to budget constraints
Observational	Pondspice (*Litsea aestivalis*): a baseline study on density and distribution of a state sensitive species at Alapaha River WMA, Irwin County, GA	Random strip transects in appropriate habitat, presence/absence, density, 95% confidence intervals
Observational	Assessing gopher tortoise burrow damage following timber harvest at Alapaha River WMA	Percent of total by damage score
Observational	Management plan for gopher tortoise (*Gopherus polyphemus*) on ABAC's Langdale Forest, Tift County, GA	Line transect distance surveys, estimated burrow occupancy and tortoise abundance
Observational, experimental	Survey of burying beetles at Alapaha River Wildlife Management Area and Marking Technique Experiment	Maximum counts, means, 95% confidence intervals, MANOVA
Observational, experimental	Fish community survey at Alapaha River WMA and a comparison of minnow trap baits	Two-factor ANOVA, species accumulation curve, catch per unit effort
Experimental	Comparing a common scent station protocol to simultaneous remote camera data for accuracy and effectiveness	T-test, cumulative frequency curve to determine if all species had been observed, visitation rate (% of all camera captures)
Experimental	Evaluating the effectiveness of two lure types for attracting meso-mammals	Pearson's chi square goodness of fit test, 95% confidence intervals

III. Do students learn to identify these ideas as well?

Students are mostly well-prepared for senior capstone projects in Natural Resources Management due to the introduction and use of information literacy and statistics throughout the curriculum. However, information retention varies greatly from student to student, depending upon how well they internalize and remember content from earlier classes, although faculty cooperate among different courses to refresh student knowledge regularly. Many of these concepts and when they are introduced were already discussed in Table 1, and an explanation of our most common information sources given in Table 2.

We offer several exercises at the beginning of senior capstone courses to refresh and remind students about not only the expectations of the course, but what are valid sources of information, where that information is found, and how it should be used in the context of their research projects. We developed a handout for students to use that details mostly reliable, somewhat reliable, and unreliable information sources in the context of natural resources management (Appendix B). Mostly reliable sources include peer-reviewed journal articles, government technical reports, government websites, symposia proceedings, theses and dissertations, extension office publications, and professional ethics guidelines. Somewhat reliable sources include professional society press releases (e.g. position statements), online publication databases (e.g. Galileo, Google Scholar, etc.), textbooks, field guides, professional magazines or newsletters, and newspapers. Mostly unreliable sources include general websites, casual magazines, advocacy organizations, and televised shows (including streaming services such as YouTube). Students are restricted to using mostly reliable sources of information as citations for the senior capstone projects, unless citing an unreliable source of information is a component of their research (i.e. evaluating misinformation).

Faculty advisors mostly develop experimental design and explain the necessary statistical tests to students, and as they conduct field work and subsequent data analysis, students learn the relationships between proper study design and statistical tests. However, we do have an exercise where students evaluate the methodology of three separate papers, two of which were published and one that wasn't (Appendix C). Students are challenged to identify which paper wasn't published and why.

IV. Is there a major difference between library research and field research in your discipline?

Students in Natural Resources Management use library research (such as searching for peer-reviewed articles) as a literature review to create research proposals, write introductions, develop and justify methodologies, and discuss how their field research fits into a larger (and published) body of knowledge. Library research, while a critical component of our senior capstone projects, is not considered adequate on its own for a senior capstone project in Natural Resources Management. Due to the nature of our program, accreditation and/or certification requirements (e.g. Certified Forester and Certified Wildlife Biologist standards), and the job expectations of graduates, actual field work and independent data collection and analysis is required for research projects.

V. Do the questions you ask in field research differ from those you ask of previously created information sources?

Field research is a critical component of wildlife and land management; one cannot happen without the other. Due to the complexities of working in natural environments where statistical and experimental controls are often impossible, where wildlife are difficult to locate and detect, and regional and local differences in soils, weather patterns, and climate, management must often be tailored specifically to local site conditions despite similar to identical research conducted elsewhere. While other fields (i.e. chemistry, microbiology, etc.) may be able to replicate an experiment once or twice in controlled settings and produce reliable results and thus make safe conclusions, this is often impossible in field conditions with numerous uncontrolled biotic and abiotic variables. Therefore, repeating past studies is not as frowned upon in natural resources management as in other fields. Indeed, repeating studies at new locations is often necessary to determine if solutions discovered elsewhere are relevant to the site and species of interest.

VI. Is there a researcher/practitioner dichotomy in your field? If so, what types of questions which require outside information sources would each of these roles ask in the course of their work?

In general, researchers and practitioners (e.g. land and wildlife managers, extension agents, etc.) work together in Natural Resources Management to identify knowledge gaps, research and study them, and implement new tools and/or solutions. This process is not supposed to be mutually exclusive, but a gradient of what is essentially the same activity: adaptive management (Sinclair 1991). While divides between researchers and practitioners do sometimes exist, for the most part this is a cooperation that is mutually beneficial and relatively functional. The main divides exist in the boundary between theoretical ideas and solutions and actual, logistical implementation of those concepts. With a few notable exceptions (particularly with game management; game are huntable and fishable species of wildlife), wildlife and natural land sciences are underfunded. What might be the best solution through research may not be possible to implement due to limited financial, equipment, temporal, and personnel resources. Additionally, due to the ephemeral nature of many plant and animal habitats, a seemingly small lapse in management can result in changed habitat conditions that result in local extirpation or extinction of species of conservation concern. For example, golden-winged warblers were nearly lost in Georgia when habitat management, specifically small clear cuts at Brawley Mountain to create early-successional, high-elevation breeding habitat essential for this species, was challenged by local hiking and forest enthusiasts and delayed for several years (Learn 2015). In many cases, experts are aware of what needs to be done to conserve these resources, but implementing those actions can be difficult due to political and/or public perception, which is why human dimensions has become increasingly important to wildlife and land management (Riley et al. 2002).

Despite the challenges, science-based management has long been praised as the hallmark of wildlife management in the United States since the late 1800s, although science is not always uniformly or transparently applied in the development of hunting policy and game management (Artelle et al. 2018). However, due to reduced stakes of research at the undergraduate level, resource managers can seek answers and solutions to questions and problems that may be too risky or “small” for graduate students and their advisors to pursue, as discussed before. This is not necessarily a weakness of graduate studies but a strength of undergraduate work, and the experiences provided allow undergraduates to partner with future employers and public clients prior to entering the workforce. Additionally, because undergraduate research is mostly based within an hour or so of the academic institution, local experts are relatively easy to identify as long as faculty are engaged with local communities.

VII. Do typical research assignments that you see in disciplinary courses mirror or contradict these processes? How?

Undergraduates are exposed to and are expected to understand and use these concepts throughout the program. In general, research assignments from prerequisite courses across campus are not field-specific and typically do not assist students with their senior capstones outside the writing practice offered by such assignments. Thus, the Natural Resources Management program at ABAC incorporates numerous assignments in a stepwise process throughout the curriculum to build students to the expectations and skills necessary to complete a satisfactory senior capstone project, as detailed earlier in this chapter. An example of a fully completed senior capstone research project is given in Appendix D.

Summary

Undergraduate research can provide useful information to cooperators despite simple study designs and simple (or lacking) statistical analysis by answering practical and useful conservation and management questions that graduate institutions and other researchers may not have the time, funding, or desire to pursue. Successful undergraduate research is the result of careful curriculum planning that prepares students throughout their degree program with the skills necessary to conduct a senior capstone project. Engaged and active faculty are also required for effective undergraduate research, as students rely upon them for the knowledge, connections, and understanding of what is needed to be addressed at the local level that may benefit the field as a whole. Undergraduate research is a valuable tool that is currently underutilized to address real wildlife, land, and human management problems and should be actively encouraged by institutions and practitioners.

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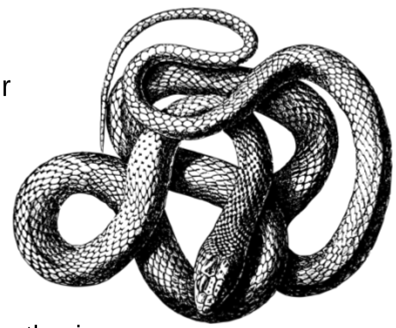
APPENDIX A

Natural Resources Management Senior Capstone Project Student Instructions

Project Objectives:



1. Identify clients and/or research topics.
2. If working with wildlife or humans, file appropriate paperwork for IRB or IACUC ethics approval.
3. Conduct field work and analyze data.
4. Develop a professional timber management plan, wildlife habitat plan, or research paper for real clients.

Senior project is the capstone of your undergraduate degree in Natural Resources Management at ABAC. As such, it represents the accumulation and synthesis of knowledge you have acquired to complete a real-life project with real-world goals and objectives.

There are a few project options in this class, depending upon your degree tract. Forestry students must complete a timber management plan as part of becoming a Certified Forester with the Society of American Foresters. Conservation Law Enforcement and Wildlife students may do either habitat management plans or research theses. The requirements of these projects may differ but the objectives and expectations do not. We expect professional-level reports regardless of the selected topics.

Timber Management Plan Directions

Required for forestry tract students.

You must identify a client and property. The property should contain a minimum of 350 acres and multiple stand types. You are responsible for creating property and stand maps, getting permission for property access, handling all logistics (including gate keys, avoiding hunting seasons, etc.), cruise all timber, and correspond actively with the client to understand their needs and goals. Your timber management plan may also include resources such as pine straw income, but should not include annual crop production, livestock, or other leases. If wildlife is a secondary objective you may include this in your report, especially as justification for timber operations that may retain or reduce basal area above or below amounts typically expected of pure timber production objectives.

Timber management plans tend to be more flexible in format than research papers, however, below are some sections that all management plans should have. Your timber management plan should consist of the following sections:

- Title page: with property name, location, size, owner, report authors, and date
- Table of Contents: include page numbers
- Introduction: which includes a brief summary of the property
- Objectives: including primary and secondary (if applicable). These are your landowner's objectives for the property, *not* your objectives for the paper.
- Site Description: a thorough description of the property, including detailed maps of the overall property, road access, addresses, cover/timber types, soil types, etc.
- Stand Descriptions: thorough descriptions of each stand, including acreage, stand maps, access, roads, cover/timber types, soil types, etc.

- Management Recommendations: this includes all revenue forecasts, planting/thinning/commercial harvest/site prep/replanting schedules and financial details of all of the above, including current rates from mills in the area for appropriate products. Prescribedfire may be included here, but a burn plan map, seasonality, and appropriate weather conditions must be explicitly detailed (i.e. just saying when to burn a stand is insufficient).
- Summary/Conclusion: A relatively short summary of the overall paper, including the most important findings you want to be sure to emphasize to your client.
- Literature Cited: **You must use Journal of Wildlife Management Author Guidelines to format your literature cited and in-text citations**. There is no partial credit for this, it's either right or wrong. JWM Guidelines are available online and on your GeorgiaView website. **You need at least 5 citations for your plan.**
- Appendices: Any additional information you think your client may want or need but are not critical to the management plan itself. For example, if you want to include more detailed soil information here, or raw data on any vegetation surveys, that's fine. Please don't include raw cruising data, however.

Research Project Instructions

Research projects are required for Conservation Law Enforcement and Wildlife Tract students, unless you are assisting with a timber management plan which has wildlife objectives.

You must work closely with an advisor to determine a research question you will investigate. As part of this process, you must identify a research question, develop hypotheses, determine study methodology and statistical methods to use to answer your question, gather data, analyze data, and write up a final report. Optimally you have already determined your research question and gathered data prior to taking Senior Project.

You must use the paper format described in the Journal of Wildlife Management Author Guidelines with the following exceptions:

- ***You DO NOT need to include line numbers.***
- ***Keep your table and figure captures next to your tables and figures, they do not need to be separated in your report. Embed your tables and figures in appropriate areas within the text; do not put them at the end of your report.***
- ***You may include appendices, which may include raw data you think may be useful to cooperators.***

A research paper is like a sandwich, with your introduction and discussion forming the bulk of your paper and including exposure to the outside world (in the form of citing other literature which agree with or contract your results). The study area, methods, and results are the meat and cheese; they define your paper and make the reader decide if your "intellectual sandwich" has any value. Your research paper should consist of the following sections.

- Title: Must be written in sentence format and be a brief description of the research project. Scientific names must be given and italicized.
- Author(s): Your name in all caps and middle initial, followed by your full business address (use the Yow Building's address).
- Introduction: Your introduction should be the bulk of your paper. This is a literature review, justifying why your research is important enough to be considered for funding. Use Journal of

Wildlife Management author guidelines for in-text citations. There will be no partial credit for improper formatting. Think of the introduction as a funnel, where you start broad and gradually focus down to the question or problem at hand. Your primary objective(s) should be given at the end of the introduction and numbered.

- Study Area: A brief description of the area you will be working in. Be sure to include state, county, and a description of the tract(s). Information on past and current land management should also go here. Start broad and then focus on the exact property. Describe the broad geographic area and ecoregion, climate descriptions are sometimes needed.
- Methods: Explain the methods you will use to measure your objectives. You should have citations and full explanations here to justify the methods you use. Your methods must be described enough for a reader to be able to conduct your study; if there is missing information or unexplained aspects of the methods you chose to the point that a reader cannot conduct this research, points will be deducted. You are responsible for researching which permits are required to do your research, if any. Your permits and permit numbers must be listed at the end of this section. You can learn about necessary permits by visiting the Georgia DNR and US Fish and Wildlife Service (if working with federally managed/protected species) websites. **The methods are always written in the past tense!**
- Results: This is just information and numbers without comment, bias, or interpretation. This section often requires graphs and tables. **Results are always written in the past tense!**
- Discussion: Evaluate the meaning of your results in terms of the original question and tested hypotheses. Point out the biological significance of your results as well as weaknesses and flaws in your project. *Incorporate results from other studies that agree or contradict with your results*.
- Acknowledgments: Here you can thank the people who helped you complete this project but who are not authors on the paper. You can thank your advisors here.
- Literature Cited: **You must have a minimum of 10 citations, *all of which must come from peer-reviewed journals* and cited as such**. Citations with urls will not be counted towards your minimum of 10. You must use the Journal of Wildlife Management format for literature cited and in-text citations. Format is either right or wrong, there will be no partial credit.

APPENDIX B

Natural Resources Management Senior Capstone Project Handout on Quality Sources of Information

Safety Rating	Publication Type	Example(s), how to identify	Warning(s)
MOSTLY SAFE	Peer-reviewed journal articles	Journal of Wildlife Management, Journal of Forestry, Southeastern Naturalist, etc.	Not all journals have a good reputation; it is easier to publish in some journals than others. Make sure the journal has a decent rating and is peer-reviewed. Trust articles from topic-specific journals more than articles from non-specific journals (such as PLOS One), due to more expert reviewers available to accept or deny publications.
	Government technical reports	All technical reports will have an agency logo and a serial number. Most will be named similar to: "e-General Technical Report SRS-203."	Not all government technical reports are peer-reviewed but they are typically safe, published by experts in the field. A true technical report will resemble a book, with a cover page, blank front matter, table of contents, etc. *Fliers are not technical reports*.
	Government websites	Will always end with .gov	*Don't just cite the website, you must find the publication and cite that instead*. For example, telling a landowner to go to the county website to find property lines will not be helpful, be specific and tell them about QPublic.
	Symposia proceedings	"Proceedings" and the name of the conference/symposia will be in the title.	While these are somewhat reliable, they are not as good as publishing in an actual journal. Sometimes these are weaker projects that were rejected from journals due to methodology and statistical problems. Sometimes these discuss incomplete projects. Always check if the article has been published elsewhere in a journal first and cite the newer article if available. Otherwise, assess articles carefully and critically before citing them.
	Theses and dissertations	Only one author (the student), the name of the college will be present, as well as whether it was a thesis (Masters) or dissertation (PhD)	These are not peer-reviewed, although they are evaluated by faculty advisors. Dissertations are generally more trustworthy than theses. If the study was any good individual chapters may be already published in peer-reviewed journals. Always cite the peer-reviewed journal articles over the thesis/dissertation.
	Extension office publications	Timber Mart South	*Fliers and websites should not be cited, find the publication or law/policy/database and cite it directly*.
	Professional Ethics Guidelines	Use of human/nonhuman animals in research ethical guidelines	You must cite these if you are working directly with humans/nonhumans for *research*, not management plans.

Safety Rating	Publication Type	Example(s), how to identify	Warning(s)
CAUTION!! NOT ALWAYS RELIABLE!	Professional society press releases	Position statements by The Wildlife Society, Society of American Foresters, etc.	Properly vetting the professional society is essential, some advocacy groups spoof themselves as professionals and can give poor or highly biased information. Be sure to frequently check position statements of TWS (wildlifers) or SAF (foresters) to ensure you are compliant with national and international standards of behavior or your certification(s) may be revoked.
	Search engines and online publication databases	Galileo, Google Scholar, etc.	Not all publications listed on these databases are peer-reviewed, some are opinion pieces and other potentially unreliable sources of information. Be sure to thoroughly evaluate any results you get with an internet search for validity.
	Textbooks	Herpetology, Ornithology, etc.	Research the authors to ensure they are experts in the field. Textbooks are not vetted as thoroughly as peer-reviewed journal articles and there are a lot of bad books out there. Textbooks can also quickly become out of date. Field guides do not count as textbooks.
	Field guides	Sibley Field Guides, Peterson Field Guides, Audubon Field Guides, etc.	Become quickly out of date as taxonomy and ranges are updated. *Field guides should never be cited.* If you need specific taxa information, go online to a professional database (e.g. American Ornithological Society, American Society of Mammalogists, The Reptile Database).
	Professional magazines/newsletters	The Wildlifer – magazine of The Wildlife Society, American Forests Magazine	These magazines are used for upcoming research projects and ethical discussions. Very rarely should you cite information from these magazines.
	Newspapers	Associate Press, Reuters, etc.	Not all newspapers contain reliable information. Be sure to research newspaper bias and accuracy ratings online before reading and/or citing information. *Popularity rankings are not reliability rankings, there is some really popular trash out there. Beware!*

Safety Rating	Publication Type	Example(s), how to identify	Warning(s)
DANGER! MOSTLY UNRELIABLE! DO NOT CITE!	General websites	Wikipedia	Some peer-reviewed journals are online-only, these are mostly safe to use as long as you follow the instructions on the green/safe page. However, *you must cite them using the electronic journal volume and page numbers, NOT the link where you found the article!*
	Casual magazines	Audubon Magazine	While some contributing authors are experts, most of the time articles are written for the general public and thus miss the entire story or nuance necessary for a reader to critically evaluate any claims.
	Advocacy organizations	Greenpeace, Sierra Club, Center for Biological Diversity, etc.	Many organizations are not honest arbiters of information and will often present biased viewpoints to fit an agenda presented as fact. If an article or website is more emotional than factual it's not trustworthy.
	TV shows	Game of Thrones	Look, were you happy? No one was happy. They're not valid sources of information and not even good stories half the time. Don't cite them.

APPENDIX C

Natural Resources Management Interpreting Methods of Scientific Articles

Objectives:

1. To learn how to interpret methods of scientific literature.
2. Draw a basic diagram of written methods.
3. Identify any possible flaws in study design.
4. To determine if the study is repeatable based upon the given methods.

Interpreting Methods of Scientific Articles

The methods section of a scientific document is the single most important section. The whole premise of science is that science is a process of testing hypotheses and progressing knowledge based upon what we learn. Repeatability is therefore essential to the scientific process, as repeating the experiment or study enables us to determine that results are not a fluke and/or a result of random variation or statistical probability.

Today we will examine the methods of three separate papers. As you read the methods, take notes on the experimental units, the number of replications, how biological surveys were conducted, while also keeping a watchful eye out for inconsistencies or mistakes. A well-written methods section should not leave any part of the study design up to the reader's imagination. If you have questions write them down, as you may have just identified an important flaw that could affect results of future studies that use these methods. Two of these papers were published, your task today is to identify the one paper that was rejected from publication and determine why this was so.

Questions to answer for each paper:

1. Where was this study conducted?
2. What is the objective (e.g. biological question) of this study?
3. What was the experimental unit?
4. How may replications were used (e.g. what is the sample size)?
5. Was blocking used? If so, what was the blocking unit?
6. Were the hypotheses given? If so, what were they?
7. Draw a diagram of the study design below. Include the experimental units, replicates, and blocks (if used).
8. Is there anything confusing about the methods that made it difficult to draw the study design? Could you repeat this study on your own with the information given? If not, what questions do you have that would interfere with your ability to repeat this study?
9. What were some other sources of variation the study accounted for in the study design? These may not be explicitly stated, but generally authors will describe methods that are not directly associated with the hypotheses that were used to reduce factors that may affect the data. (Variation that was accounted for statistically should not be included in this question, so if blocks were used this is not the type of variation I'm looking for.)

APPENDIX D

Natural Resources Management Senior Capstone Project Example

Use of Highway Culverts by Winter-Roosting Bats in Georgia's Coastal Plain

Senior Capstone Project

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Use of Highway Culverts by Winter-roosting Bats in Georgia's Coastal Plain

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ABSTRACT
The conservation of bat species in the Southeast is becoming more of an issue as the cave-dwelling fungus *Pseudogymnoascus destructans (Pd)* ¸ the causative agent of white-nose syndrome in bats, makes its way farther south. White-nose syndrome is known for awakening bats from torpor and forcing them to prematurely burn fat stores necessary for survival during winter. Although there are very few caves in Georgia's Coastal Plain, culverts have been documented to mimic cave conditions which expands the range in which *Pd* could potentially persist across the landscape. Minimal research exists related to culvert selection as winter hibernacula and this study is crucial for future mitigation of *Pd* and bat habitat management. We surveyed culverts for bats between Tifton and Brunswick, Georgia along U.S. Highway 82. A total of 44 suitable culverts (>3 ft. in height) were surveyed between 16 February 2019 and 4 March 2019. Our study was modeled after the Georgia Department of Natural Resources (GADNR) ongoing survey protocol for bats along other Georgia highways. A maximum of 5 sample swabs were taken from randomly selected bats within each culvert to be tested by GADNR for the presence of *Pd*. Among 29 occupied culverts, we documented 195 individuals of 2 different species, southeastern myotis (*Myotis austroriparius*) and tri-colored bat (*Perimyotis subflavus*). Most roosts (68%) were found in drains and weep holes with an average of 4 individuals per roost. Culvert characteristics were analyzed in conjunction with species presence or absence. No statistical significance of culvert variables was found. Regardless of statistical difference between culvert characteristics and bat presence, documentation of culverts being utilized as winter hibernacula indicates the need for increased dialogue between GADNR and GA Department of Transportation (GADOT). Culverts are being used by cavity and cave dwelling bats which gives natural resource managers another opportunity to promote and conserve these species.

KEY WORDS bat, bridge, coastal plain, culvert, presence-absence, South Georgia, southeastern myotis, tri-colored bat, *Myotis*, *Perimyotis*

Human-wildlife interactions complicate both research and management of natural resources (Messmer 2018). Human presence, regardless of spatial scale, has the potential to influence animal behavior and ecology (Cable 2013, Gaynor et al. 2018). Researchers study different aspects of animal ecology to determine future management strategies that promote selected wildlife species, and human impacts remain a constant consideration. Like most taxa, bats have not avoided anthropogenic influence (Keeley and Tuttle 1999). Bats play essential roles in agricultural pest control, seed dispersal, and pollination, making the group a conservation priority (Keeley and Tuttle 1999, Kunz and Fenton 2003).

An important conservation issue involving North American bat species was the introduction of the fungus *Pseudogymnoascus destructans* (*Pd*), the causative agent of white-nose syndrome (WNS), that grows in cave systems (Blehert et al. 2009, Frick et al. 2010, Blehert 2012). *Pd* infection was first discovered near Cobleskill, New York, in 2006 and has spread south and west, greatly diminishing numerous bat species including some native to Georgia (Blehert et al. 2009). WNS can be identified by the powdery white fungal conidia growing on the muzzle, ears, and patagium of affected cavity and cave dwelling species (Blehert et al. 2009, Gargas et al. 2009). Bats infected with *Pd* exhibit frequent arousals during torpor, a form of environmentally-dependent hibernation, which can result in mortality (Gargas et al. 2009, Cryan et al. 2010, Frick et al. 2010). *Pd* growth inhibits cutaneous respiration along the bat wing membrane, limiting the amount of oxygen an individual receives in torpor. As the bat breathes to compensate for lost oxygen, water is expelled from the lungs and adds to the already present evaporative water loss (EWL) from the patagium (Cryan et al. 2010). Disturbance from torpor can be a result of either poor thermoregulation or thirst. Bats may leave winter roosts in search of water, diminish necessary fat stores, and die from starvation (Cryan et al. 2010, Frick et al. 2010). This epizootic disease has greatly reduced populations in the northeast United States and mitigating the spread of it is crucial to the conservation of many bat species (Blehert et al. 2009, Frick et al. 2010, Blehert 2012).

Cave and cavity dwelling bat species have been documented to regularly use human structures such as buildings, bridges, and culverts (Walker et al. 1996, Keely and Tuttle 1999, Adam and Hayes 2000, Felts and Webster 2003, Martin et al. 2005, Bender et al. 2010, Cervone et al. 2016). Caves maintain a constant temperature similar to the yearly atmospheric average temperature above ground, and bridges/culverts have been described to loosely mimic cave settings due to similarities in reduced temperature fluctuation which may contribute to the spread of WNS (Cervone et al. 2016). Culvert and bridge use as winter hibernacula is not only a WNS issue; these structures are subject to concentrated human traffic, escalating human-wildlife interaction and altering potential management practices. Research related to culvert/bridge selection as winter hibernacula is critical for future mitigation of *Pd* and habitat management to promote multiple bat species. Studies related to selection of anthropogenic winter hibernacula in the southeastern U.S. are scarce. Our objective was to better understand the winter roosting ecology of bat species in highway culverts across the Coastal Plain of Georgia.

STUDY AREA

Culvert surveys were conducted along US Highway 82 from Tifton to Brunswick, Georgia (Figure 1). This section of US Highway 82 passes through a variety of land cover types including residential, forested, agricultural, and commercial. The surveyed distance was 185 km and spanned across six counties: Tift, Berrien, Atkinson, Ware, Brantley, and Glynn. Elevation change from Tifton to Brunswick, GA, was a decrease of 340 ft.

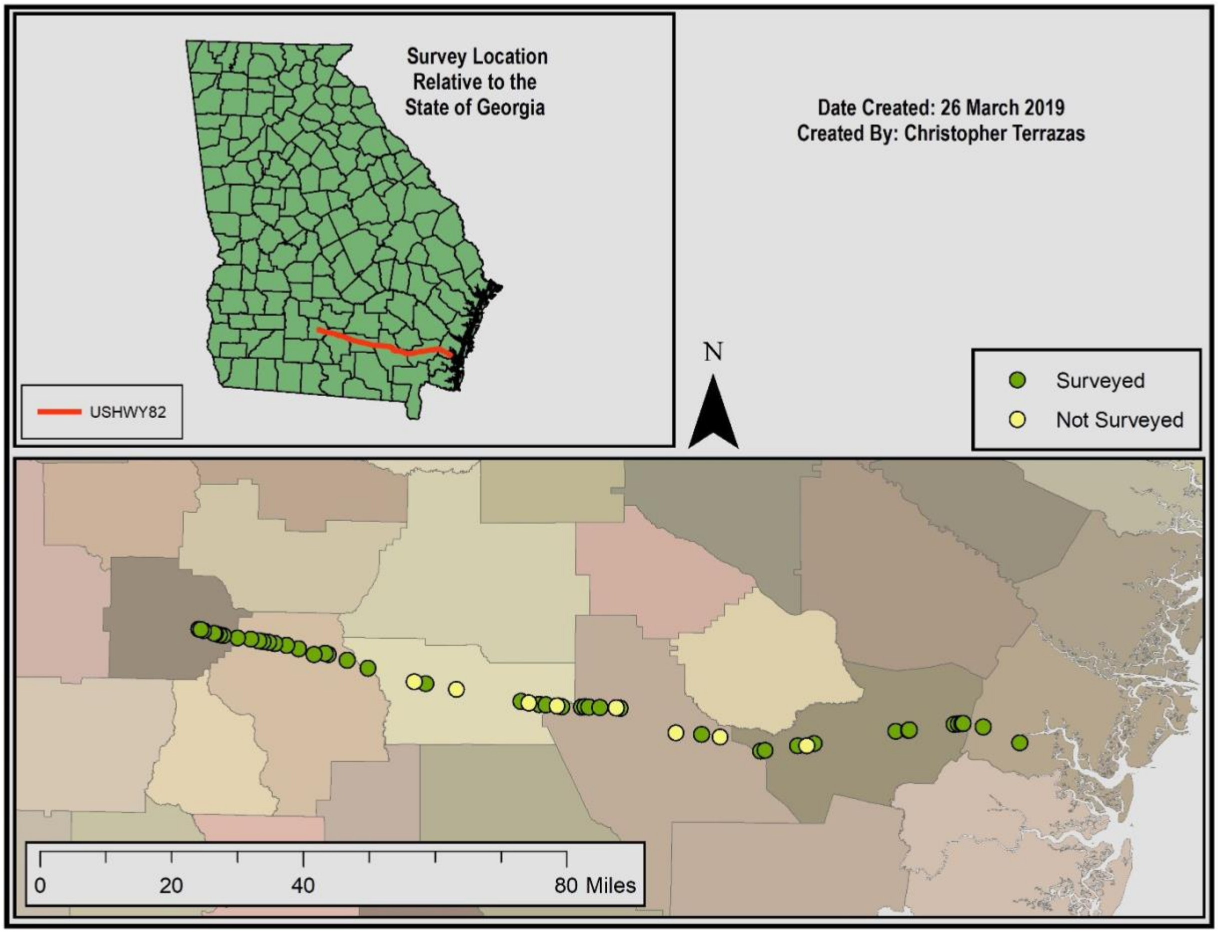

Figure 1. Locations of culverts along Georgia Highway 82. Culverts that were surveyed are shown in green and unsurveyed culverts are shown in yellow.

METHODS

Culverts were noted in our database with an identification number and GPS coordinates while traveling east on US Hwy 82 2-10 February 2019. All culverts were previously marked by the Georgia Department of Transportation (GDOT) with reflectors or signage. We recorded only culverts that were surveyable (>3 ft. in height). For safety, researchers wore reflective vests, used vehicle hazard lights, placed a “Survey in Progress” sign on the back of the vehicle, and a permission letter from the Georgia Department of Natural Resources (GADNR) and GDOT was placed on the dashboard during surveys.

Methods employed were similar to those currently used by GADNR to allow our results to be comparable to GADNR surveys completed in other parts of the state. Because there was a potential of handling live animals, we obtained project approval from the ABAC Institutional Animal Care and Use Committee (Project Number ST013019). Culverts were surveyed between 16 February 2019 and 4 March 2019. At each culvert, data were collected using the GADNR culvert survey datasheet (Appendix A). Site name, surveyor names, date, time, county, latitude/longitude, road name, number of lanes above, culvert type, number of culverts, and culvert material was recorded for each site. Height, width, and water depth were also collected. Sky code, Beaufort wind code, and outside temperature were recorded at each survey site.

Interiors of all culverts were surveyed once, starting from the north aspect. Headlamps and spotlights were used to survey for bat indicators including visual, smell, sound, staining, and/or guano. Internal temperature and light readings were taken at the halfway point. Internal temperature was taken using a General® IRT207 Infrared Thermometer aimed at the interior eastern wall of the culvert. A light reading was taken using the Sper® Scientific Light Meter 840006 held out at chest level, parallel to culvert floor, and set at 200 lux. Interior culvert substrates including mud, rocks, sand, or concrete and presence of flowing or standing water was recorded.

Walls, ceilings, plugged drains/weep holes, cracks, and crevices were searched for bat presence. A single roost was defined as an area at which an individual or group of bats was roosting at the time of survey. If bats were located, the species, number of individuals, and roost type were recorded. White-nose syndrome swabs were taken using GADNR protocol for culvert sampling (Appendix B). Evidence of migratory birds using culverts or bats using migratory bird nests was recorded as well. Gloves, equipment, and waders were sanitized with alcohol or hydrogen peroxide after exiting each culvert to prevent the spread of *P. destructans* if we unknowingly came in contact with the fungus.

We conducted an analysis of variance (ANOVA, $\alpha = 0.05$) to compare the means of culvert characteristics (culvert dimensions, interior and exterior temperature, and lumens/m^2) at occupied and unoccupied sites. The ANOVA also determined the amount of variation between groups to detect the presence or absence of a statistical difference that would indicate a culvert characteristic effect on bat presence.

RESULTS

Of 52 marked culverts, 44 were surveyed. Among them, 29 (66%) were occupied and 15 (34%) were not (Figure 2). Two bat species were present during the survey, southeastern myotis (*Myotis austroriparius*) and tri-colored bat (*Perimyotis subflavus*). We detected *M. austroriparius* at 22 culverts and *P. subflavus* at 7 culverts. Only 2 culverts were found to be occupied by both species simultaneously. We found no effect of culvert external temperature ($F_{1,42} = 0.208$, $p = 0.650$), internal temperature ($F_{1,42} = 4.007$, $p = 0.052$), light amount ($F_{1,42} = 2.551$, $p = 0.218$), entrance area ($F_{1,42} = 2.090$, $p = 0.156$), entrance height ($F_{1,42} = 0.159$, $p = 0.692$), or entrance width ($F_{1,42} = 2.551$, $p = 0.118$) on bat presence (Figures 3-8). We detected 195 individuals within 65 different roosts. A majority of individuals were found inside of weepholes (83.16%) (Figure 9).

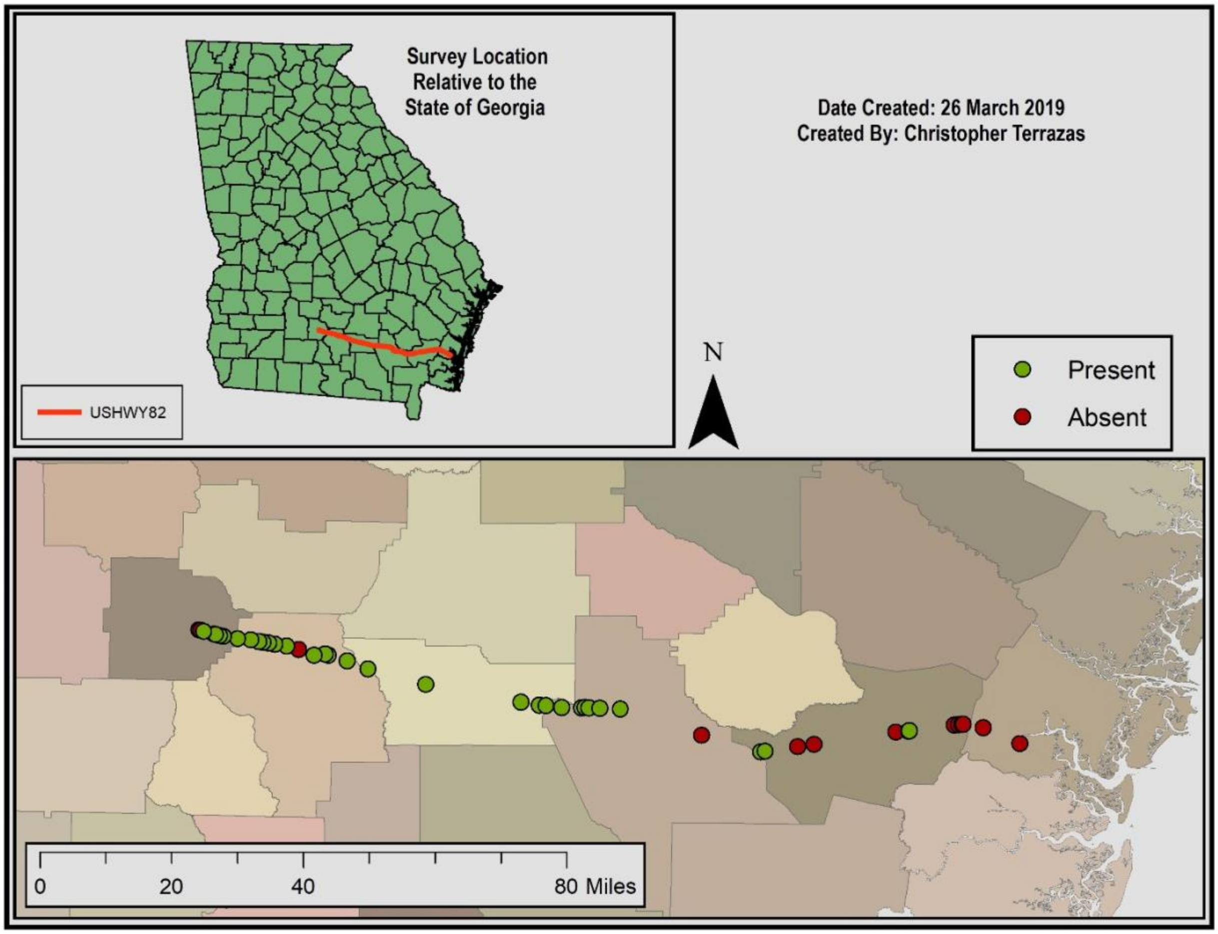

Figure 2. Locations of culverts surveyed for bats along US 82 between I-75 and I-95. Occupied culverts are marked in green and unoccupied culverts are marked in red.

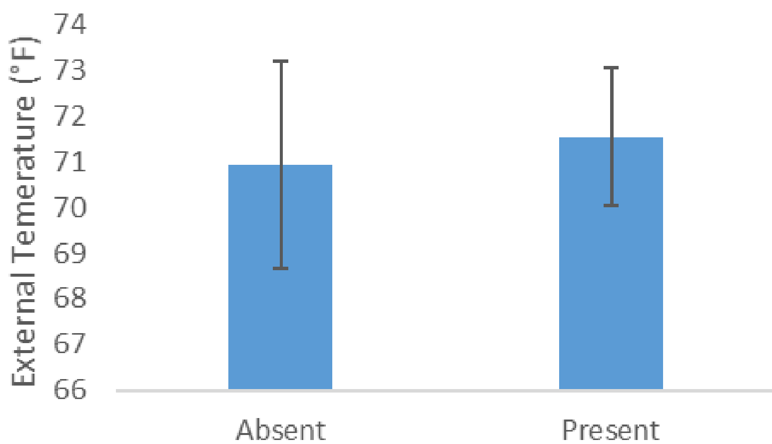

Figure 3. Compared mean external temperature of occupied and unoccupied culverts surveyed for bats along US 82 between I-75 and I-95. Error bars were constructed based on a 95% confidence interval.

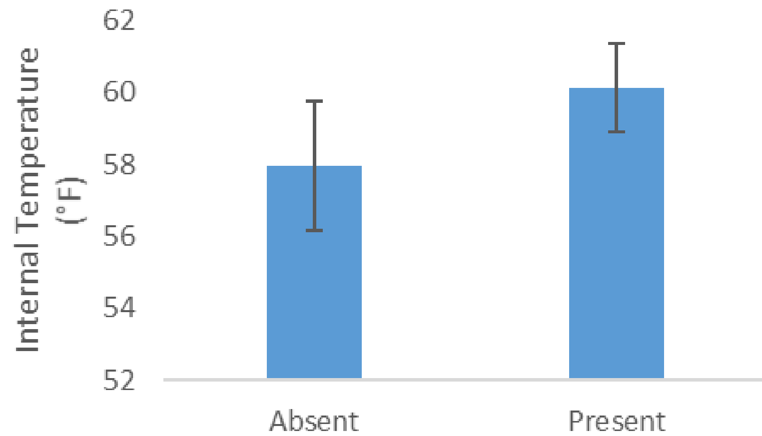

Figure 4. Compared mean internal temperature of occupied and unoccupied culverts surveyed for bats along US 82 between I-75 and I-95. Error bars were constructed based on a 95% confidence interval.

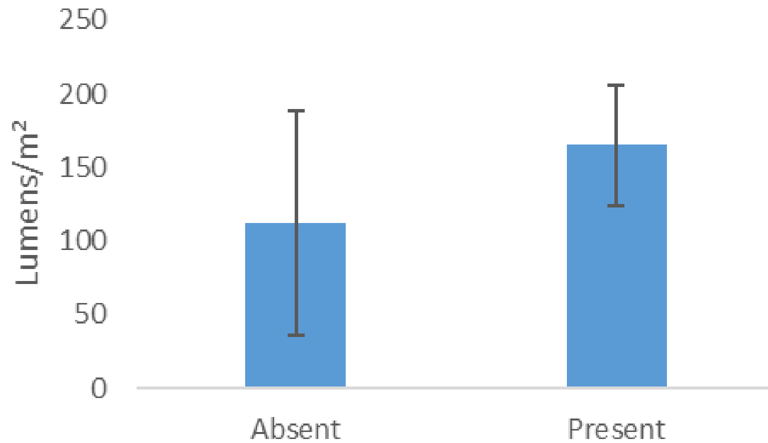

Figure 5. Compared mean amount of light reaching the center of occupied and unoccupied culverts surveyed for bats along US 82 between I-75 and I-95. Error bars were constructed based on a 95% confidence interval.

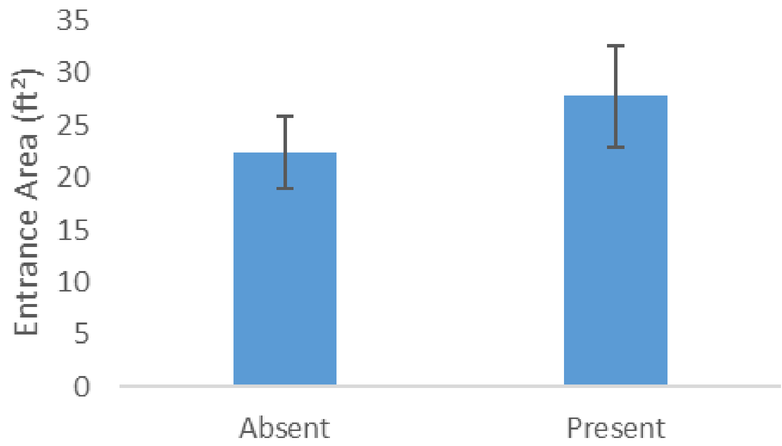

Figure 6. Compared mean entrance area of occupied and unoccupied culverts surveyed for bats along US 82 between I-75 and I-95. Error bars were constructed based on a 95% confidence interval.

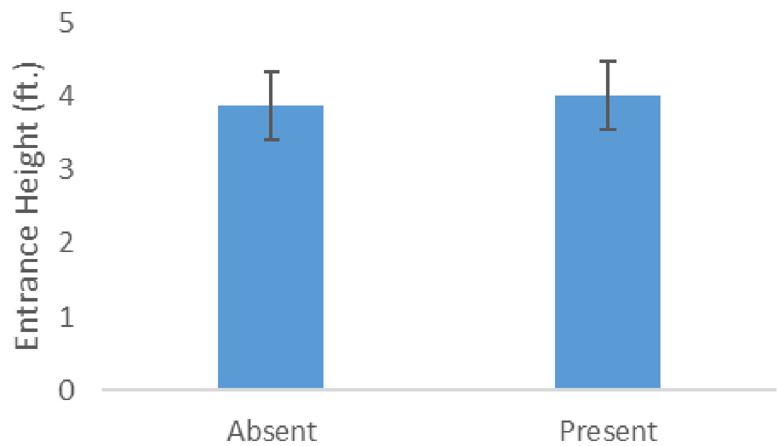

Figure 7. Compared mean entrance height of occupied and unoccupied culverts surveyed for bats along US 82 between I-75 and I-95. Error bars were constructed based on a 95% confidence interval.

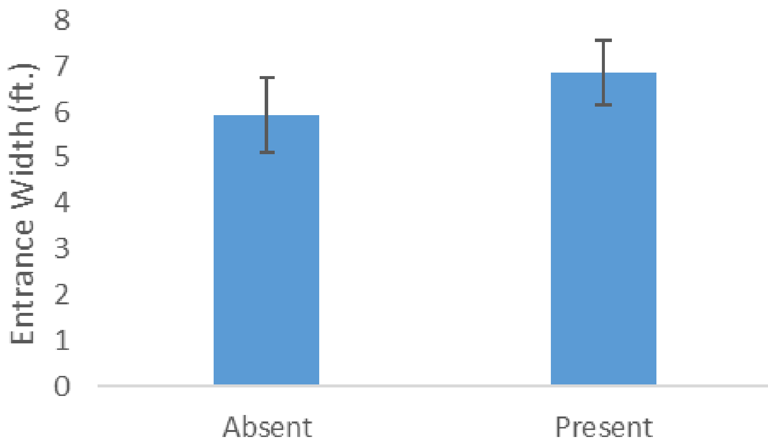

Figure 8. Compared mean entrance width of occupied and unoccupied culverts surveyed for bats along US 82 between I-75 and I-95. Error bars were constructed based on a 95% confidence interval.

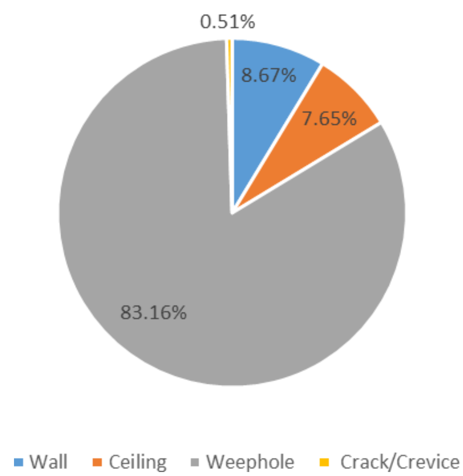

Figure 9. Percentage of culvert-roosting individual bats found in different roost types during surveys along US 82 between I-75 and I-95.

DISCUSSION

P. subflavus, is known to roost in foliage of larger trees in open forests and hibernate in moist caves and mines (Avery 1985, Sandel et al. 2001, Briggler and Prather 2002). *M. austroriparius* is known to use a similar habitat for torpor, but general roosting habits are associated with large hollow cypress (*Taxodium* spp.) and gum (*Nyssa* spp.) trees (Rice 1957, Clement and Castleberry 2013, Fleming and Jones 2013).Old growth trees such as gum, cypress and pine species have been removed from areas occupied by both bat species and we believe that highway culverts have contributed to the species resilience to habitat loss. Until our survey, *P. subflavus* had been known to be or potentially extirpated from Ware County, Georgia and not previously documented in Brantley County, Georgia. (GADNR 2019). Our rediscovery of this species is important for prioritizing management practices and encouraging future researchers to look for bats in unexpected places.

The lack of equal replication between occupied and unoccupied culverts combined with our low sample size may have contributed to the amount of variation between groups. Larger sample size reduces sample variation, which could solidify some of our more suggestive data. For instance, average internal temperature may affect bat presence ($p = 0.052$), but our small sample size could have captured a more-varied sample than what is present across the landscape. We could have also captured a less-varied sample than what is present, and a larger sample could have shown the variation that we missed. External temperature measurements were inconsistent, collection-wise, because we switched between using cellphone applications and our portable Kestrel weather station. Weather changes throughout our sampling period, daily and weekly, could have also increased the amount of variation within our sample. We recommend that future researchers use data loggers to track daily averages, similar to a past study that evaluated roost selection of the cavity-roosting Rafinesque's big-eared bat (Hurst and Lacki 1999).

Measuring lumens/m^2 at each culvert was also inconsistent, and as a result, the variation within this group was the highest among all others. Instantaneous light measurements were dependent on the sun's relative position to the culvert which changes throughout the day. This variation could have also been a function of the type of light meter used, which had a directional bias. If the technician was not holding the light meter vertically at the exact center of the culvert, the amount of light could be higher or lower than reality. A globular light meter that has less directional bias could help reduce the amount of variation in future samples. Data loggers recording daily average amount of light reaching a culvert could reduce the amount of variation in a sample, as compared to our instantaneous values recorded at different times of day over three weeks. Another issue with measuring light was the occasional presence of a large center drain in the road median, which allowed more light to reach the center of culverts possessing them.

Data collection for culvert dimensions remained consistent, although the limited sample size could have also affected our results. Of the 52 culverts identified, 6 were omitted due to either hazardous entryways or deep water. Our inability to enter those culverts does not imply the same limited access for bats. The lack of data related to smaller culvert entries limits our ability to accurately interpret bat presence in relation to culvert dimensions. Roost volume has been identified as a potential limiting factor for bat occupancy and we recommend that future research includes this attribute when analyzing culvert use as winter hibernacula (Clement and Castleberry 2013).

Pd has been found to marginally persist in roosting areas that reached no higher than 68° F throughout the year, indicating that the potential for its presence in Georgia's Coastal Plain is unlikely (Blehert et al. 2009). Georgia cave systems that maintain a temperature below 68° F are still at risk of *Pd* invasion and potential roosting hibernacula in those areas should remain under constant monitoring. Our white-nose swabs were still in processing at the end of our project. However, one culvert contained an individual southeastern myotis that exhibited a fungus-like growth on the ears and joints of the wings and several additional swabs were taken and sent to GADNR for processing.

The primary objective of our research was to determine the extent to which bats were utilizing highway culverts in Georgia's Coastal Plain. Supplementary culvert characteristic data were recorded beyond required variables on original GADNR survey protocol, and suggestive data opens the door for more detailed studies in the future to further our understanding of bat culvert roosting ecology. This improved awareness of bat presence in culverts also provides wildlife managers with other opportunities to promote the health of important southeastern bat populations, especially if *Pd* finds its way into southeastern roosts.

MANAGEMENT IMPLICATIONS

Future research in culvert characteristics and bat presence is needed to determine what variables can be altered to both promote and prevent bat presence when necessary. Managers should maintain contact with DOT officials to stay updated on culvert and bridge repairs and replacement. Efforts should be made to provide temporary roosting habitats during these repair times and general maintenance should be avoided during winter months when possible. If this is not feasible, bat houses may need to be installed prior to hibernation times to allow bats to discover and begin using the bat houses because both southeastern myotis and tri-colored bats have been documented to use artificial houses.

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APPENDIX A. GADNR Culvert Survey Datasheet

GADNR Site Name: ______________________

Investigator Name(s): ____

Date & Time:______________________ **County:**______________________

Lat: ______________________ **Long:** ______________________

Road Above:______________________ **Number of Lanes Above:** ______________________

Culvert Type:	**Number of Culverts:**	**Culvert Material:**	**Individual Culvert Dimensions:**
☐ Box ☐	☐ Single ☐ Other:	☐ Concrete	Width:____________
☐Pipe/Round ○	☐ Double ________	☐ Corrugated Steel	Height: ____________
☐ Other: ________	☐ Triple	☐ Other: ________	

	Sky Codes
0	Clear
1	Few clouds
2	Partly cloudy
3	Cloudy or overcast
4	Fog or smoke
5	Drizzle or light rain
6	Thunder Storm

	Beaufort Wind Code
0	Calm (0 mph)
1	Very light wind: Leaves in motion, small branches sway w/ wind (1-3 mph)
2	Light: Pole size trees sway, wind felt on face, loose paper moves, wind flutters small flag (4-7 mph)
3	Gentle breeze: Pole size trees in open sway noticeably, large branches toss, tops of trees in dense stands sway, wind extends small flag (8-12 mph)
4	Moderate breeze: Pole size trees in open sway violently; whole trees in dense stands sway noticeably, dust raised on road (13-18 mph)

Sky Code: ________ **Wind Code:** ________ **External Outside Temperature (F):** ________

Conditions Inside Culvert: (check all that apply) **Temperature Inside Culvert (C):**

☐ Mud ☐ Sand ☐ Flowing water → Water Depth: ______________

☐ Rocks ☐ Concrete ☐ Standing water ________ ________

Bat indicators: (check all that apply) ☐ Visual ☐ Smell ☐ Sound ☐ Staining ☐ Guano

Bats Present: ☐ YES ☐ NO **Total number of roosts:** ______________

<u>**Species Present**</u> (Indicate number of bats observed next to each species seen)

- ________ Myotis septentrionalis (Northern long-eared)
- ________ Myotis sodalis (Indiana)
- ________ Myotis leibii (Eastern small-footed)
- ________ Myotis lucifugus (Little brown)
- ________ Myotis grisescens (Gray)
- ________ Myotis austroriparius (Southeastern)
- ________ Lasiurus borealis (Eastern red)
- ________ Lasiurus seminolus (Seminole)
- ________ Lasiurus intermedius (Northern yellow)
- ________ Lasiurus cinereus (Hoary)
- ________ Lasiurus noctivagans (Silver-haired)
- ________ Perimyotis subflavus (Tri-colored)
- ________ Eptesicus fuscus (Big brown)
- ________ Nycticeius humeralis (Evening)
- ________ Tadarida brasiliensis (Braz. free-tailed)
- ________ Corynorhinus rafinesquii (Rafinesque's)
- ________ UNKNOW

Roost design: (check all that apply; indicate number of this roost type; and number of bats in each roost location)

☐ Hanging on side wall	# roost type ________	# bats each roost __,__,__,__,__,__
☐ Hanging on ceiling	# roost type ________	# bats each roost __,__,__,__,__,__
☐ Plugged drain/ weep hole	# roost type ________	# bats each roost __,__,__,__,__,__
☐ In crack/crevice	# roost type ________	# bats each roost __,__,__,__,__,__
☐ Other:______________	# roost type ________	# bats each roost __,__,__,__,__,__

A B C D E F G H I J K L M N O P Q R S T U V W X Y Z

Bats Processed: ☐ YES ☐ NO ☐ N/A **Bat Samples Taken:** ☐ YES ☐ NO ☐ N/A

Areas Inspected: (check all that apply)

☐ Interior walls ☐ Interior ceiling ☐ Other:___________________________

☐ Crevices/Cracks ☐ Weep holes

Areas NOT Inspected because of safety or inaccessibility:

____

____

____

Additional Comments / Sketch:

Evidence of bats using bird nests? ☐ Yes ☐ No (If yes, please describe and photograph nest location)

Is there evidence of migratory birds using the structure? ☐ Yes ☐ No

If yes, what species (excluding pigeons) are present, what evidence is there, and locations (check all that apply)?

nests

___ **Barn Swallow** ☐ Old Nest ☐ Adults ☐ Building ☐ Complete Nest ☐ Eggs ☐ Young ☐ Unkn Stage
☐ under deck, exterior sides ☐ under deck, interior

___ **Cliff Swallow** ☐ Old Nest ☐ Adults ☐ Building ☐ Complete Nest ☐ Eggs ☐ Young ☐ Unkn Stage
☐ under deck, exterior sides ☐ under deck, interior

___ **Eastern Phoebe** ☐ Old Nest ☐ Adults ☐ Building ☐ Complete Nest ☐ Eggs ☐ Young ☐ Unkn Stage
☐ under deck, exterior sides ☐ under deck, interior

___ **Other:___________** ☐ Old Nest ☐ Adults ☐ Building ☐ Complete Nest ☐ Eggs ☐ Young ☐ Unkn Stage
☐ under deck, exterior sides ☐ under deck, interior

APPENDIX B. GADNR Protocol for Culvert Sampling

MATERIALS TO PACK:

- ◻ Swabs
- ◻ Sample vials
- ◻ Latex gloves
- ◻ Ziploc bags
- ◻ Trash bags
- ◻ Data sheets & Protocol
- ◻ Decon materials
- ◻ Cooler & ice packs
- ◻ Sharpie (thick & fine point)
- ◻ Pencils
- ◻ Extra rite-in-rain paper or notebook
- ◻ Batteries (AA & AAA)
- ◻ Headlamp
- ◻ Spotlights & chargers
- ◻ Long rubber dish gloves (if desired)
- ◻ Temperature gun
- ◻ Measuring tape
- ◻ Reflective vest
- ◻ Waders
- ◻ Rubber boots
- ◻ 'Survey in Progress' sign
- ◻ Lighter for sterilizing tools
- ◻ Scissors and tweezers for hair clipping
- ◻ Ethanol for sterilization of tools
- ◻ Sampling toolbox (scale, bat bags, ruler, bands, etc.)
- ◻ Clipboard
- ◻ GPS
- ◻ Hobo data loggers (and supplies to deploy)
- ◻ Knee pads
- ◻ Gardening gloves for crawling

PROTOCOL FOR SAMPLING:

A. *The culvert monitoring data sheet must be filled out for **EVERY** culvert surveyed, regardless of bat presence. When bats are present fill out the bat data sheet for all bats found.*

B. Culvert Monitoring Data Sheet:
   a. Number of lanes above refers to area directly above culvert (including exit/ramp lanes)
   b. External temperature can be taken via Weather Underground phone app. Take current outside temperature and make sure to note time of day of site visit.
   c. Use temperature gun to record temperature inside the middle of the culvert.
   d. If applicable, record water depth in the middle of the most central culvert.

C. Samples to Take:
   a. **No bats should be awakened from torpor to be handled.** Swabs and hair samples can be taken from bats in torpor, when accessible, with caution to not overly disturb the bat.
   b. If present and accessible, *Myotis* spp. and *Perimyotis subflavus*. should be prioritized for swab sample collection, but all bat species found during surveys should be swabbed.
   c. A maximum of 5 bat swabs should be taken per species per site based on accessibility.
   d. Hair samples should be collected from each bat swabbed if the bat is awake and able to be handled.
      i. If you capture an awake bat in hand, conduct full processing on bat. Collect data on species, FA, weight (can use empty Ziploc bag for this), sex, reproductive status, and condition. Band with a 2.9 mm (MYAU) or 2.4 mm (PESU) GA band and record number. Collect hair samples of bats in hand and conduct swabbing at this time.
   e. Environmental swabs should be taken only in locations where bats are present on their roost.

D. Bat Data Sheet--Swab collection protocol:
   a. Gather empty vial, unused swab, and new latex gloves. Put on clean gloves.
   b. Remove swab from sterile wrapping, careful <u>not to touch swab tip to anything</u>.
   c. With non-dominant hand under (but not touching) the bat, ROLL the swab up and down along the forearm 5 times. If bat arouses, safely remove and handle to continue swabbing.
      i. For environmental swabs roll the swab 10 times in area of bats roosting under the bat. If many bats are roosting together (i.e. 3 bats together in a single weep hole), then only one environmental swab is needed in that area for this grouping, even if all bats are swabbed separately for analysis.
      ii. Environmental swabs should only be taken in culverts with bats when it is safe and accessible to do so near roosting bats.
   d. Swab the muzzle 5 times, rolling as you go, using the same swab as step C.
   e. Place the swab's tip into empty storage vial and break off shaft near the cotton tip.
   f. Once closed, wipe all vials with alcohol wipes. Label the vial using proper code below.
      i. It is not necessary to change gloves between each bat/sample tube provided the persons performing these tasks do not directly contact individual bats or the environmental substrate. Once culvert sampling is complete dispose of all wrappers, swab handles, and contaminated exam gloves into trash.
      ii. Make sure both sides of the 'Bat Data Sheet' are completed from each sample to indicate exact bats (reference bat # on page 1) sampled.

E. Bat Data Sheet—Hair collection protocol:
   a. Dip scissors and tweezers in ethanol, flame to sterilize, let cool.
   b. Take a clip of hair from dorsal side of bat and place in empty Ziploc bag. Collect a few mg of hair.
   c. Label Ziploc bag with proper code below. Store with associated swabs for bats so samples are grouped together.

F. Sample Storage
   a. On day in the field when samples are collected store those in a cooler with ice packs. For long term storage, a home freezer can be used temporarily, but ideally samples will be put into a -80C freezer at KSU.

<u>CULVERT ID CODE GUIDE</u>

- Every sample taken from a single bat should have the same code to indicate the individual bat used for collection.
- All vials should include <u>R</u>oad information-- <u>M</u>onth, <u>D</u>ay - <u>L</u>etter (alphabetical order) to indicate which culvert on that roadway sampled, and a unique number (<u>#</u>) , followed by swab <u>T</u>ype of B (Bat Swab) or E (Environmental Swab) when applicable: **<u>RRRR-MMDD-L##-T</u>**

Chapter 4: Information Literacy for Research in Biology

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What are common research methods, theories or approaches in your discipline?

We are currently living in the age of information. Thanks to the internet, individuals can create and disseminate information to a world-wide audience. Technological advancements have accelerated, due to the access of humanity's collective knowledge at our fingertips. However, this blessing can also be a curse, as the internet is slowly turning into a knowledge dump. This has led to the problem of deciphering between what is good and bad information. Therefore, the ability to understand how to find and evaluate appropriate information has never been harder and more important. As biology has evolved over the past 500 years, it is natural to assume it has become more and more complex (Gannon, 2007). This complexity is seen even in reporting of science in the form of published articles. A 2017 study showed that the use of difficult words and sentence length has slowly increased from the 1960s (Plavén-Sigray et al., 2017). This has created communication barriers between scientists and the rest of the population. For an undergraduate biologist (and those paid to help them e.g. faculty, librarians etc) deciding to do research, there is clearly a lot to learn. How to find the correct information? How to interpret this information? How to keep up to date with research? In writing this chapter, I hope to be able to answer some of these questions.

A trained Biologist will be skilled in the use of the scientific method. In science textbooks, the scientific method is presented as a four or five step procedure involving:

I. Observation of a phenomenon.
II. Formulation of hypothesis based on your observation.
III. Designing and conducting experiments based on hypothesis.
IV. Analyzing results of experiment
V. Concluding to reject or not reject hypothesis

Hypothesis formulation is the cornerstone of any good experiment and is a skill all research biologists must possess. A well thought out scientific hypothesis will state clearly independent and dependent variables. The independent variable is manipulated by the researcher, whereas the dependent variable is the measurable outcome of the experiment. A hypothesis in general is a statement that may or may not be true but can be explored via experimentation. Therefore, a hypothesis must be falsifiable i.e. it can be proven wrong. A phenomenon that we cannot physically measure e.g. existence of ghosts, would not be a good basis to form a hypothesis. Due to the necessity of a hypothesis to be falsifiable, a hypothesis can only be rejected or not rejected, but never true. In biology, a good experiment will be testing two hypotheses: A null hypothesis, stating that there is no relationship between variables, and an alternate hypothesis, which is the opposite of a null hypothesis. Therefore, at the end of an experiment, one hypothesis will always be rejected and the other not rejected. The more a hypothesis is tested, the more likely it is to be true, but can never give a definitive answer.

Science (and hypotheses) are based on inductive and deductive reasoning. Inductive reasoning involves making a generalization based on observations. Whereas deductive reasoning is the exact opposite, making an observation based on a generalization.

In my own experience as a graduate student, I was using these methods every day. My research looks at morphological evolution in vertebrates. Essentially, I try to ask and answer questions relating to why/how the shape of vertebrates evolved. On my first day in graduate school, my PhD supervisor gave me a great example of inductive reasoning related to my project. The story goes that he was examining specimens in the zoology museum at Cambridge University and noticed a difference in tooth root placement between two species of rodent. The two species used their teeth in very different ways relating to their ecology. That observation led him to formulate the hypothesis that was the backbone to my PhD (*see appendix A for handout on developing a good hypothesis*).

How can you recognize these ideas when looking at materials produced in your field?

When designing a good experiment one of the most important aspects is to group your data in a way that isolates the variables being testing in your hypothesis. Once the experiment has been completed and your data collected, statistical tests are needed to identify significant differences between the groups in a quantitative context. In the field of biology, a statistically significant difference between groups is enough to disprove the null hypothesis and potentially publish results (as long as the experiment is novel). However, due to competition for space in high impact biological journals, results are skewed towards only publishing significant results. This has led the biological community to be obsessed with significant differences and the P-value (Chuard et al., 2019). Publication biases have led to the 'file-drawer effect'(Rosenthal, 1979; Fanelli, 2012) where non-significant results are not being disseminated to the wider biological community. This creates inefficiencies in biological research, with unnecessary repetition in experiments taking place due to the knowledge of previous experiments not being known to the community.

The ability to select an appropriate statistical test is a skill that every scientist needs. If the wrong statistical tests are used, the wrong conclusions may be drawn from your experiment. Inadequate statistical training is not only a problem at undergraduate level (Baglin et al., 2017), but is a problem within the scientific community as a whole (e.g Barraquand et al., 2014; Diong et al., 2018). If this statistical training gap is not addressed, it may lead to an increase in peer reviewed articles drawing wrong conclusions (Schroter et al., 2008; Makin & Orban de Xivry, 2019).

Clearly, statistical training is an issue in biology (Weissgerber, 2021). However, when it comes to statistics in the context of undergraduate research, the expertise of the instructor should be utilized. It would be unfair to assume an undergraduate researcher understands which statistical test to use in their given project. This is especially important if the research group are thinking about publishing their results. Errors in statistical methodology can often lead to retraction of published papers (Brown et al., 2018).

For student researchers to feel confident interpreting biostatistics, a good knowledge of variable types is important to understand what type of statistical test is required. As discussed above, the variables should already be defined in a good hypothesis, therefore, the appropriate statistical test should already be selected before the experiment phase. In biology, there are 3 types of variables to consider: measurement (quantitative), nominal (ordinal) and ranked (see McDonald, 2014 for more examples and *Appendix B for a tutorial on selecting the right statistical test*).

In fields such as comparative anatomy, an animal's shape is quantified to study form and function of a particular group. To achieve this, complex multivariate shape statistics is used to represent shape. This means that each observation/specimen (N number) examined has multiple variables attributed to it. Therefore, typical examples of statistical tests include MANOVA (multivariate analysis of variance) and principal components analysis (method for graphical representation of high dimensionality data).

The last 10 years has seen biotechnology becoming cheaper and more readily available in laboratories across the world. DNA genetic sequencing, imagining analysis and artificial intelligence have exponentially increased the amount of data needed to be analyzed. Data management is now an important skill in the biologist's repertoire. This abundance of data has led to efforts to create platforms that enable sharing of data. For example, due to cheaper access to imagining technology, the use of X-ray, microCT and MRI has exploded in the field of digital morphology. Researchers from this field have come together to create a common pipeline for analyzing and sharing data (Davies et al., 2017). When data is used in a publication, it is now commonplace for the journal to require the data to be open access. There are many different online repositories e.g. Dryad, figshare, Github, Morphosource. These different repositories normally specialize in specific data types. For instance, Github specializes in the sharing of computer code, whereas Morphosource specializes in 3D-surface files. Many of these repositories are free to upload data, and in many cases the journal will pay if they require data to be uploaded to a specific repository. The future of biological research is moving towards making all data accessible to everyone. This transparency will drive efforts of reproducibility and accountability. It will also give researchers access to data that was inaccessible due to cost e.g. microCT scans can still be quite expensive.

With this increased amount of data sharing comes a need for analysis of data. As biotechnology has become cheaper, analysis of data has also become cheaper. A decade ago, proprietary statistical programming such as SPSS, MATLAB and SAS were ubiquitous on biological lab computers. Now, the open-source statistical program, R has replaced these expensive programs. The reason for the popularity of R is down to its flexibility as it has over 13000 packages in its repository, CRAN (Comprehensive R Archive Network, https://cran.r-project.org/). R also has a very active online community with many free resources on how to learn. Increasingly complex problems are being solved using R as users share their code freely via repositories such as Github. Learning R should be part of every major undergraduate biology program e.g. (Auker & Barthelmess, 2020)

Is there a major difference between library research and field research in your discipline? How do these types of research interact?

In order to write relevant research questions, an extensive knowledge of your field is required. This kind of knowledge will accumulate over years of graduate training. Having said this, understanding how to find relevant literature is a skill that will increase the speed and efficiency of accumulative knowledge.

The process of acquiring skills in biological information literacy has changed drastically in the last 10 years. During the early years of the internet, a student was expected to be familiar with multiple database search engines e.g. PubMed, Medline, JSTOR, Science Direct, Wiley Online. Each of these databases are run by different for-profit publishers, with their own syntax and methods for adequate searching. Therefore, it was not surprising to find that students did not have the required skills for information literacy, due to the overwhelming number of options. During these years, faculty and librarians had to concentrate their efforts in making sure students were familiar with these databases (e.g. Porter, 2005)

The current generation of scientists have grown up in the 'age of google' and therefore it is unsurprising to find that the preferred way to search for information online is through this search engine. Google's popularity is due to their extensive indexing of information. However, the very reason why it's so popular could also be its weakness in the context of information literacy. Students with this kind of access to information may struggle to differentiate between quality scientific literature (i.e. peer reviewed articles) and less relevant information (e.g. blogs, biomedical company websites etc.). A study showed that dental/biomedical students who use google as their primary scientific literature search engine struggle to find relevant citations for assignments (Kingsley et al., 2011). However, this argument against Google may come across as a little unfair, as Google was not originally designed for the dissemination of scholarly articles. Indeed, Google itself identified this issue and created Google Scholar (GS), essentially Google with much of the extraneous material removed. When GS was first released, in 2004, many researchers did not see it as good enough to fill the information literacy gap (e.g Cathcart & Roberts, 2005). This was mostly down to the fact that many important articles were not in an electronic format and therefore required library databases to prove of their existence. This is no longer a problem as currently only a negligible number of articles are not in an electronic format. With that being said, it is not best practice for undergraduate students to solely rely on GS as it has a number of issues. Google and GS run into the same problem in that their searches can be too broad and can lead to information overload. This is especially problematic for the undergraduate researcher as information overload can lead to issues such as decision fatigue (Anderson, 2003). Library databases/search engines are often subject specific and use keywords to catalogue articles and therefore can be more concise in their outputs. Additionally, the majority of academic journals are behind paywalls. Therefore, when searching GS, a student might be shown a link where they are expected to pay for the article. This may lead the student to think they cannot get access and give up on what might be a potentially important paper. However, university libraries purchase subscriptions that will pay for these papers and grant the student access. An easy fix would be to tell the student to sign in and search the library database after finding the paper on GS. This runs into the problem of making sure the student is well trained in finding the article in a library database.

Many students get frustrated with internal library search engines e.g. Galileo, which will not return results if incorrect subject headings and author-supplied keywords are not inputted by the student (*see appendix C- a handout on identifying keywords*). This generation of students must be instantly satisfied with a plethora of results as google will return information to them no matter what words are used as an input. If the student has inadequate training using a library database (i.e. lack of understanding on how library databases are indexed compared to google), they are more likely to not find the information they are looking for and give up on the database and return to google. This mentality is found at all levels of undergraduate students and needs to be urgently addressed in order to improve information literacy. I have addressed this problem by inviting our school's librarian into my research class on the first week to give them instruction on the proper uses of our library's databases. This has resulted in my students producing research papers with a high number of appropriate citations.

In biology, 'appropriate citations' are almost exclusively peer reviewed journal articles (book sections are included in this section as they are also peer reviewed in biology). Traditionally, college information literacy training has highlighted the difference between primary (e.g. peer reviewed articles), secondary (e.g. textbook) and tertiary (e.g. Wikipedia article) sources. In general, it is good for students to understand these groupings but in biological research, citing anything less than a peer reviewed article is normally deemed unacceptable. There are of course some exceptions. For example, review articles, which are classified as secondary sources, are normally acceptable to cite in a manuscript where a concept has been backed up by a large amount of research. For example, geometric morphometrics is a statistical shape technique that allows researchers to quantify and compare animal shape. This technique has been developed and researched over the past 40 years and has thousands of articles relating to it. Therefore, it is acceptable to cite a review article as a substitute to the other cited work. However, many researchers do not like citing review articles at all, as they have been shown to reduce the impact of a paper conducting original research (Miranda & Garcia-Carpintero, 2018; McMahan & McFarland, 2021). Indexed abstracts from conferences do sometimes get cited in peer reviewed papers, but this is rare.

Students must be cautious even when citing peer reviewed articles due to the presence of predatory journals (Grudniewicz et al., 2019). Due to the profitability of scientific publication, many predatory journals have appeared. These journals exist due to the 'publish or perish' environment found within academia. They ask for high fees in exchange for publications. However, the articles do not go through rigorous peer review, which can lead to highly dubious publications. Hyper-competitiveness for academic jobs and grant funding has led to candidates with most publications receiving the job offers/grants and thus focus has turned from quality to quantity of articles. Although at first predatory journals were seen only to be publishing work from developing countries, it is clear that researchers from all over the globe fall prey to these journals (Shaghaei et al., 2018). Articles from predatory journals have even appeared on Google scholar. Therefore, researchers at all levels must be familiar with how to identify these journals. There isn't a single reliable list of predatory journals that can be looked up to verify if the research is credible. Currently, the only tool we have to avoid citing these predatory journals is experience. Generally, the more experience a researcher has, the more likely they will know most researchers in their field. Therefore, a good rule of thumb would be to use caution if there are no recognizable authors on the article. Another good way to avoid predatory journals is looking at the impact factor of the journal. Impact factors are calculated by how often articles in a journal are cited and predatory journals tend to have very low scores. Having said this, do not avoid citing articles in journals with low impact factors, as there can be other variables that affect a journal's impact factor. Indeed, some very reputable journals have low impact factors relative to others but are considered important journals in their field e.g. American Journal of Physical Anthropology (AJPA) has an impact factor of 2.8 but is considered to be biological anthropology's premier journal.

Many biological researchers have grown despondent with the peer review system of scientific publication. For-profit publishers own the rights to articles that have been paid for by public money and reviewed by biological researchers on a voluntary basis. These articles are then put behind paywalls where researchers can only access them via expensive paid subscriptions. This has led to massive profits for publishing companies, without any money filtering back into research. As a result, many of the experienced reviewers are now refusing to do peer review work. At a time when journals are seeing a large quantity of manuscript submissions with a reduction of willing reviewers, the reviews fall to the less experienced researchers. Over time this could/will lead to the questioning of the entire process of peer review publication and the integrity of the articles it produces. This problem will eventually lead to peer reviewers being paid for their hard work but until then it is always good for researchers at all levels to be critical of every published article. This issue has even driven researchers to create a checklist that can be used to help identify questionable papers that may have slipped through the peer review process (Grey et al., 2020).

An alternative method of disseminating research has grown in popularity over the years, the pre-print server (e.g. arXiv, BioRxiv, ChemRxiv, MedRxiv). An additional short coming of the peer review process (on top of the issues described above) is the length of time it takes to publish in a peer reviewed journal. For example, articles involving clinical trial data take an average of 3 years from data collection to publication (Welsh et al., 2018). Pre-print servers are online repositories where researchers can upload their non-peer reviewed manuscripts. Before being given public access on the server, these manuscripts are 'screened' by scientific volunteers for problems such as plagiarism and appropriate content. Manuscripts can then be immediately seen by everyone in the community and the authors can get immediate feedback without having to wait months/years being peer reviewed. Obviously, the downside of these pre-print servers is the lack of formal peer review by a journal. However, these pre-print servers can garner the power of the 'hive mind' of the internet which gives a chance for much needed critical feedback to the authors. This is a much more transparent process of 'peer review' relative to the more traditional peer review organized by each individual journal, where peer review is only seen by the authors, editors and reviewers of the journal. Additionally, to add more credibility (and transparency) to these uploaded manuscripts, BioRxiv has decided to allow independent review services (independent of journals) to post peer reviews of the manuscripts on the servers (Brainard, 2019). Independent review services such as Review Commons and Preprint Review, are groups of experts organized independently of a journal to give peer review to manuscripts on pre-print servers. This kind of transparency is far superior to the opaque nature of traditional peer review process as opacity allows reviewers to hide behind the anonymity of peer review, which results in many reviews being biased and nonobjective (Mavrogenis et al., 2020). This is the beginning of a complete overhaul of the scientific peer review process that may release it from the stranglehold of for-profit publication organizations.

Open access journals have become popular in the last few years. This comes as no surprise as the community is moving towards open access knowledge. Open access journals solve the problem of accessing information, by removing the paywall. However, APC (article processing charges) for each article published normally runs in the thousands of dollars. This ‘prices out’ many researchers, especially in the developing world. This leads to only researchers associated with large grants able to afford to publish. Publications should display the best work, not just the work of the rich.

Social media has had a surprisingly positive impact on research, especially Twitter. Communities of scientists are always updating their followers on the latest research they are doing. This has allowed other researchers to stay in touch with the most up to date science in their fields. Twitter also enables communication and collaboration between experienced and inexperienced researchers, opportunities that were once only possible through academic conferences e.g. (Taylor & Weigel, 2016). Twitter also allows scientists to demonstrate their up to date research with the public (Côté & Darling, 2018). Cutting out the middlemen (e.g. popular science magazine articles) between scientists and the public will decrease the chances of miscommunication e.g. (Boutron & Ravaud, 2018). When teaching a class, it is very important to let students know the importance of keeping up to date with current research. Students tend to happily use Twitter for this endeavor due to the popularity of the platform. There are some good examples of college research classes creating student led twitter accounts to communicate their research with other scientists and the general public (Gagnon, 2015; Oufiero, 2019).

In conclusion, information literacy needs to be embedded in college curriculum. Due to the complexity of information (good and bad) spreading at a lightening pace via the internet, information literacy training needs to begin at the freshman level. This begins with training in identifying good sources, reading good papers etc (e.g. Thompson & Blankinship, 2015).Information literacy, along with data management and statistical training, should be core skills taught at the undergraduate level. Without these skills, the current undergraduates will get lost in a sea of (mis)information.

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Appendix A How to develop a good hypothesis (modified from Price et al., 2020)

Criteria for evaluating scientific hypotheses

This list is a set of guidelines for identifying interesting and publishable scientific questions. It takes the form of a set of questions, ranging from critical to trivial, you should ask yourself when formulating your hypotheses. *Points in italics are specific to our project asking comparative evolutionary questions.*

Critical

- Are your hypotheses and predictions testable? i.e. are counter examples logically possible?

- Is there citable background information/context (previous studies or theory) to justify your question and explain your predictions?

- Replication – how many replicates do you need? In experimental systems you run the experiment several times – the exact number of replicates necessary to identify statistically significant trends depends on the study design. *In our comparative phylogenetic framework we ideally need evolutionary replicates, which means checking that our character of interest e.g. locomotion differences in rodents, has evolved more than once in our group of interest.*

Feasibility

- Do you have the ability to collect the necessary data? Think about:
    - Measurability – is the character well defined? e.g. Intelligence vs body weight.
    - Availability – are data readily available? For example, you would not want do a broad study comparing the locomotion of obscure rodents that scientists have not been able to validate
    - Accessibility – do you have access/rights to these data?
    - Comparability – if you are combining data from different sources, are they equivalent?

- Do you have adequate time and resources to study this question?
    - Be cognizant of scope and taxonomic scale

- Be aware that many broad scale questions require a lot of computational power to analyze the data.

- Do the methods currently exist to answer your question?

- Do you have an adequate sample size to identify statistically significant results?

- Are the data you will be using reliable? For example, species identifications on GenBank gene sequences may be incorrect at times.

‘Publishability’

Knowing whether a project stands a good chance of being published in a scientific journal takes experience and relies a lot on knowledge of intangible issues concerning the degree of interest in the topic. In reality it also involves a degree of luck, as just 2-3 reviewers get to decide the fate of your paper at a journal although picking the right journal with editors that understand your research can ameliorate this issue. There are quite a few things you should think about that all contribute to the likelihood of getting your study published.

- Is it concise? Limit your question to a few, clear predictions as long rambling papers are hard to understand and hard to get published.
- Applications – to current issues in fisheries or climate change
- Predictive ability – do you generate lots of opportunities for new studies?
- Has this exact study been conducted before? Investigating previously investigated questions in novel groups, systems or using new methods, etc. is acceptable but a duplicated study will not get published.
  - Publishing norms emphasize novel, positive results. Does your study generate novel and interesting results regardless of whether the hypothesis is supported or rejected? This is the holy grail of hypotheses!
  - Is your question sufficiently interesting?
    - Who is your target audience? The scope of your topic will dictate interest level and determine your target journals for publication. Specific (specialized, smaller, lower impact journals) → General (integrative, bigger, higher impact journals).

- More novel questions may fill an important knowledge gap and hence be of wide interest. However, if you fail to justify your novel question based on existing work people will struggle to put it into context and will likely reject it.
- Are your species charismatic? For example, the general public would be more interested in a study on giant rodents compared to a house mouse. However, people who study myomorphs would likely read your mouse study.
- Controversial questions can be good or bad depending on the question and your findings.

Appendix B How to choose the correct statistical test (adapted from OCR resources, UK).

Select and use a statistical test

Tutorials

Learners may be tested on their ability to select and use:

- the chi squared test (χ^2) to test the significance of the difference between observed and expected results
- the Student's *t*-test/ unpaired *t*-test
- the Paired *t*-test
- the Spearman's rank correlation coefficient.

Statistical tests

Choosing and using statistical tests can seem daunting at first, but they are very useful tools for analysing data. In simple terms each type of statistical test has one purpose: to determine the probability that your results could have occurred by chance as opposed to representing a real biological effect.

Why do we need statistical tests? As scientists we are interested in finding results that apply as general rules. For example, on average are students in Year 10 taller than students in Year 9? The best and most complete way to do this would be to find every single student across the whole country that is currently in Years 9 or 10 at school and measure every single one. In reality we cannot collect data from every school in the country, it would just take too long. Therefore in this example, and with all experiments, we collect data from a small subset of the population instead (this is our sample). From the sample data (e.g. all of Year 9 and 10 in one school) we infer things about the population as a whole.

Statistical tests allow us to make quantitative statements about the inferences we have made. We can put a number on how confident we are that our conclusion about the whole population is correct based on the sample we have taken.

We will cover four types of statistical test: **the chi squared test, the Spearman's rank correlation, the Student's *t*-test /** unpaired *t*-test**, the paired *t*-test**.

The choice of which statistical tests we use on our data depends on the question being asked. So always look at your data and ask yourself whether you can say yes to these questions – the one that fits best tells you which statistical test to perform.

1) Am I looking at frequencies, and whether my observations differ from expected values? For example – count the number of red, purple and white flowers that come from a genetic cross of two purple flowers where I expect a ratio of 1:2:1

2) Test – **chi squared test**

3) Am I looking at the relationship between two variables?

For example – ice-cream consumption and blood sugar levels, to see if people who eat a lot of ice-cream have higher blood sugar.

Test – **Spearman's rank correlation**

4) Am I looking at the whether there is a difference in the means between two separate/independent groups?
For example – measuring the heights of men and women to see if there is a difference in the average height by gender

Test – **Student's t-test/** unpaired *t*-test

5) Am I looking at whether there is a difference in the mean between the same group before and after a change?
For example – measuring the cholesterol levels in people before and after switching to a vegetarian diet to see if there is an effect on cholesterol of this dietary change

Test – **Paired t-test**

Which of the four tests is most appropriate for answering the example question we had earlier: 'on average are students in Year 10 taller than students in Year 9?'?

Hypotheses

Statistical tests allow us to test hypotheses about relationships. With every statistical test we generate two competing propositions:

the null hypothesis (H_0)

the alternative (H_1)

The alternative hypothesis comes from your idea that a particular effect will be present, while the null is simply the opposite, that the effect is absent.

Taking our previous example of height and year group we can generate the following hypotheses:

H_1 : Students in Year 10 are taller on average than students in Year 9

H_0 : On average students in Year 10 do not differ in height from students in Year 9

The reason we have a null hypothesis is because we cannot prove experimental hypotheses but we can reject dis-proven hypotheses. This can be quite confusing but, simply put, it is easier to dis-prove a theory than prove one. If our data gives us the confidence to reject the null hypothesis then this provides support for our alternative hypothesis, but it does not prove it.

Similarly if our statistical test shows no significant effect, we refer to this as failing to reject the null hypothesis. This is the statistics equivalent of using “not guilty” rather than “innocent” in a court verdict; we have not provided the evidence to reject the null hypothesis at this time but it doesn’t preclude changing our minds if more evidence comes to light at a later date.

Student’s *t*-test / unpaired *t*-test

This is the best test for looking at average differences between independent groups. So this is the test we would use to compare, for example, the average height of children in Year 9 and the average height of children in Year 10. We would take a sample from each of the year groups (one Year 9 class and one Year 10 class) and measure the variable we’re investigating (height) for all the individuals in each sample. Then, on the basis of these measurements, we use the Student’s *t*-test to say whether we can be reasonably confident that there really is a difference in the mean height of all Year 9 children compared to all Year 10 children.

Year 9		**Year 10**	
Name	**Height (cm)**	**Name**	**Height (cm)**
Connor	170	Mick	178
Tristan	181	Keith	174
James	178	Charlie	173
Brad	170	Ronnie	175
Alana	174	Danielle	178
Este	180	Taylor	178
Tegan	157	Jenny	174
Sara	157	Gemma	163
Mean	**170.9**	**Mean**	**174.1**
Standard deviation	**9.5**	**Standard deviation**	**4.9**

You can see that the means of our two sample groups **are** different.

Mean	**170.9**	**Mean**	**174.1**

No-one can say there is **no** difference there.

But we are not interested in the samples. We are interested in using the data from our samples to say things (with confidence) about the **whole population** (in this case all of year 9 and all of year 10). The important thing for us to find out, therefore, is whether the difference we see between the sample means is **significant** – is it big enough (given the size of the sample and how much variation we see in the data) for us to be confident that it reflects a real difference between the two year groups rather than just chance variations in the samples we happen to have picked?

Our **null hypothesis** is that there is no significant difference between the heights of Year 9 and Year 10 children. If this is true the difference between the sample means is **not** because there is really any difference between the means for all Year 9s and all Year 10s. It just arose by chance in the particular samples we took. The difference we see in our samples is not big enough to make us confident in saying that the two year groups really are different. We would say that there is **'not a significant difference'**.

The **alternative hypothesis** is that the there **is** a significant difference in height between the two whole year groups. In order to reject the null hypothesis we need to identify a 'significant difference' between the sample means. The difference is big enough that we can be confident it is telling us there is a real difference between the year groups. We can make a statement such as "on average the students in Year 10 are taller than students in Year 9".

The statistical test allows us to find out whether we can confidently reject the null hypothesis.

The Student's *t*-test formula is as follows:

$$t = \frac{|\bar{x}_A - \bar{x}_B|}{\sqrt{\frac{s_A^2}{n_A} + \frac{s_B^2}{n_B}}}$$

The modulus sign (vertical lines) in the numerator tells us to ignore any minus sign once we have subtracted one mean from the other

Subscript $_A$ and $_B$ refer to the two groups – Year 9 and Year 10.

$\bar{x}$ refers to the mean, so that $\bar{x}_A$ is the group mean of the Year 9 class

S is the standard deviation

n is the sample size

So that

$$t = \frac{(170.9 - 174.1)}{\sqrt{\frac{(9.5)^2}{8} + \frac{(4.9)^2}{8}}}$$

$\underline{t = 0.4}$

To understand what this means we must look up the value in the Student's *t*-test significance tables.

First calculate the degrees of freedom (df) which is *n-1* for each group:

(8-1)+(8-1) = 14

At 14 df the value of *t* = 0.4 is below the threshold of *t* = 2.15 which is the threshold at which we consider the difference to be significant

There is no significant difference between the height of students in Year 9 and Year 10 in our dataset.

Therefore we state that we have failed to reject the null hypothesis

This does **not** mean that we have proved that the mean height of Year 9 and Year 10 children is the same. It means that we have failed to show a significant difference based on the data we have gathered. Perhaps there really is no difference, or perhaps there really **is** a difference but our samples failed to show it (which could be for many reasons but most obviously it could simply be that the samples were not large enough).

Assumptions

When performing a Student's *t*-test the following things are assumed about the data in order to trust the test result.

- We have two independent groups
- For each group we have taken an unbiased sample and measured the same variable
- The variable is continuous
- The continuous variable is normally distributed for each group
- Each group has approximately equal variances (i.e. similar standard deviations) for this variable
- The sample sizes are roughly equal

Paired *t*-test

When looking for differences between means in two groups we use a *t*-test. If the two groups are independent of each other we use the unpaired version of this test. However, if the two groups come as related pairs we can use the paired *t*-test, allowing us to identify quite subtle but significant differences that might be missed with the unpaired test. It is essential to understand that the pairing must be done according to some **genuine relationship** between the members of each pair and must always be done based on that relationship **not based on the data gathered**.

For example if we measure a variable such as systolic blood pressure in a set of patients on Monday and then measure the same variable in the same set of patients on Tuesday we have two groups (patients on Monday and patients on Tuesday) and there is a natural pairing across these two groups (data on patient A on Monday will obviously be paired with data on the same patient the next day). This is a prime example where using the paired *t*-test is appropriate.

But beware! You might think that the following scenario would also allow analysis by the paired *t*-test **but it would not**:

We measure systolic blood pressure in two groups of ten patients.

We then rank the data in each group from highest to lowest.

Now can we pair up the highest in each group, then pair up second highest and so on? **No!** This is pairing after data gathering and is using the data itself to guide the pairing. Using a paired *t*-test in this case could easily lead us to mistakenly identify a significant difference where none exists.

As an example we will use the paired *t*-test to compare the mean difference in shell size of the same hermit crabs, before and after they are given the opportunity to swap out their shells for one of a range of others. These are measurements on 15 individual crabs measured twice (before and after shell swapping) .

Hermit crab	**Shell size before shell swapping (mm)**	**Shell size after shell swapping (mm)**	**Difference d**	**How far is difference from mean difference? $(d-\bar{d})$**	**$(d-\bar{d})^2$**
1	8	8	0	-2.2	4.84
2	10	12	2	-0.2	0.04
3	5	7	2	-0.2	0.04
4	6	8	2	-0.2	0.04
5	4	5	1	-1.2	1.44
6	7	11	4	1.8	3.24
7	9	10	1	-1.2	1.44
8	11	13	2	-0.2	0.04
9	13	13	0	-2.2	4.84
10	15	14	-1	-3.2	10.24

Hermit crab	Shell size before shell swapping (mm)	Shell size after shell swapping (mm)	Difference d	How far is difference from mean difference? $(d-\bar{d})$	$(d-\bar{d})^2$
11	8	11	3	0.8	0.64
12	9	14	5	2.8	7.84
13	7	15	8	5.8	33.64
14	9	10	1	-1.2	1.44
15	11	14	3	0.8	0.64
		Total	**33**		**70.4**

$\bar{d}$ = Mean difference = 33/15 = 2.2

Calculate for each hermit crab how far the difference in shell sizes is from the mean difference. Square these numbers and add them up to find the total = **70.4**

From this we can calculate the standard deviation of the difference $s_d = \sqrt{\frac{\sum(d-\bar{d})^2}{n-1}}$

$= \sqrt{\frac{70.4}{14}} = 2.24$

The paired *t*-test is as follows:

$$t = \frac{\bar{d}\sqrt{n}}{s_d}$$

Now we need to see whether this value of *t* is large enough for us to reject our null hypothesis. We can refer to a critical values table, picking the entry for our desired confidence level (95% or p=0.05) and the correct degrees of freedom. In a paired *t*-test the number of degrees of freedom is n-1.

15 individuals were used so n-1 = 14

The critical value at p = 0.05 for 14 degrees of freedom is 2.15

3.8 > 2.15 so our *t* value is greater than the critical value and we can **reject the null hypothesis** that there is no significant change in average shell size after being given the opportunity to swap shells. Giving hermit crabs the option to change their shells does have an effect on average shell size.

Assumptions

When performing a paired *t*-test the following things are assumed about the data in order to trust the test result.

- We have two groups with some dependency or relationship between specific pairs (one from one group one from the other) (e.g. same subjects measured before and after)
- We have taken an unbiased sample of these pairs and measured the same variable
- The variable is continuous
- The continuous variable is normally distributed for each group with the same variance

Spearman's rank correlation coefficient

If we have data on two variables for a set of items and we want to see if these variables are related we can test them for correlation. Correlation comes in two forms:

Positive correlation – as one variable increases in value, so does the other

Negative correlation – as one variable increases in value, the other decreases in value

As an example we will use the Spearman's rank correlation coefficient to comment on the relationship between the size of a locust and the length of its wings. So in this example the set of items is the locusts in our sample and the two variables we are looking at for each locust are body length and wing length.

When we use the Spearman's rank coefficient to calculate a correlation, we first have to rank the data for each of the variables.

Locust	Body length x (mm)	Wing length y (mm)	Rank x	Rank y	*d*	d^2
1	15	7	9	10	-1	1
2	10	6	10	9	1	1
3	80	32	1	1	0	0

Locust	Body length x (mm)	Wing length y (mm)	Rank x	Rank y	*d*	d^2
4	45	23	6	5	1	1
5	53	19	5	6.5	-1.5	2.25
6	62	29	2	2	0	0
7	35	18	8	8	0	0
8	41	19	7	6.5	0.5	0.25
9	58	28	4	3	1	1
10	61	27	3	4	-1	1

If two equal values appear e.g. for Rank y at rank 6, then both are given the rank 6.5 (halfway between rank 6 & 7) and no values are given rank 6 or 7.

Next we calculate the difference between the ranks = *d* and then square this = d^2

Then we find the sum of all the d^2 values

$\sum d^2$ = 1+1+0+1+2.25+0+0+0.25+1+1 = 7.5

Now we can calculate the correlation coefficient using the formula:

$$r_s = 1 - \frac{6\sum d^2}{n(n^2-1)} = 1 - \frac{6 \times 7.5}{7(7^2-1)} = 1 - \frac{45}{336} = 0.8661$$

An r_s value of +1 shows perfect positive correlation

An r_s value of -1 shows perfect negative correlation

An r_s value of 0 shows no correlation

To find out whether the r_s value we have calculated is sufficient evidence to reject our null hypothesis we need to refer to the critical values table. Some versions of this table have entries listed according to n, the number of items (locusts in this case, n = 10). Some versions have entries listed by degrees of freedom.

The number of degrees of freedom is:

d.f. = n - 2 = 8

The critical value for the Spearman's rank correlation coefficient for n = 10 or df = 8 at p=0.05 is 0.6485

Our calculated value for r_s is therefore greater than the critical value

0.8661>0.6485

Therefore we can reject the null hypothesis that there is no significant correlation between locust body size and wing size. We can accept the alternative hypothesis that there is a significant correlation between locust body size and wing size.

Our r_s is positive (+0.8661), therefore we have positive correlation: as the size of a locust increases there is a tendency for its wing length to increase.

Remember - correlation does not equal causation – we have shown that these two variables tend to change together, but we have not shown that there is a cause and effect.

Assumptions

When performing a Spearman's rank correlation the following things are assumed about the data in order to trust the test result:

We have a set of items and we have data on the same two variables from every one of those items

Both variables are ordinal (i.e. they can be placed in order (ranked)) or a measurement.

We also assume that there are few (or no) tied ranks. In cases where there are many ties we can correct for this by using a slightly different formula but that is beyond the scope of the A Level Biology maths requirements.

The chi squared test

When we want to look at distributions of frequencies and whether they differ from expected values we can use the chi squared (χ^2) test. Our expected frequencies can be based on previous observations from experiments, or simply an expectation that there should be equal proportions in each category.

For example, we cross two flowers with pink petals – we know that both of these plants are heterozygotes and they carry two co-dominant alleles, one for red petals and one for white petals. We then count the frequency of offspring that develop with either red, white or pink petals.

Our hypothesis is that any differences in the observed numbers of offspring with white, red and pink petals from the expected numbers are due to chance. The null hypothesis is that there is no significant differences between the observed numbers of offspring with white, red and pink petals from the expected numbers. The alternative hypothesis would be that there is a significant difference between the observed numbers of offspring with white, red and pink petals from the expected numbers

We start by working out what our expected frequencies should be. A Punnett square is a good way to do this. In the table below the alleles present in the parental gametes are shown and then, within the outlined section, the four equally likely outcomes of each fertilisation event, giving the alleles present in the offspring and the **resulting appearance**

		Parental gamete alleles	
		Red	White
Parental gamete alleles	Red	Red/Red **Red**	Red/White **Pink**
	White	Red/White **Pink**	White/White **White**

From this simple table we can see that we expect to see frequencies in the offspring of White:Red:Pink petals at a ratio of 1:1:2.

Let's say we count a total of 160 offspring from the cross, we can therefore calculate the expected numbers of white, red and pink petals – let's compare that to the observed numbers in the table below

	Expected	Observed
White	40	28
Red	40	46
Pink	80	86

Is there a significant difference between the expected and observed frequencies?

The χ^2 value is calculated as follows: $$\chi^2 = \sum \frac{(f_o - f_e)^2}{f_e}$$

f_0 = observed frequencies

f_e = expected frequencies

$$\chi^2 = \frac{(28-40)^2}{40} + \frac{(46-40)^2}{40} + \frac{(86-80)^2}{80} = 4.95$$

Once again we must look up this value in the appropriate statistics data table and compare it to the critical value at the appropriate degrees of freedom.

There are 3 offspring types – red, white and pink, so n = 3

Therefore degrees of freedom = n-1 = 2

On the χ^2 table the critical value where p = 0.05 and df = 2 is 7.81

4.95 < 7.81 therefore our χ^2 value does not reach the critical value for significance at 2 degrees of freedom.

Therefore we cannot reject the null hypothesis: that there is no significant differences between the observed numbers of offspring with white, red and pink petals from the expected numbers .

<u>Assumptions</u>

When performing a Chi-squared test the following things are assumed about the data in order to trust the test result.

There is a minimum sample size for performing the chi squared test – this is indicated by each expected value in a cell being >5

Appendix C- Identifying key words (from Indiana University library)

Identifying Keywords

A ***keyword*** expresses a central concept or idea about a topic. When you search Google, you are keyword searching.

To Identify Keywords:

Identify the major concepts of your topic. Then develop keywords related to the major concepts of your topic.

Databases can be picky about search terms. Identify synonyms for your concept, and consider the words most likely to be used in the database.

Example: the *environmental consequences* of *fracking*

Concept 1: Fracking	Concept 2: Environmental consequences
Keywords:	**Keywords:**
Fracking	Environment
Hydraulic fracking	Pollution Natural gas drilling
	Global Warming

NOTE-When searching library resources (e.g., databases, library catalog), you may need to be more selective with keywords.

Tips For Using Effective Keywords

Use Subjects to Identify Keyword

A search for fracking environment:

Select relevant terms to refine your results.

Concision: Begin with only 2-3 terms. Avoid long phrases. (The more terms you enter, the fewer results you'll get.)

Synonyms:

If your first term doesn't work, try a synonym or a broader term.

Example: environment instead of environmental consequences

Database Search Results:

Do a quick database search. View the search results page to identify relevant terms.

Titles and article abstracts (summaries) include helpful terms.

Most databases list **subject terms**. Subject terms show how a database organizes records: they can help you locate more items on that topic and related topics.

Background Research:

Do some quick background research. Note terms that are often used to discuss the topic.

(Reference sources like Wikipedia or the library databases Ency- clopedia Britannica and Credo Reference offer overviews of many topics. Of course, remember to evaluate information in Wikipedia with particular care.)

Chapter 5: Describing the Research As Inquiry Frame of Information Literacy in The Social Sciences

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Introduction

Advances in technology have made information easier to find than ever. However, it is important to teach information literacy skills in higher education so that individuals can not only locate information, but also evaluate and assess it critically. Learning about information literacy benefits students by helping them to find and evaluate information more effectively and expanding their knowledge on the subjects they research, transforming their thinking skills to be more independent and more critical (Rosman et al., 2018). Yet, even university students in upper level courses may not have sound information skills or familiarity with their university's library resources (Brady & Malik, 2019). Students may also have trouble with the more nuanced aspects of information literacy mastery; in one study, students were successful in locating sources for an assignment, but struggled with effectively using the sources as evidence and giving credit to their sources (Markowski et al., 2018).

Barriers to teaching students effective information literacy skills are that students may be overconfident, faculty and librarians may not collaborate and may not be familiar with the literature and best practices in each others' fields, and that students are unlikely to seek help from librarians when working on assignments for their courses (Kissell et al., 2016). It is difficult to give comprehensive education about information literacy in the short amount of class time that instructors can allocate to the topic, as information literacy encompasses at least six key parts (Association of College and Research Libraries, 2016).

Research as inquiry is one of the six frames of information literacy described in the Association of College and Research Libraries' Framework for Information Literacy for Higher Education (2016). This frame is important because individuals need to do research in order to find information in the first place. In one study, students were given an information literacy test as freshmen and it was administered again when the students were seniors. Developing a research strategy was the skill set with the second greatest difference in scores from freshmen to senior year (Ault & Ferguson, 2019). In another study, academic librarians reported that teaching general research strategies was their second most important instructional objective (Julien et al., 2018).

Information literacy is contextual and the application of it varies in different academic disciplines (Miller, 2018). Information literacy instruction may even need to be tailored to students within the same discipline, as Pinto and colleagues (2019) found that there were differences among students in five majors in the learning style that they preferred for achieving information literacy competency, even though all five majors were in the social sciences discipline.

This chapter describes research as inquiry as it applies in the author's disciplines, based on the author's experience teaching research methods and mentoring senior thesis students. Much of the content is tacit knowledge acquired from the author's graduate program and professional experiences. Therefore, it should be acknowledged that the information may not be generalizable to everyone's work—even those in the same discipline, because researchers in the same discipline may have been trained differently. The author's degrees are in psychology and the author teaches in the rural community development degree program. The rural community development degree program is a multidisciplinary program that broadly focuses on training students to help rural communities thrive, whether it be by a career doing therapy in a rural community, working for the chamber of commerce in a small town, advocating for health policies that benefit rural residents, or some other professional activity. The core faculty hold degrees in psychology, sociology, criminal justice, medicine, and education.

What are common research methods, theories, and approaches in the discipline?

Research methods in both psychology and rural community development typically involve collecting data from individuals, most commonly through self-report. However, some research projects may take the form of analyzing archival data (for example, analyzing United States Census data) or a literature review. There are hundreds of theories and approaches. In psychology, common broad theories might focus on the humanistic perspective, the psychoanalytic perspective, the behaviorist perspective, the cognitive perspective, or the evolutionary perspective. Several specific theories have been derived for each of these perspectives; for example, Maslow's theory of the hierarchy of needs is related to the humanistic perspective, Freud's theory of psychosexual stages is related to the psychoanalytic perspective, Skinner's theory of operant conditioning is related to the behaviorist perspective, Piaget's theory of development is related to the cognitive perspective, and Buss' sexual strategy theory is related to the evolutionary perspective. Of the common broad perspectives, the psychoanalytic perspective is the least common. In rural community development, common theories and approaches include those in psychology, as well theories and approaches pertaining to sociology, criminal justice, medicine, and education.

How do methods, theories, or approaches impact the way that research questions areformulated?

Methods, theories, and approaches impact the way that research questions are formulated mainly based on the topic of the research question. As an example, consider that an investigator wants to research romantic relationships. Their research question would be different depending on which theoretical perspective they used.

If the investigator used the humanistic perspective to frame their project on relationships, the research question would be formulated in a way that emphasizes that human nature is to seek growth and be positive. The research question might be, "How do couples' strengths complement each other when working together to solve a problem?" In contrast, if the psychoanalytic perspective were used, the research question would be formulated in a way that emphasizes that human nature is to be self-serving and is guided by the unconscious mind. The research question might be, "What experiences are likely to cause couples to have unconscious feelings of resentment toward each other that guide the way they interact with each other?" The behaviorist perspective emphasizes observable actions, reinforcement, and punishment. If the investigator used the behaviorist perspective, the research question might be, “Does the frequency of times that couples say “I love you” predict the frequency of doing small acts of kindness for one another, like making each other coffee?” The cognitive perspective emphasizes thoughts and concepts like memory and attention that cannot be concretely seen or heard. For an investigator coming from the cognitive perspective, the research question might be, “How do couples’ memories of the first five years of their relationship influence their current feelings of passion?” The evolutionary perspective emphasizes that all species—including humans—are driven by two goals, to survive and to pass their genes on to their offspring by reproducing. If the evolutionary perspective was used, the research question might be, “Is the belief that men are attracted to women with large breasts based on an implicit assumption that women with large breasts will be successful in nurturing the man’s offspring by breastfeeding?” It is evident from these examples that the theoretical perspective the investigator uses to frame their research will have a substantial influence on what the research question is.

What do research questions look like in the field in terms of the null hypothesis and thequestion?

Research questions in the field are generally specific. For example, “Do students who went to high school in a rural area have lower confidence in their ability to use technology in college compared to students who went to high school in an urban area?” is preferable to “How do students perceive technology in college?”. Many published studies have more than one research question and the research questions usually build on each other. Research questions should be parallel to a null and alternative hypothesis. The null hypothesis always states that there is no effect or that the groups are equal. (H_0: There are no difference in students’ confidence in their ability to use technology in college between students who went to high school in rural areas and students who went to high school in urban areas.) The alternative hypothesis states that there will be differences, or what the predicted difference is. (H_A: Students who went to high school in rural areas will have lower confidence is their ability to use technology in college compared to students who went to high school in urban areas.) According to the logic of the scientific method, the null hypothesis is the hypothesis tested with statistical tests (with the goal being to reject the null hypothesis). However, in published papers, authors often state only their alternative hypothesis. This may be because it is understood that the null hypothesis will state that there is no effect or the groups are equal, whereas the alternative hypothesis might state that the expected effect is in one direction or the other.

How can you recognize these ideas when looking at materials produced in your field?

What kind of methodologies are frequently used in reporting data?

In both psychology and rural community development, data is most commonly reported through peer-reviewed academic journal articles, reports from professional organizations, and presentations at professional conferences. Empirical projects are more common than literature reviews (research where no data was collected) in all three of these outlets, but literature reviews can be valuable as well. (Empirical projects will also include a literature review as part of the paper.) Peer-reviewed academic journal articles are typically the most extensive outlet and typically use inferential statistics (statistical tests) to test original data. Reports from professional organizations usually contain original data as well, but may lack a literature review describing previous work and a theoretical framework. Reports from professional organizations are also more likely to contain only descriptive statistics (statistics that summarize the data—such as the mean and mode—in contrast to inferential statistical tests). Presentations at professional conferences are similar in scope and format to peer-reviewed academic journal articles, but provide only a snapshot of the research project. It is common for a researcher to produce both a peer-reviewed academic journal article and a conference presentation on the same project.

What kind of statistical tests are used and why?

There are numerous types of statistical tests that are used in psychology and rural community development research. At the undergraduate level, common statistical tests that are used include independent samples t-tests, dependent samples t-tests, linear regression, chi square tests, and analysis of variance (ANOVA). At the graduate level, common statistical tests that are used include special types of regression, multivariate tests, structural equation modeling, tests for nested designs, and tests to determine factor structure. At both levels, parametric statistics are more common than non-parametric statistics. Researchers determine which statistical test should be used by examining the rules of each test and the design of the research study. For example, an independent samples t-test should be used if the design of the study is comparing two independent groups on one dependent variable. The rules for an independent t-test include that the data must be normally distributed, the observations must be independent of one another, and the variance for each group must be approximately the same. Researchers may consult decision trees showing different statistical tests to decide which one is appropriate to use.

How are theories utilized as frames for the research?

Theories are used to place research questions in an appropriate context. There is a circular relationship between theories and research: When a researcher starts a study, they should base their research question on a theory so that the theory informs research. But when the results of the study are known, the results can provide further support for the theory, or show a limitation or expansion of the theory (for example, showing that the theory does or does not apply to individuals in a certain age group or in a certain culture), so in that way, research studies inform theories.

What are common approaches to collecting and analyzing data?

Data are collected by both quantitative and qualitative methods. Quantitative methods are more common in psychology. Quantitative methods also seem to be more common in rural community development, but the difference in the number of studies utilizing quantitative versus qualitative methods is not as large. Perhaps the preference for quantitative data is because the analyses and results of quantitative data are more objective and able to be replicated, whereas qualitative analyses are largely dependent on the researcher's subjective interpretation.

Do students learn to identify these ideas as well?

What kind of aspects of research are appropriate at the undergraduate level?

All of the fundamental parts of doing a research study are appropriate for undergraduates in the discipline to learn: Coming up with an idea, doing literature searches, formulating research questions and hypotheses, making materials to be used in the study, obtaining approval from the institutional review board, collecting data, coding and analyzing data, and writing a paper. However, the expected breadth and depth of most of these steps is different for the undergraduate level compared to the graduate or professional level. At the undergraduate level, a research idea might have only one independent variable and one dependent variable, whereas at the graduate or professional level there would most likely be multiple independent and dependent variables. Literature searches at the graduate or professional level would be expected to be longer and more comprehensive than literature searches at the undergraduate level, and the types of analyses used would be more sophisticated at the graduate or professional level compared to the undergraduate level. Writing a paper is appropriate for all three levels of researchers, but at the graduate or professional level it is expected that the paper will be presented at a conference or published in an academic journal. At the undergraduate level, a paper may be turned in for a grade or requirement in a course, but may go no further than that.

What activities work well in demonstrating how communities of practice operate?

Activities that work well in demonstrating how communities of practice operate often include involving the students in the community of practice through practicums, internships, collaborating with a professional organization on a class project, or other applied learning experiences.

Examples of successful exercises and outcomes used to teach research within the classroom

The following list contains examples of exercises that the author has used to teach research within the classroom in an upper-division research methods course:

Portfolio assignment (see Appendix A): Students work on completing a portfolio throughout the semester that serves as the foundation for a research proposal. The first section asks students to come up with a topic that they could do a research study on, and subsequent sections ask the student to do a literature search and summarize the articles they find on their topic, describe who the participants would be and how they would be recruited, describe how data would be collected and analyzed, describe the results that would be expected, describe what the implications would be, and identify obstacles that could come up and how those obstacles could be addressed. At the end of the semester, each student presents their portfolio to the class and the class discusses the students' research idea and gives them feedback, such as additional variables that would be interesting to include or additional obstacles that would need to be addressed.

Class Research Project: Students complete a research project as a class throughout the semester that mirrors a senior thesis, but is more manageable because the work is divided up among the students in the class. Students are assigned parts of the project to complete throughout the semester and earn participation points for each part. The steps vary somewhat depending on what the topic of the project is, but the basic steps are: (1) Each student is told to come up with an idea for a research study (2) We discuss everyone's idea during class and vote on which one we will do (3) We have a class discussion to refine the idea and establish the study design, methodology, and how data will be analyzed (4) Each student is assigned to find and present an academic journal article on our topic (this serves as the literature review) (5) We have another class discussion to refine our idea, the study design, and methodology based on what we've learned from the literature review (6) Each student is assigned to find a scale or measure on our topic and then we work as a class to construct our questionnaire/make materials (7) Students are divided into pairs or small groups and each pair or group completes a section of the institutional review board application (8) Each student collects data and enters it into a statistical software, such as SPSS (9) The instructor guides the students through analyzing and interpreting the data as a class (10) Each student writes an abstract of the study and the instructor compiles them into one abstract to submit to the undergraduate research symposium (11) Students are divided into pairs or small groups and each pair or group does a section of a research poster (12) The students all present the poster during the undergraduate research symposium.

Picture of a Researcher Activity (see Appendix B): On the first day and last day of class, students are told to draw a picture of a researcher doing research. After students draw their pictures on the first day, the instructor discusses what doing research in the social sciences might look like. At the end of the semester, the instructor compares each student's pictures from the first and last day to see if the pictures on the last day were representative of the types of research activities that students did during the course (for example, doing literature searches, collecting survey data, analyzing data using a statistical software program, or presenting a poster).

CITI training (see Appendix C): Student complete online ethics training through the Collaborative Institutional Training Initiative (CITI) program as an assignment. Any individual who submits an institutional review board application to do a research project is required to do this training, so it prepares students to submit their institutional review board applications for the class research project and for the senior thesis that they will do the following year.

Using Qualtrics (see Appendix D): Qualtrics is an online tool for making and distributing surveys (similar to Survey Monkey and Survey Gizmo). The instructor demonstrates how to make various types of survey questions on Qualtrics during class. Students are then given an assignment to find a journal article containing a scale or measure, make the scale or measure into a survey using Qualtrics, and come up with additional, related questions to include on the survey.

APA Style (see Appendix E): Students review the APA (American Psychological Association) style and formatting guidelines during class and are given an assignment where they find sources authored by professors at their college and write APA style citations for them, as well as a citation for the textbook used in the research methods course.

Research Scenarios (see Appendix F): The instructor writes short scenarios of research projects, including what the research question is, what the variables are, and the response format for each of the variables. Students read the scenarios and practice identifying the independent variable(s) and dependent variables(s), writing the null and alternative hypotheses, and deciding which statistical test would be used to analyze the data for each scenario.

Reliability and Validity Activity (see Appendix G): Students are given a journal article on the development and testing of a happiness scale. (Students respond to this scale during class earlier in the semester to gather data to demonstrate using a statistical analysis software.) Following a lecture on reliability and validity, students read the article and respond to questions such as "How many participants were in the sample?" "What types of reliability were assessed and what were the coefficients for each type?" "What types of validity were assessed?" and "What did the authors conclude about the overall psychometric properties of the scale?"

Is there a major difference between library research and field research in your discipline? How do these types of research interact?

Library and field research differ in the social sciences. Library research is generally considered to be literature reviews or thought papers and field research is generally considered to be empirical projects that involve collecting and analyzing data. However, library and field research do interact. Good field research starts with doing literature reviews to inform the research questions and development of materials. And the journal articles that result from field research will become part of the body of literature that another researcher cites while doing a literature review (library research).

Define how data is collected in the field.

In the social sciences, data is most commonly collected through self-report surveys and questionnaires. Data can also be collected through archival research (analyzing records, such as data from the United States Census), experiments, or task outcomes (e.g., reaction time). In some cases, data is collected through physiological measures—for example, taking a saliva sample from participants and analyzing the stress hormones that are present in it. In other cases, data is collected through observations of behavior or through interviews.

What does the data look like and how is the data typically shared?

In many studies in the social sciences, particularly self-report surveys and questionnaires, the data is anonymous. Participant numbers or codes may be used in the dataset in place of names to keep the data organized. Likert-type rating scales (e.g., rate yourself on a scale of 1 to 5 with 1 = Strongly Disagree and 5 = Strongly Agree) are common. In student research projects, data is typically shared with the faculty mentor(s). It is also common for professional level researchers to share data while doing collaborative research projects. Typically, the principal investigator will specify in the institutional review board application who will have access to the data and how the data will be stored and protected.

Books versus journal articles and other materials – How quickly is information disseminated?

Journal articles in the field are typically published much more quickly than books, but the use of eBooks has narrowed the gap.

How are different materials weighted in value?

Generally speaking, peer-reviewed academic journal articles are the gold standard in the field. Journals with high impact factors are generally considered the best, and journals with no impact factors (especially open-access journals) are generally considered weaker. The least sound sources are generally considered to be .com websites, blog and social media posts, and magazines. However, the best type of source to use depends on the research question being asked. For example, if the research question is about trends in United States Census data, the best source would be the United States Census website. If the research question is about themes of depression in adolescents' social media posts, then social media posts would be a good source of data. However, in these cases the researcher would still be expected to use and cite peer-reviewed academic journal articles in the literature review section of their manuscript.

Do the questions asked in field research differ from those asked of previously createdinformation sources?

A general guideline is that good research builds on other research, so the questions asked in field research are often similar to those asked of previously created information sources.

Interpretation versus Information

Information can be interpreted in different ways, and the researcher writing the article, book, etc. has a lot of influence on how information will be interpreted based on the context that they provide for the results. For example, if a researcher does a study on depression and wants the reader to conclude that their sample had a high level of depression, the researcher can cite studies in their literature review where the depression scores were lower than what this researcher found. Conversely, if the researcher wants the reader to conclude that their sample had a low lower of depression, they could cite studies in their literature review that found depression scores that were higher than what this researcher found.

Two notable problems in the field with how information is presented and interpreted are "cherry picking" and "HARKing." "Cherry picking" is when an author does many analyses but only reports the results of the analyses that were consistent with their hypothesis. "HARKing" is an acronym for Hypothesizing After the Results are Known. This occurs when an author finds that the results of their analyses do not support their hypothesis, so when they report their study they come up with a new, different hypothesis that is consistent with the results, even though that hypothesis was not part of the initial study.

How does your field build on research?

It is common for research to build upon previous research in the fields of both psychology and rural community development. This can occur in several ways. One way is that researchers might do a partial replication of another study but add one or more new variables. For example, maybe a researcher publishes a study that found that having older adults listen to classical music resulted in lowering their blood pressure when compared to groups who listened to rock and to jazz. Another researcher might build on the study by doing a similar investigation where additional groups were recruited and listed to additional genres of music. Another way that investigators might build on research is to test the limits of a theory, or replicate a study with a new population to see if the results are consistent.

How do you give credit to the creation of information?

New information is cited to give credit. If the new information has not yet been published, those who wish to cite the information can cite a conference presentation or lecture if the information has been disseminated that way, or can cite the new information as personal communication with the creator of the new information.

Is there a researcher/practitioner dichotomy in your field?

In psychology, there is mostly a researcher/practitioner dichotomy (meaning that researchers and practitioners do different things), although some individuals do both. In rural community development, there is a less of a dichotomy because research in that field tends to be more applied, making it more feasible for one individual to assume the role of both researcher and practitioner. There is an interaction in that practitioners frequently read research, and the best practices in which they are trained are guided by research on what is most effective. Likewise, current practices in the field can inform the questions and variables that researchers investigate.

Define how experts are determined.

In general, individuals are identified as experts by educational degrees and years of experience. However, the term expert is relative, and a layperson might be more of an expert than someone who has a Ph.D. in some situations. For example, imagine that someone wanted to address vaccine hesitancy among residents of a rural town. An individual who has no specialized education or training but who lives in the community and knows many of the residents there and is familiar with the local culture might be more of an expert than an individual who has advanced degrees and years of experience with vaccine development.

Are practitioners' information weighted as significant?

In psychology, practitioners' information is weighted as less significant than in rural community development because in psychology there is more of a researcher/practitioner dichotomy and there is less communication between researchers and practitioners. In rural community development, practitioners' information is weighted as more significant because it is more common for individuals to be in the role of both applied researcher and practitioner.

What does the divide look like between practitioners and researchers? Is it a collaborative relationship?

One of the noticeable differences between practitioners and researchers is that researchers usually have advanced degrees, and practitioners may or may not have advanced degrees. However, this is not to say that researchers are superior in any way; it is likely because there is a broader range and level of careers in applied practice than there are in research. The relationship between practitioners and researchers is generally collaborative, but due to the rigorous nature of both jobs, there is not always communication between the two. One barrier to communication between researchers and practitioners is that researchers tend to use research jargon when presenting their results, and it is difficult for practitioners who do not have training and education in statistics to understand the meaning of the research results.

Do typical research assignments that you see in disciplinary courses mirror or contradict these processes? How?

Research assignments in disciplinary courses generally mirror the processes of professional research. For example, most students do a senior thesis (senior capstone) and write a paper that contains the major sections found in a peer-reviewed academic journal article. However, student research is less rigorous and narrower in scope than professional level research. Upper division or honors students sometimes give presentations at professional conferences, but rarely publish peer-reviewed academic journal articles or contribute to reports from professional organizations.

There is one important way that research assignments typically seen in disciplinary courses contradicts the processes of professional research: teaching versus using experimental designs. In research methods courses, students are taught that experimental designs with random assignment, a true manipulation, and a control group are the strongest methodological design to use. Therefore, many assignments assess students' knowledge and understanding of experimental designs. However, in practice, professional researchers in the field do not employ experimental designs with random assignment, true manipulations, and control groups very often. This is because the types of topics that social scientists are interested in studying often cannot be studied with an experimental design or it would be unethical to use an experiment. An example of a topic that could not be studied using an experimental design is gender differences in math anxiety. It would not be possible to use random assignment to assign participants to the male, female, non-binary, or other gender group. An example of a topic that would be unethical to study using an experimental design is child abuse. To do an experiment on whether or not being abused as a child causes a decrease in mental health, children would have to be randomly assigned to one of two groups: abuse or no abuse. Then, children in both groups would be assessed for mental health symptoms. Obviously, children cannot be purposely subjected to abuse for the sake of research, so child abuse needs to be researched using non-experimental research designs.

Conclusion

Information literacy is an essential skill for the twenty-first century. Individuals need to use information literacy skills not only in school and work, but also in everyday life (Saunders, 2017). Information literacy is so important that some have suggested that access to information and to information literacy education is a basic human right (Saunders, 2017).

There are several barriers to information literacy education, but faculty and librarians can implement evidence-based practices to help students improve their information literacy skills. For example, having students meet with a librarian when they are working on a specific assignment (as opposed to a general instructional session on information literacy) may increase the chances of students seeking out consultation with the librarian throughout their time in college (Bingham et al., 2017). It is essential for faculty and librarians to have working relationships (Bingham et al. 2017). In one study, faculty and librarians acknowledged that they had much to learn from each other; librarians acknowledged that faculty views are essential because the faculty have regular, direct contact with the students and know the expectations in their discipline, and faculty acknowledged that librarians have a central role in the learning process, especially for students in underclassmen courses (Yevelson-Shorsher & Bronstein, 2018).

Students should be taught about information literacy using the types of sources that they will encounter in practice in their discipline (Bingham et al., 2017), as the research as inquiry frame of the information literacy framework is dependent upon the discipline. Psychology and rural community development are relatively similar, but are distinct from disciplines like the humanities and fine arts. Students in psychology and in rural community development typically take courses in research methods and statistics. During these courses, they learn about common theories and approaches, statistical tests, quantitative and qualitative methodology, and master the skills for both library and field research. By reflecting on how research and information literacy are different in various disciplines, educators can better equip students with the skills needed to locate information and evaluate it in a critical way. This will help students not only to master the research skills needed to complete their education, but also help them in everyday life.

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Appendix A: Portfolio Assignment

Throughout the semester, you will make a portfolio centered around an idea for a research project you could carry out in the future. You will submit each section to the GeorgiaVIEW dropbox by the due date listed below.

You will submit your entire portfolio on GeorgiaVIEW with all of the sections and any needed revisions before class time on May 1st (100 points). If most of your submitted sections throughout the semester are excellent, you will have only minor revisions to improve the final portfolio you submit. If you receive feedback for improvements on most of your sections throughout the semester, the revisions you make before submitting your final portfolio should be more substantial.

You will give a short class presentation on the information in your portfolio, during which you will receive additional suggestions for revisions.

Content for Each Section:

Section 1:
Due: February 5th, 2021

• What are three broad topics that you find interesting? (See Chapter 2 in the textbook for suggestions on thinking of ideas.)
• Choose 1 of those topics to use for your portfolio.
• What is some background information on your topic? This should be about ½ page (typed, double-spaced). You do not need to cite sources, but include where the information came from (personal experience, talking to other people, browsing online, etc.)

Section 2:
Due: February 12th, 2021

• Find, cite, read, and summarize two studies from academic journal articles that have been done on your topic. Each summary should be at least 1.5 pages (typed, double-spaced), use two or less direct quotes, and address these questions:
  - What was the topic?
  - What was hypothesized (or what were the research questions)?
  - How was the hypothesis tested?
  - Did the results support the hypothesis (or research questions)?
  - What is your opinion of the study?

Section 3:
Due: March 26th, 2021

• Describe how you would collect data and analyze it to do a study on this topic. Include what your independent and dependent variables would be and the response format for each. Include what statistical test you would use for the analysis.
• If you would use a method of data collection or an analysis that is not described in the textbook or in your notes from class, justify why that method would be appropriate for your topic and research questions.

• Include who your participants would be and how you would recruit them in your response. Then, describe the supplies and resources you would need to carry out the data collection and analysis. (Example of supplies are a printer, paper, pens and a copy machine to administer surveys. Examples of resources are a gift card to raffle off as a participant incentive and personnel who would be involved.)

Section 4:
Due: April 2nd, 2021
• What results would you expect to find?
• What would the implications be if the results were as expected?
• What would the implications be in the results were not as expected?

Section 5:
Due: April 19th, 2021
• Identify two potential obstacles that might come up if you were to do this study.
• For one of them, describe how it could be addressed in this study or in future studies on the same topic.

Portfolio Presentation Guidelines

Your presentation should be 6 – 10 minutes long.

- The student used a visual aid (typically a PowerPoint presentation) (4 points)_______/4
- The student thoroughly addressed each of the following points: (4 points each)
    - What is the topic and research question(s) you used for your portfolio?_______/ 4
    - Summarize the previous research that has been done on this topic. You should include citations for the two articles you used and may also describe what you learned from searching for the articles you selected.________/ 4
    - Describe who participants would be and how you would recruit them._____/ 4
    - Describe the supplies & resources you would need to carry out this study.____/ 4
    - Accurately & specifically describe how you would collect and analyze data._____/ 4
    - Describe the results you would expect to find._______/ 4
    - Describe what the implications would be if the results were as expected and also what the implications would be if the results were *not* as expected._____/ 4
    - Identify 2 potential obstacles that could come up.______/ 4
    - For one obstacle, describe how it could be addressed.______/ 4

Appendix B: Picture of a Researcher Activity

Draw a picture of a researcher doing research. (You can label parts of your picture if your artistic skills fail you.)

Appendix C: CITI Training Assignment

The purpose of this assignment is for you to be trained on various ethical principles of doing human subjects research. Go to https://stallionsabac.sharepoint.com/sites/Resources/Shared%20Documents/Student_CITI_walkthrough.pdf?csf=1&e=psTnLu&cid=b54fa75c-4c43-4a5f-a7d9-75e64e477d97 and follow the instructions to create an account and do the training on the CITI website.

Here are a few notes:

- In step 5, you do NOT need to register for continuing education unit credits (CEUs).
- In step 7, make sure you select Social and Behavioral Research Investigators. You are doing research with human subjects.
- In step 7, you do NOT need to take the Conflicts of Interest course.
- Once you are done, submit the digital certificate of completion to the GeorgiaVIEW assignment submission folder. Save a copy of your certificate for your own records, too, because you will need to verify that you've completed CITI training when you submit an IRB application for your senior capstone project application in the future.
- I'd recommend that you write down the CITI username and password you created, because you may need to go back and do additional modules when you submit an IRB application for your senior capstone project.

Appendix D: Using Qualtrics Assignment

The purpose of this assignment is for you to learn how to make an online survey that could be used to collect data.

- Find a published scale or measure (on any topic that interests you) that could be administered through an online survey.

- Log into My ABAC and add the application for Qualtrics, an online survey program. Do **not** create a free Qualtrics account (it will end up giving you problems when you try to access your data). Only log in to Qualtrics with your MyABAC credentials.

- Make the scale or measure you found into a survey. (See https://www.qualtrics.com/support/survey-platform/survey-module/editing-questions/creating-questions/ for instructions on how to create survey questions.)

- Add at least 4 more questions to your survey. Demographic questions (e.g., sex, age) are acceptable, or you can make up your own questions to supplement the measure you used.

- You can add additional, entertaining or fun questions if you like, but keep it class appropriate.

- You can click “preview” to make sure the questions appear the way you want them to.

- When your survey is complete, publish it and click the “share” tab at the top of the screen. Copy the link.

- Submit the scale or measure you used (or the article containing it) and the survey link to the GeorgiaVIEW assignment submission folder.

Appendix E: APA Style Assignment

The purpose of this assignment is for you to practice citing references in APA style. Review the rules for making an APA reference list at https://owl.purdue.edu/owl/research_and_citation/apa_style/apa_formatting_and_style_guide/reference_list_basic_rules.html (see the menu on the left for examples of specific types of sources) and then type four APA citations, one for your textbook and three for sources that are authored or co-authored by present or former ABAC instructors. Tell me what type of source it is (e.g., book, journal article, blog post) above or below each citation.

Appendix F: Research Scenarios Assignment

A researcher is doing a study on future time perspective (the extent to which an individual enjoys thinking about the long-term future). She recruits a sample of participants and has them complete a questionnaire using the Future Time Perspective Scale and variables listed below, then has all of them participate in a workshop designed to increase their level of future time perspective and has them complete the Future Time Perspective Scale again.

Data is collected on these variables:

- Score on the Future Time Perspective Scale before the workshop
  Response format: rating on a scale of 1 – 5

- Score on the Future Time Perspective Scale after the workshop
  Response format: rating on a scale of 1 – 5

- Sex
  Response format: Choose male or female

- Age
  Response format: Enter a number

- Annual income
  Response format: Enter a number

- GPA
  Response format: Enter a number between 0 and 4.0

- Class Rank
  Response format: Choose freshman, sophomore, junior, or senior

Which two variables could you use to do an independent samples t-test?
Which would be the independent variable, and which would be the dependent variable?

Which two variables could you use to do a dependent samples t-test?
Which would be the independent variable, and which would be the dependent variable?

Which two variables could you use to do an ANOVA? Which would be the independent variable, and which would be the dependent variable?

Which two variables could you use to do a regression?
Which would be the independent variable, and which would be the dependent variable?

A researcher is doing a study life satisfaction and happiness among people at different points in life. She recruits a sample of participants and has them complete a questionnaire consisting of the variables below.

- Score on the Satisfaction with Life Scale
  Response format: rating on a scale of 1 – 5

- Score on the Subjective Happiness Scale
  Response format: rating on a scale of 1 – 5

- Score on the Relationship Satisfaction Scale
  Response format: rating on a scale of 1 – 5

- Age group
  Response format: Choose 20-30, 31-40, 41-50, 51-60, or 61+

- Whether or not retired
  Response format: Are you retired? Choose yes or no.

Which two variables could you use to do an independent samples t-test?
Which would be the independent variable, and which would be the dependent variable?

Which two variables could you use to do an ANOVA? Which would be the independent variable, and which would be the dependent variable?

Which two variables could you use to do a regression?
Which would be the independent variable, and which would be the dependent variable?

A researcher is doing a study about job satisfaction among college faculty. She recruits a sample of participants and has them complete a questionnaire consisting of the variables below.

- Score on the Job Satisfaction Scale
  Response format: rating on a scale of 1 – 5

- School
  Response format: Choose Arts & Sciences, Agriculture & Natural Resources, Business, or Nursing & Health Sciences

- Age
  Response format: Enter a number

- Sex
  Response format: Choose male or female

- Part-time or Full-time status
  Response format: Choose part-time employee or full-time employee

Which two variables could you use to do an independent samples t-test?
Which would be the independent variable, and which would be the dependent variable?

Which two variables could you use to do an ANOVA? Which would be the independent variable, and which would be the dependent variable?

Which two variables could you use to do a regression?
Which would be the independent variable, and which would be the dependent variable?

Appendix G: Reliability and Validity Activity

Read this article and then answer the questions below:

Lyumbomirsky, S., & Lepper, H. S. (1999). A measure of subjective happiness: Preliminary reliability and construct validation. *Social Indicators Research, 46*, 137-155.

1. How many items are on the final version of the scale?

2. What is the response format?

3. What type of data would responses to the subjective happiness scale be—nominal, ordinal, interval, or ratio?

4. Fourteen samples of participants were recruited to assess the reliability and validity of the scale. What was the total *N*?

5. What types of reliability were assessed?

6. What types of validity were assessed?

7. What was the range of the reliability coefficient (alpha) for each type of reliability assessed?

8. For each type of validity that was assessed:
   - What measure(s) did the authors correlate with the subjective happiness scale to establish each type of validity?
   - What was the range of the correlation coefficients for each type of validity?

9. What did the authors conclude overall about the psychometrics properties of the subjective happiness scale?