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Work in Progress: Developing Undergraduate Research Experiences in Unmanned Aircraft Systems (UAS) Cybersecurity

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Dr. J. Philip Craiger is an Associate Professor of Cybersecurity in the Department of Security Studies and International Affairs. He is currently serves as a co-PI of the NSF-funded National Cybersecurity Training and Education Center (NCyTE). Philip previously served as Professor in the School of Engineering Technology at Daytona State College, where was the Principal Investigator of the $1.8 million NSF-funded Advanced Cyberforensics Education Consortium. From 2004-2010 he served a dual appointment at the University of Central Florida as the Assistant Director for Digital Evidence at the National Center for Forensic Science, and as an Assistant Professor in the Department of Engineering Technology. At UCF Philip was instrumental in developing the first online Master of Science in Digital Forensics in the U.S. Philip started his academic career as an Associate Professor in the Department of Computer Science at the University of Nebraska at Omaha. He is a member of the American Academy of Forensic Sciences, and holds numerous professional certifications, including Certified Information Systems Security Practitioner (CISSP), and a Certified Cyber Forensics Practitioner (CCFP) from (ISC)2, SANS GIAC Computer Forensics Analyst, and an EC-Council Certified Ethical Hacker. His research and teaching interests include sUAS cybersecurity, and general aviation cybersecurity.

Dr. Craiger is a certified NAUI technical SCUBA instructor and instructor trainer (certifies NAUI instructors). He has hundreds of technical dives including cave diving in over 50 caves throughout the U.S. and Mexico, and several cave dives to 300 or more feet.

Work-In-Progress: Developing Undergraduate Research Experiences in Unmanned Aircraft Systems (UAS) Cybersecurity

During the fall 2020 semester, nine students were recruited to participate in a UAS cybersecurity-focused undergraduate research experience. Three faculty members each identified a small topic area for undergraduate students to pursue. The three areas are:

1. Small UAS (sUAS) Vulnerability and Threat Assessment and Mitigation
2. Effects of Cyber Attacks on Communication in UAS Swarms with Distributed Swarm Control
3. Enhancing Security of Cloud-Connected UAS Services

Students were placed onto teams based on their prior course experiences and the project requirements. Common resources were provided for all students to train them in conducting research. Teams were then tasked with developing a more comprehensive research plan for their specific project and carrying out that plan throughout the 2020-2021 academic year.

Students completed a pre-survey at the start of the project and a mid-project survey shortly after the winter break. The surveys combined project specific skills questions as well as relevant questions from the Undergraduate Research Student Self-Assessment (URSSA), an NSF-funded assessment tool to measure student gains in research skills.

This work-in-progress paper will describe the broader project, the individual student team projects, the research training materials, and some of the results from the pre- and mid-project surveys. Additional discussion will be had regarding the COVID-related precautions implemented by both the institution and the project teams. The purpose of this paper is to provide an example approach for future undergraduate research programs looking for practical approaches to implementing undergraduate research programs, particularly those in the cybersecurity area.

Introduction

In 2013 Jeff Bezos announced on the TV program 60 Minutes that Amazon wanted to deliver packages via "drones," which at the time sounded ludicrous. In August 2020, the Federal Aviation Administration (FAA) approved Amazon's use of drones for package delivery. According to the FAA, the number of recreational drones in the U.S. is predicted to peak at around 1.5 million, and the number of commercial drones is expected to double by 2024. With a massive increase in civilian and commercial use of drones (also called unmanned aircraft systems or UAS), cybersecurity has become a topic of great concern, as they are essentially "flying computers," containing much of the same components as laptops and smartphones, such as CPU and RAM, high-resolution cameras, WiFi, GPS, as well as a host of other sensors. Particularly concerning to the U.S. government is that most commercial off-the-shelf (COTS) UAS are manufactured by Chinese companies, such as DJI, who holds as much as 75% market share of an $21 billion per year industry. The cybersecurity implications of this led the U.S. Department of Defense (DoD) to ban the purchase and use of COTS UASs for DoD work in 2018, and the following year the U.S. Department of the Interior grounded its fleet of 70 DJI UASs. Accordingly, there has been an increased interest in how to secure UASs.

Project Overview

This project took place at a medium-sized, business-and-STEM only institution in the south-eastern U.S. Sponsored by the Office of Naval Research (ONR), the intended purpose of this project is to develop "innovative solutions that directly maintain, or cultivate a diverse, world-class STEM workforce in order to maintain the U.S. Navy and Marine Corps' technological superiority."(Office of Naval Research, 2020) The project team accordingly developed a paid undergraduate research experience for students to participate in throughout the academic year exploring research in cyber-security related topics. Nine (9) students were recruited into the program and divided into three project teams of three students each based on a brief interest survey and their respective backgrounds. The three projects were:

Project #1 – Effects of Cyber Attacks on Communication in UAS Swarms with Distributed Swarm Control (Cybersecurity Engineering Focused): Students will investigate the effects of link losses in UAS swarms due to communication jamming on the biologically inspired swarming solutions. The students will study how the disruption of inter-agent communication, jamming and communication range impact the achievement of behavior consensus. In addition, the students will study the results for developing optimal defense and recovery techniques.

Project #2: Small UAS (sUAS) Vulnerability and Threat Assessment and Mitigation (Cybersecurity Policy and Applications Focused): Students will survey UAS hardware/software architectures for drones to identify applicable penetration and security testing protocols, assess one or multiple commercial off-the-shelf UAS systems utilizing identified testing protocols, and reporting the results of the security assessment(s).

Project #3: Enhancing Security of Cloud-Connected UAS Services (Cybersecurity engineering focused): Students shall investigate security considerations of cloud-connected UAS services, identify and investigate at least one privacy-preserving UAS security service such as telemetry data collection and anomaly detection.

Each project was identified and led by a faculty member who mentored their project team through the research process. A graduate student oversaw all three teams and helped coordinate and address any ongoing issues.

Participants

Nine (9) students were recruited with the following demographic characteristics:

- Seven male, two female
- Seven White, two Black or African American
- Three of Hispanic, Latino, or Spanish origin
- Four computer science majors, one software engineering major, two homeland security majors, and two unmanned aircraft systems majors
- One Freshman, four Juniors, and four Seniors
- The average cumulative GPA was 3.46 with a range from 3.274-3.771
- Seven ROTC participants, two non-ROTC participants

- None of the students had participated in non-course related research during the academic year prior to this research
- 1 student had participated in non-course related research during the summer

While ONR sponsored the program and preferred students to also be participating in ROTC, there was no requirement that students be affiliated with the military. Students were recruited in late August and early September via email from the ROTC commanders, departmental communications in cyber-security focused majors (specifically, computer science and homeland security), and personal invitations from the project PIs to former students. Students completed a brief application describing their background and verifying that they meet ONR's participation requirements. All applicants met the requirements, and no applicants were rejected from the program.

Student teams were given a general focus area with guidance from their faculty advisor. Throughout the fall, student teams focused on refining those focus areas toward specific research questions through a literature search. The deliverable for the fall term was a project proposal and presentation describing the research questions and the research plan the team had developed to address those questions. The deliverable for the spring term is to carry out that proposal and provide a presentation on the results. Teams shall be encouraged and mentored to develop their results into a publication.

Participants completed a program pre-survey in mid-September based on the URSSA (University of Colorado Boulder, n.d.; Weston & Laursen, 2015), as well as a few project-specific evaluation questions related to students knowledge of cybersecurity topics. Students were then asked to take a similar mid-project survey in late January.

Survey Responses

In total, 66 paired questions were given on both the pre- and mid-survey. All 9 students responded to both surveys and responses were matched for analysis, though with only 9 responses, no statistical analysis was conducted. Questions were divided into 5 categories shown in Table 1.

Table 1. Survey Question Groupings

#	Response Options	Category
37	Not at all, Just a little, Somewhat, A lot, A great deal	Knowledge of Research
6	Yes, Somewhat Yes, Somewhat No, No	Desire activities from experience
5	Strongly Agree, Agree, Disagree, Strongly Disagree	Expectations from experience
7	Very Likely, Likely, Unlikely, Very Unlikely	Future career/education plans
11	Yes, No	Reason(s) for participation

The focus on this paper will be on the 37 Knowledge of Research portion of the survey. Results are shown for each question in the Appendix.

Analysis

The results are generally as expected and are consistent with the results seen in similar contexts (West et al., 2011; Wylie et al., 2020). All students show some improvement in their knowledge of various research related topics and the overall project appears to be having the desired effect of increasing their research skills and interest. With only nine participants and only quantitative survey data, meaningful trends are difficult to identify. Some items of particular interest are:

2. Presently, I understand how to figure out the next step in a research project

While there was high variability in the pre-survey response, all participants considered themselves somewhat able to figure out the next step by the mid-survey. This is interesting, as up to that point in time, they had largely been focused on conducting a literature review, defining their research question, and formulating their methods; largely all planning and paper tasks, not conducting the work to carry out those methods.

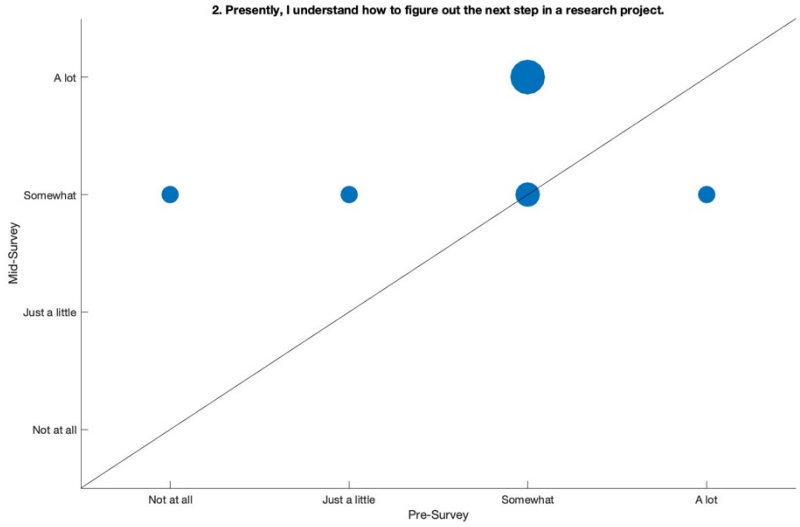

Figure 1. Survey Question 2 Results

13. Presently, I am able to work independently

Because of restrictions due to COVID-19, teams rarely met face-to-face. Instead, all meetings occurred online, forcing more independent work than would traditionally be included in an undergraduate research program. In a free-response question about how COVID has affected their experience, one student pointed out that "it does pose an extra challenge for us to try and combine all of our work".

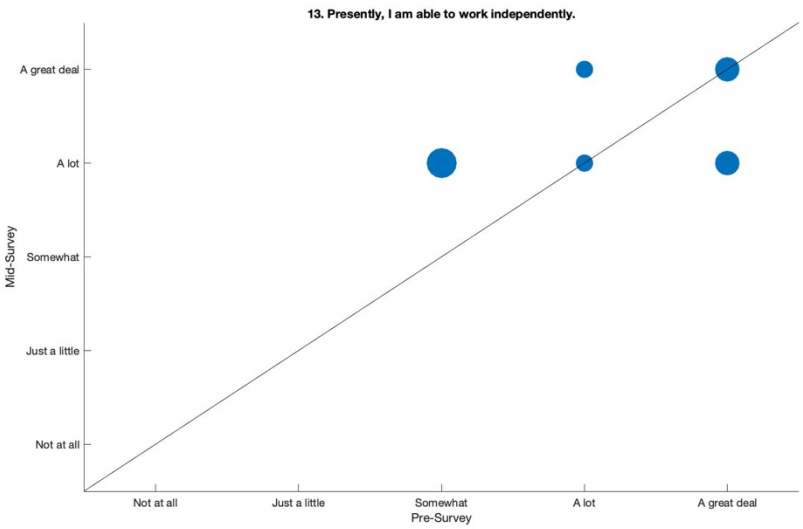

Figure 2. Survey Question 13 Results

27. Presently, I can understand journal articles

All but one student either maintained or increased their understanding of journal articles. For that one student, they went from feeling that they had "A lot" of understanding to "Not at all". One possible explanation is that they learned how complex a journal article can be; they became aware of their own Dunning-Kruger effect.

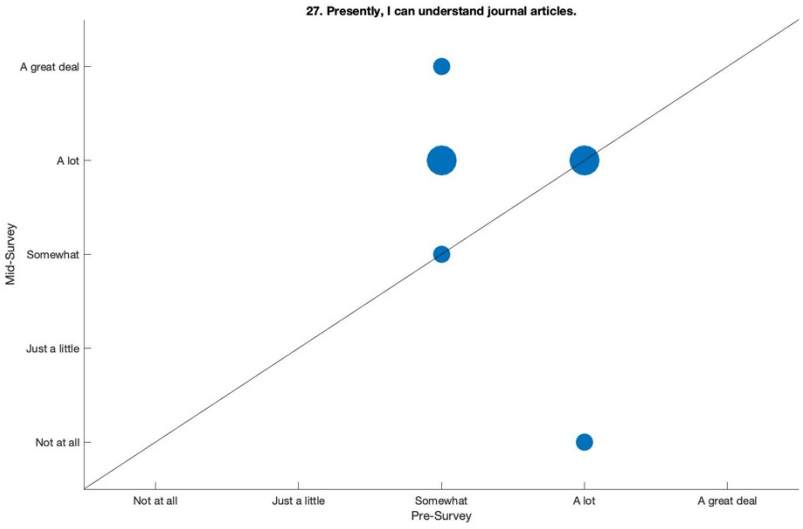

Figure 3. Survey Question 27 Results

30. Presently, I can engage in real-world scientific research and 31. Presently, I feel like a scientist

Of particular interest is that, according to item 30, all students felt they were better able to engage in real-world scientific research, mainly because they were engaging in real-world

scientific research, yet one student felt less like a scientist. In reviewing their free-response items, there was no clear indication why this disparity existed.

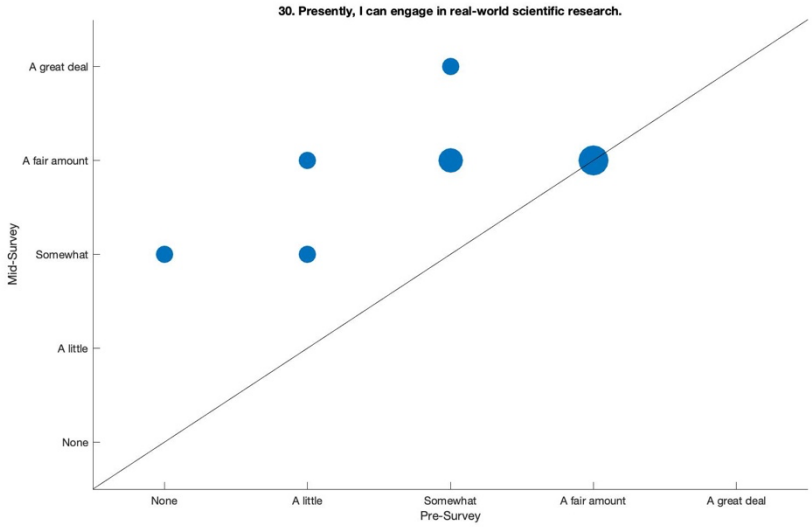

Figure 4. Survey Question 30 Results

COVID Precautions

The institution implemented a wide range of COVID protocols. Room capacities were reduced to enable social distancing, with most capacities being cut in half. This included seating in common areas. Anyone coming to campus had to have a daily wellness check with a temperature scan. Masks were mandated indoors and outdoors on campus unless in your room/office with the door closed. Enforcement was overseen by campus safety and students were suspended or expelled for extreme violations. In addition to as-needed tests, weekly COVID testing was done for random samples of specific "close proximity" student groups (e.g., athletics, ROTC, residence halls) and random samples of the general student population. Student clubs were encouraged to hold their meetings virtually or with reduced participation.

Because of the strict requirements and the digital nature of the projects, project teams only met virtually. One participant commented "In fact both for good and for bad I haven't met my teammates or [the graduate student mentor] or [the faculty mentor] in person yet." The teams have had to get creative. One student commented that, "This has required us to use different applications like MS paint to sketch ideas and such."

Conclusions and Future Work

This project aimed to increase student understanding of research and cyber-security topics and thus far appears to be successful in achieving that aim. The self-reported understanding of research topics are generally favorable and students feel meaningfully engaged in their respective research projects. This work-in-progress paper highlights that the overall project is trending toward success and that the small-group approach used could be successful for other programs seeking to implement more undergraduate research programs.

Upon completion of the research projects, participants will complete an additional survey iteration (i.e., post-survey), as well as an interview about their experience. The pre-mid-post survey model will provide a clearer indicator of their learning trajectory and the interviews will provide deeper, more nuanced, insight into the project strengths and weaknesses.

Acknowledgments

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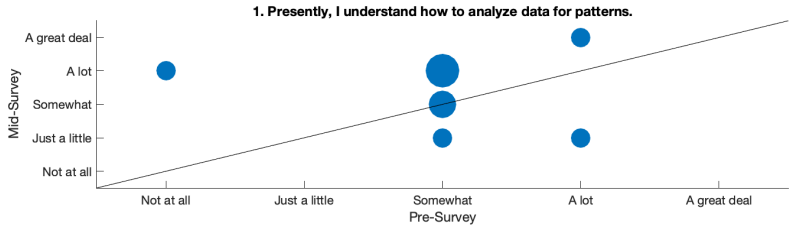
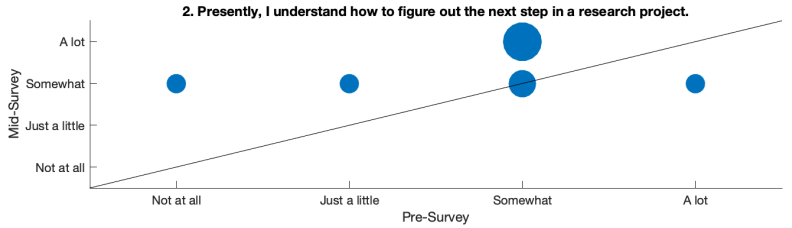
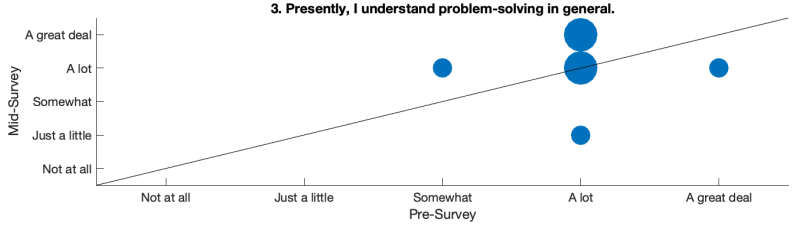
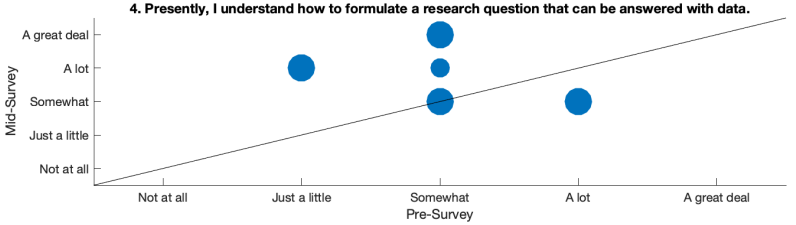
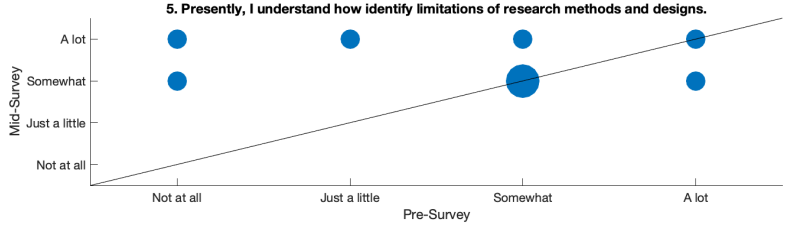
Appendix – Survey Responses

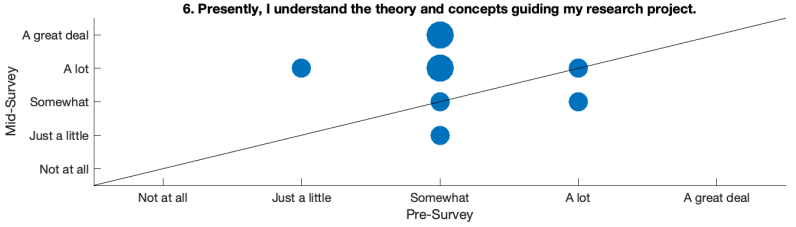


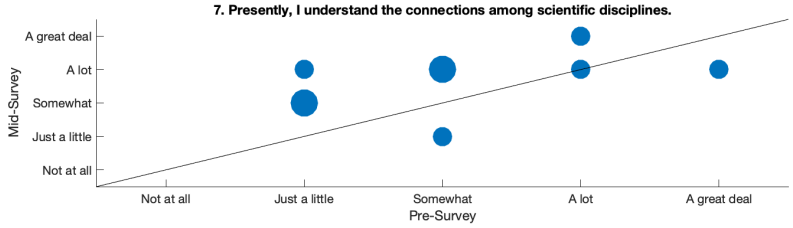


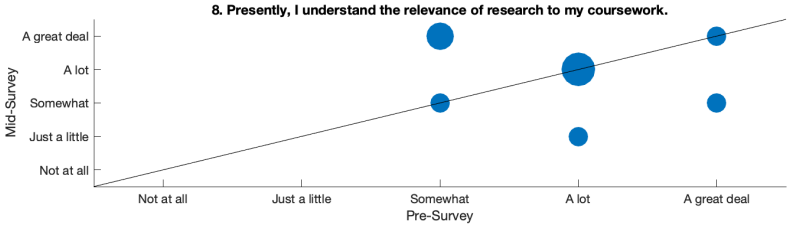


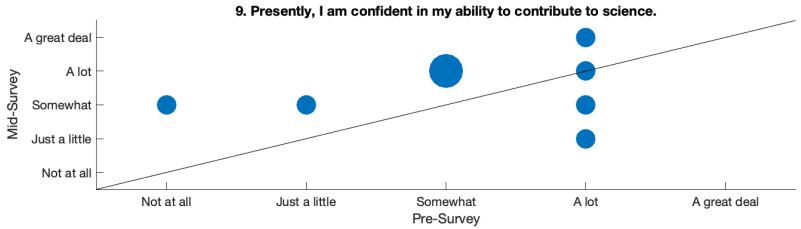


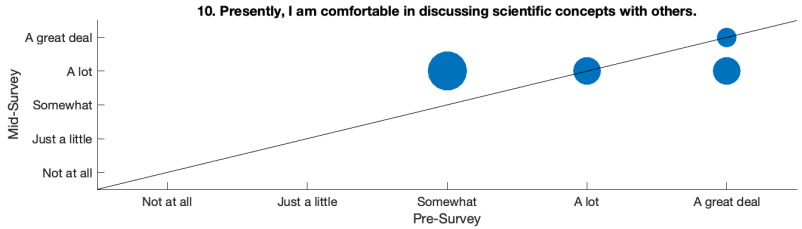


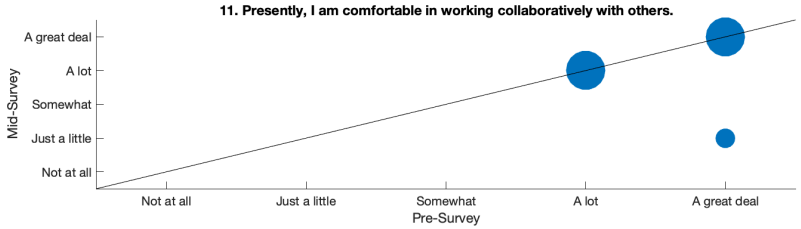


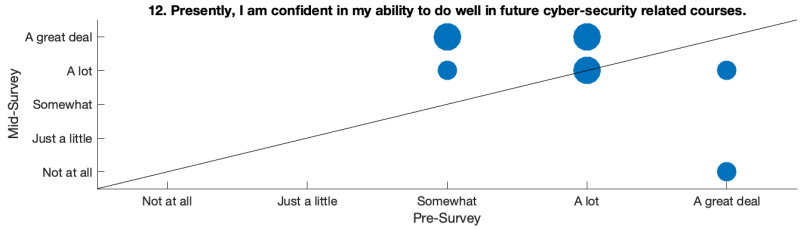


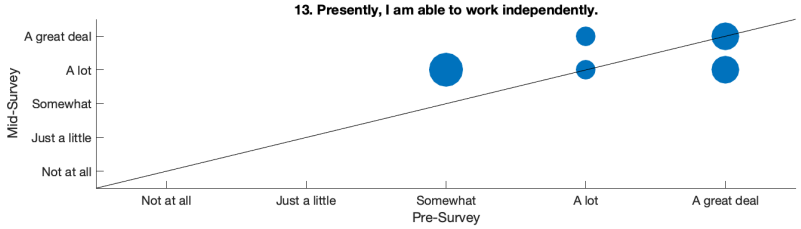


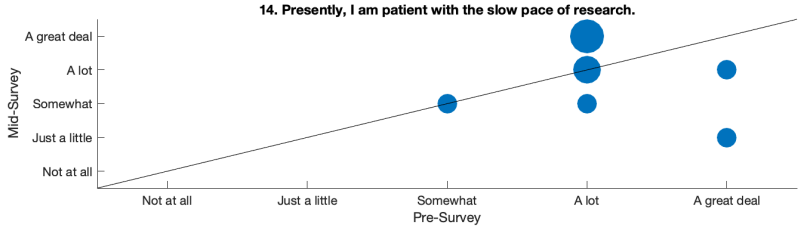

9. Presently, I am confident in my ability to contribute to science.
A great deal
A lot
Somewhat
Just a little
Not at all
Mid-Survey
Not at all
Just a little
Somewhat
A lot
A great deal
Pre-Survey

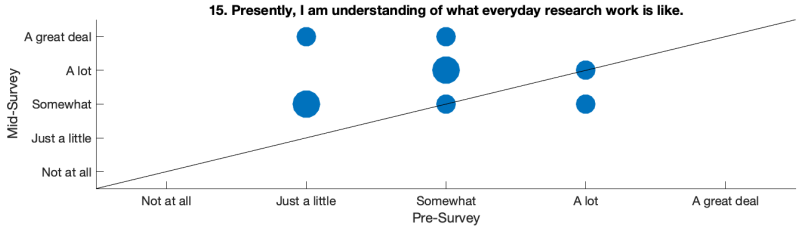

10. Presently, I am comfortable in discussing scientific concepts with others.
A great deal
A lot
Somewhat
Just a little
Not at all
Mid-Survey
Not at all
Just a little
Somewhat
A lot
A great deal
Pre-Survey

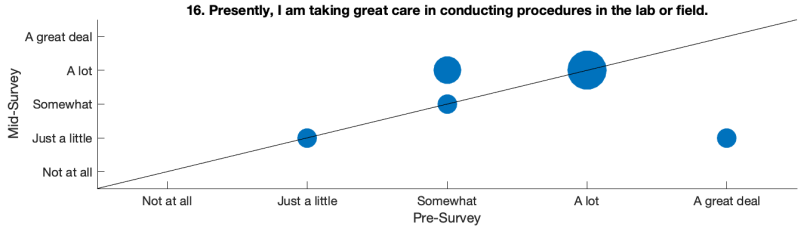

11. Presently, I am comfortable in working collaboratively with others.
A great deal
A lot
Somewhat
Just a little
Not at all
Mid-Survey
Not at all
Just a little
Somewhat
A lot
A great deal
Pre-Survey

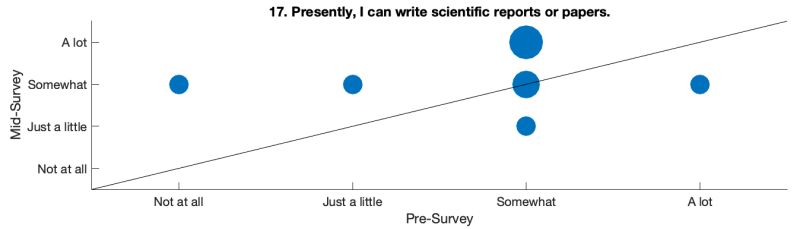

12. Presently, I am confident in my ability to do well in future cyber-security related courses.
A great deal
A lot
Somewhat
Just a little
Not at all
Mid-Survey
Not at all
Just a little
Somewhat
A lot
A great deal
Pre-Survey

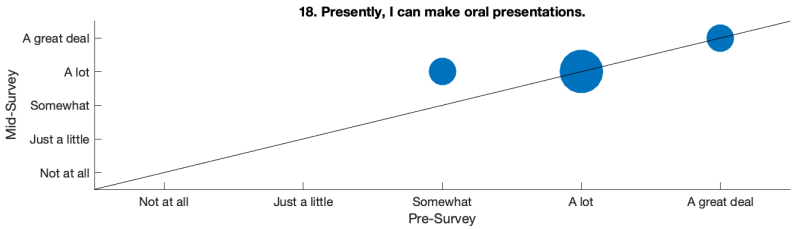

13. Presently, I am able to work independently.
A great deal
A lot
Somewhat
Just a little
Not at all
Mid-Survey
Not at all
Just a little
Somewhat
A lot
A great deal
Pre-Survey

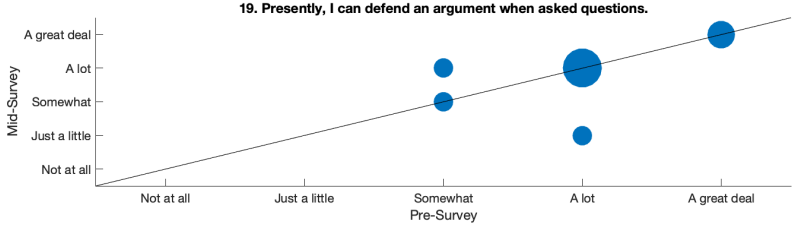

14. Presently, I am patient with the slow pace of research.
A great deal
A lot
Somewhat
Just a little
Not at all
Mid-Survey
Not at all
Just a little
Somewhat
A lot
A great deal
Pre-Survey

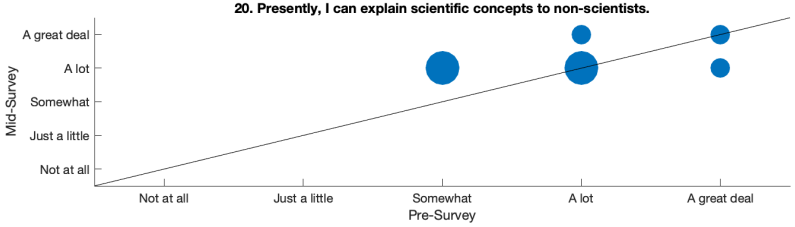

15. Presently, I am understanding of what everyday research work is like.
A great deal
A lot
Somewhat
Just a little
Not at all
Mid-Survey
Not at all
Just a little
Somewhat
A lot
A great deal
Pre-Survey

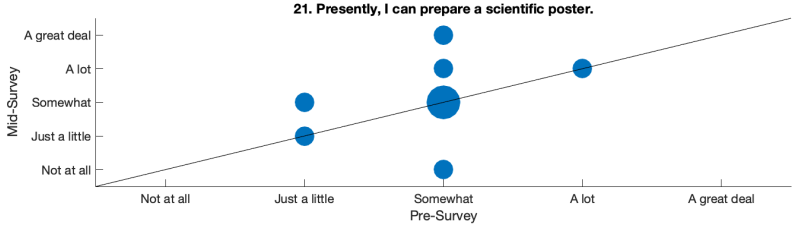

16. Presently, I am taking great care in conducting procedures in the lab or field.
A great deal
A lot
Somewhat
Just a little
Not at all
Mid-Survey
Not at all
Just a little
Somewhat
A lot
A great deal
Pre-Survey

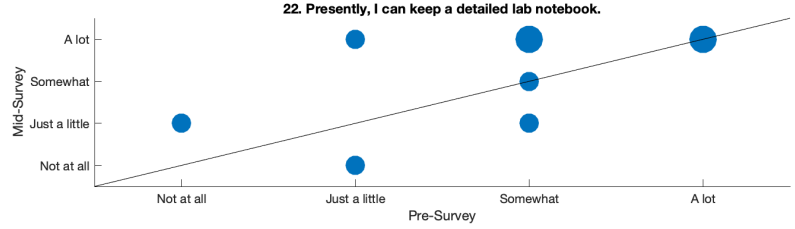

17. Presently, I can write scientific reports or papers.
Mid-Survey
A lot
Somewhat
Just a little
Not at all
Not at all
Just a little
Somewhat
A lot
Pre-Survey

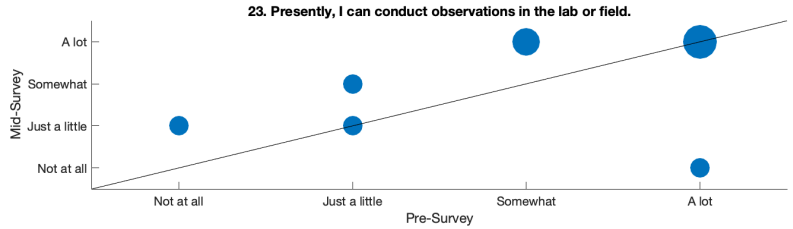

18. Presently, I can make oral presentations.
Mid-Survey
A great deal
A lot
Somewhat
Just a little
Not at all
Not at all
Just a little
Somewhat
A lot
A great deal
Pre-Survey

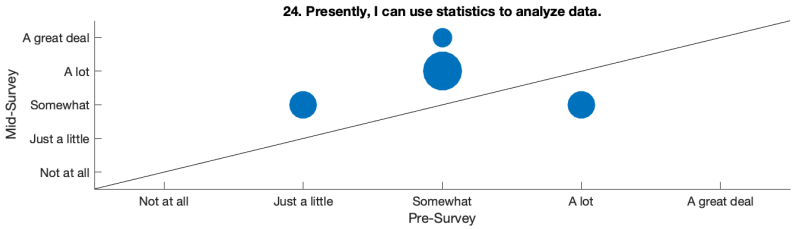

19. Presently, I can defend an argument when asked questions.
Mid-Survey
A great deal
A lot
Somewhat
Just a little
Not at all
Not at all
Just a little
Somewhat
A lot
A great deal
Pre-Survey

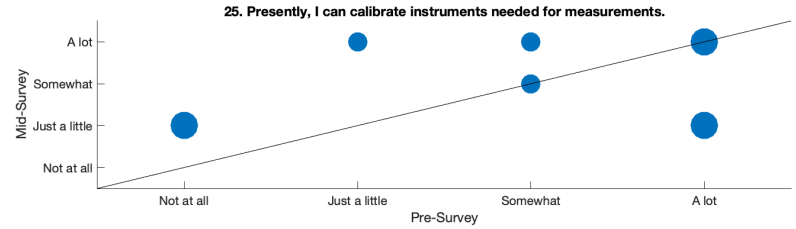

20. Presently, I can explain scientific concepts to non-scientists.
Mid-Survey
A great deal
A lot
Somewhat
Just a little
Not at all
Not at all
Just a little
Somewhat
A lot
A great deal
Pre-Survey

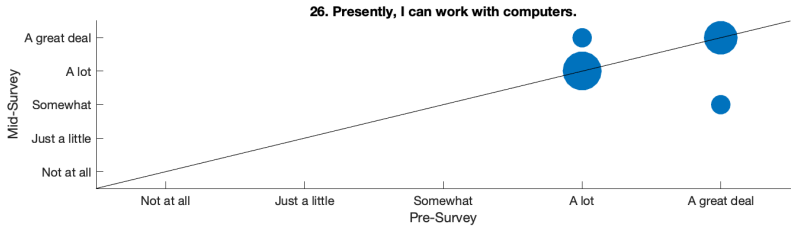

21. Presently, I can prepare a scientific poster.
Mid-Survey
A great deal
A lot
Somewhat
Just a little
Not at all
Not at all
Just a little
Somewhat
A lot
A great deal
Pre-Survey

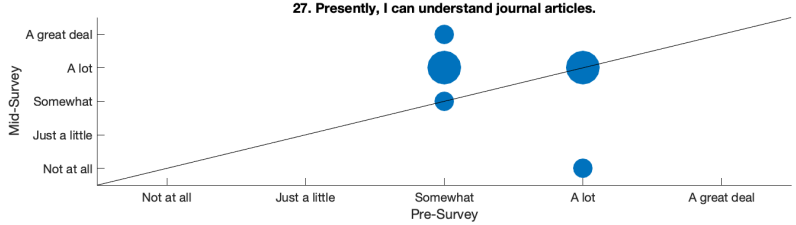

22. Presently, I can keep a detailed lab notebook.
Mid-Survey
A lot
Somewhat
Just a little
Not at all
Not at all
Just a little
Somewhat
A lot
Pre-Survey

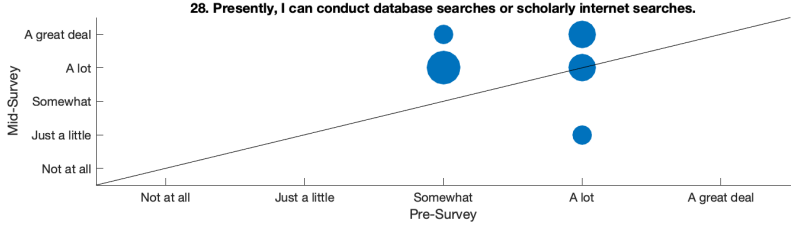

23. Presently, I can conduct observations in the lab or field.
Mid-Survey
A lot
Somewhat
Just a little
Not at all
Not at all
Just a little
Somewhat
A lot
Pre-Survey

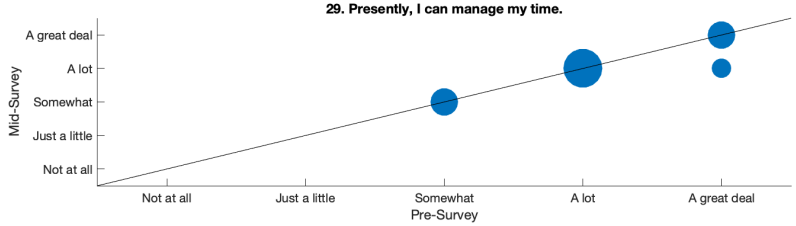

24. Presently, I can use statistics to analyze data.
Mid-Survey
A great deal
A lot
Somewhat
Just a little
Not at all
Not at all
Just a little
Somewhat
A lot
A great deal
Pre-Survey

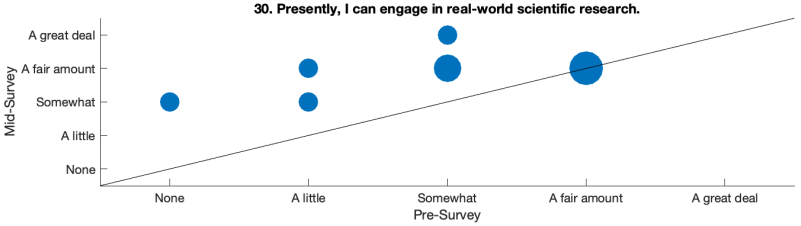

25. Presently, I can calibrate instruments needed for measurements.
Mid-Survey
A lot
Somewhat
Just a little
Not at all
Not at all
Just a little
Somewhat
A lot
Pre-Survey

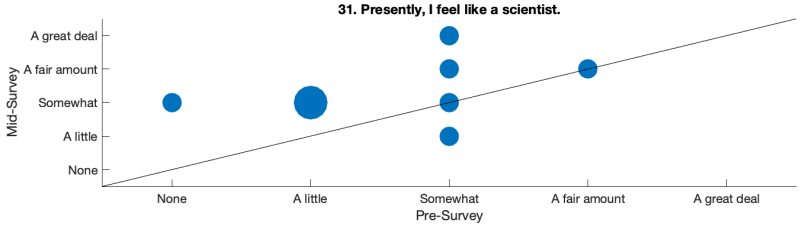

26. Presently, I can work with computers.
Mid-Survey
A great deal
A lot
Somewhat
Just a little
Not at all
Not at all
Just a little
Somewhat
A lot
A great deal
Pre-Survey

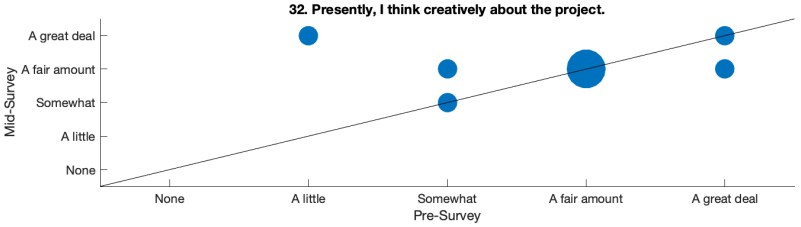

27. Presently, I can understand journal articles.
Mid-Survey
A great deal
A lot
Somewhat
Just a little
Not at all
Not at all
Just a little
Somewhat
A lot
A great deal
Pre-Survey

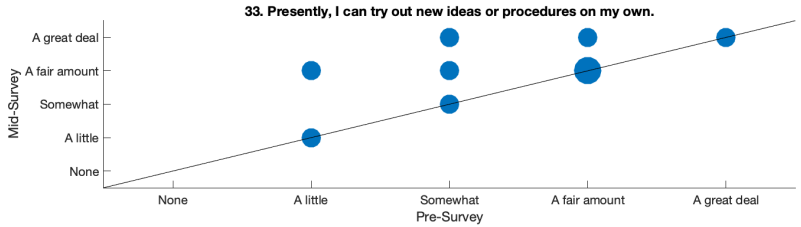

28. Presently, I can conduct database searches or scholarly internet searches.
Mid-Survey
A great deal
A lot
Somewhat
Just a little
Not at all
Not at all
Just a little
Somewhat
A lot
A great deal
Pre-Survey

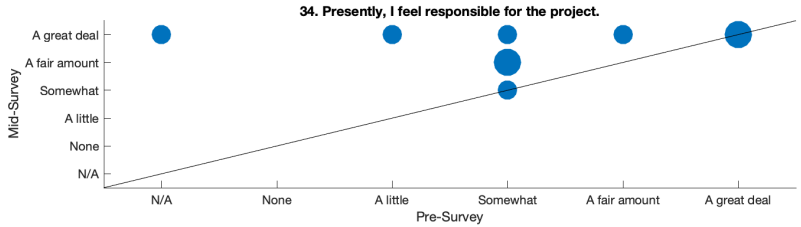

29. Presently, I can manage my time.
Mid-Survey
A great deal
A lot
Somewhat
Just a little
Not at all
Not at all
Just a little
Somewhat
A lot
A great deal
Pre-Survey

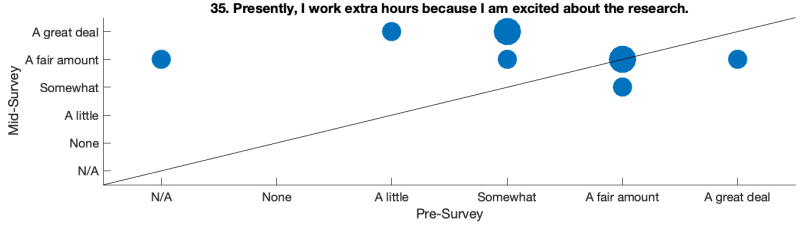

30. Presently, I can engage in real-world scientific research.
Mid-Survey
A great deal
A fair amount
Somewhat
A little
None
None
A little
Somewhat
A fair amount
A great deal
Pre-Survey

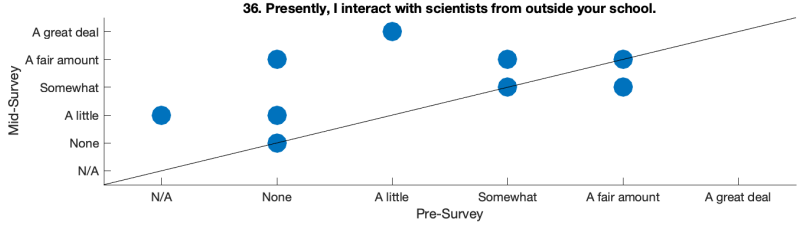

31. Presently, I feel like a scientist.
Mid-Survey
A great deal
A fair amount
Somewhat
A little
None
None
A little
Somewhat
A fair amount
A great deal
Pre-Survey

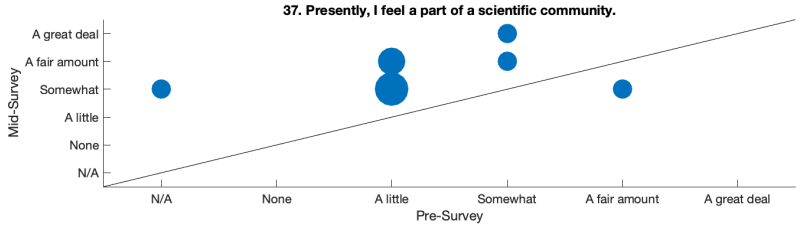

32. Presently, I think creatively about the project.
Mid-Survey
A great deal
A fair amount
Somewhat
A little
None
None
A little
Somewhat
A fair amount
A great deal
Pre-Survey


33. Presently, I can try out new ideas or procedures on my own.
A great deal
A fair amount
Somewhat
A little
None
Mid-Survey
None
A little
Somewhat
A fair amount
A great deal
Pre-Survey


34. Presently, I feel responsible for the project.
A great deal
A fair amount
Somewhat
A little
None
N/A
Mid-Survey
N/A
None
A little
Somewhat
A fair amount
A great deal
Pre-Survey


35. Presently, I work extra hours because I am excited about the research.
A great deal
A fair amount
Somewhat
A little
None
N/A
Mid-Survey
N/A
None
A little
Somewhat
A fair amount
A great deal
Pre-Survey


36. Presently, I interact with scientists from outside your school.
A great deal
A fair amount
Somewhat
A little
None
N/A
Mid-Survey
N/A
None
A little
Somewhat
A fair amount
A great deal
Pre-Survey


37. Presently, I feel a part of a scientific community.
A great deal
A fair amount
Somewhat
A little
None
N/A
Mid-Survey
N/A
None
A little
Somewhat
A fair amount
A great deal
Pre-Survey