Education theories applied to a cyber security bootcamp

by

Logan M. Prough

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Carl R. Ice College of Engineering

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Approved by:

Major Professor
Joshua L. Weese

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Abstract

Prior to the ubiquity of information technology, United States military doctrine recognized four warfighting domains: land, sea, air, and space. The creation of the internet and a growing reliance on connected, integrated systems introduced an unfamiliar environment not governed by the same laws as the four physical warfighting domains. The United States Air Force recognized its need for a cyber force to operate in cyberspace. In 2003, the Information Directorate of the Air Force Research Laboratory (AFRL/RI) created a 10-week cyber security bootcamp called the Advanced Course in Engineering (ACE) to educate and train future cyber operators. Despite its record of success, the ACE lacks a formal, proven method to assess its effectiveness and improve the program. A formal assessment method may provide more exact, objective measurements of the effectiveness of the program. This work provides a case study in the use of learning theories (informed by and complementing participant feedback and staff observations) to assess ACE and provides recommendations to improve the ACE. We analyze available data from the 2019 ACE class and use relevant education theories to reveal insights regarding what the ACE program does well, ways it could improve, and future work that could further improve the program and other cyber security bootcamps.

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Acknowledgements

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Chapter 1 - Introduction

This chapter introduces the necessity of a cyber force able to operate in cyberspace. The chapter focuses on a line of effort at the Information Directorate of the Air Force Research Laboratory to train and educate cyber warriors in a 10-week bootcamp program called the Advanced Course in Engineering (ACE). The introduction to the ACE describes the structure of the first iteration of the ACE program. This description intends to provide context for the reader when this thesis discusses components of the ACE, ways to assess the ACE, and the use of learning theories to improve the overall effectiveness of the program.

Prior to the ubiquity of information technology, United States military doctrine recognized four warfighting domains: land, sea, air, and space. The creation of the internet and a growing reliance on connected, integrated systems introduced an unfamiliar environment not governed by the same laws as the four physical warfighting domains. An alarming aspect of cyber warfare is its asymmetry. Cyberspace grants an adversary with minimal resources and a few brilliant minds the capability to generate effects that deny, degrade, disrupt, deceive, or destroy within cyberspace or any of the four physical domains due to the prevalence of cyber-physical systems.

The United States Air Force recognized its need for a cyber force to operate in cyberspace. In 2003, the Information Directorate of the Air Force Research Laboratory (AFRL/RI) created a 10-week cyber security bootcamp called the Advanced Course in Engineering (ACE) to educate and train future cyber operators. The AFRL/RI ACE program took inspiration from the General Electric Advanced Course in Engineering, a training General Electric designed to teach employees technical problem-solving skills often absent from academic curricula.

The inaugural AFRL/RI ACE class had 12 Air Force Reserve Officers' Training Corps (AFROTC) cadets and 2 civilians. The 10-week ACE internship taught the interns about the science of mission assurance and trained them on the art of cyber warfare through several program components: a research project, academic lectures with challenge problems, and an 8-mile run.

Interns received a research problem from AFRL/RI to solve by the end of the internship. The research problem described a real-world challenge and asked for a solution or deliverable the Air Force planned to employ after the internship ended. A research mentor in charge of the research problem guided and mentored the interns as they worked to complete a solution for their research problem.

Every week, interns attended an academic lecture on a cyber security topic of interest. A subject matter expert from industry, academia, or the military gave each lecture. At the conclusion of each lecture, the lecturer presented interns with a challenge problem. The interns applied concepts they learned from the lecture to solve the problem and deliver their solution in a comprehensive technical report due one week later. The required format of the report coaxed interns into learning and following an effective problem-solving strategy. Each week concluded with an 8-mile run. The 8-mile run served as a teambuilding activity that encouraged interns to challenge themselves and support their peers.

The inaugural ACE class began a history of success. The ACE program continued to evolve throughout the next several years. Figure 1-1 shows the change in ACE class size and composition each year. In 2019, the ACE class had 42 interns made up of civilians, Air Force ROTC, Air Force active duty, cadets and officers from the United Kingdom, and a few civilians from Australia.

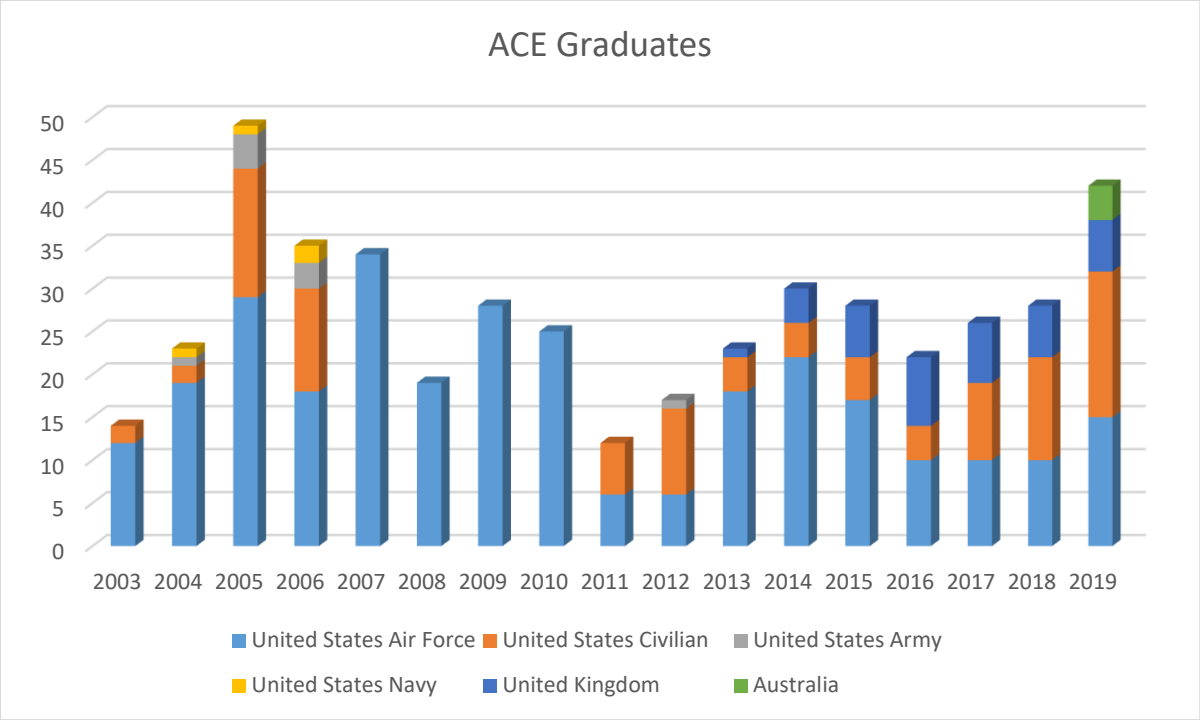

Figure 1-1: Figure 1-1 shows the number of ACE graduates each year with their affiliation.

The ACE states its objective as developing the next generation of cyber security leaders. Due to the abstract nature of the concept of a cyber security leader, assessing the effectiveness of the ACE program proves challenging. In the past, ACE staff assessed the program by asking interns for feedback. The collection of intern feedback varied year to year in terms of type, quantity, quality, completeness, and timing because no formal process existed.

Despite its record of success, the ACE program lacks a formal, proven method to assess its effectiveness and suggest improvements. A formal assessment method may provide more exact, objective measurements of the effectiveness of the program. The application of learning theories may provide recommendations to improve the ACE supported by research on learning and education intended to complement suggestions from intern and staff feedback. This thesis shall identify applicable learning theories and apply them to the ACE to aid the assessment objectives such as identification of program strengths and weaknesses.

This thesis shall use the lessons learned from the case study of the ACE and the application of learning theories to draw general conclusions about the creation of an effective cyber security boot camp. These conclusions shall discuss elements such as the quantity of information taught, the method of teaching, the timing and amount of time to spend on each topic, and how to find an optimal balance between education and training. The results from the examination of the ACE supply groundwork for a general methodology to assess similar cyber security bootcamps and general conclusions about elements that make an effective cyber security bootcamp.

Chapter 2 - Background

The first section of this chapter summarizes related work and the conclusions of other researchers regarding the effectiveness of bootcamps covering other computer science topics such as coding and information technology. The next section describes several learning theories this thesis considers in its assessment of the ACE program and general conclusions for creating an effective cyber security bootcamp. The final sections share background on the AFRL/RI ACE program, the evolution of the program over time, and the current structure of the ACE in more detail than covered in the introduction chapter.

Section 2.1 – Related Work

Many organizations have begun to develop bootcamps of varying lengths to teach specific computer science topics in a brief period. Students enroll in these programs to learn marketable skills in the computer science field without the cost or time commitment of a standard four-year degree. Due to the new nature of these bootcamps, research into the effectiveness of these bootcamps remains an open problem. In the last several years, a few published papers evaluate the effectiveness of bootcamps that teach computer science topics such as information technology and coding.

In their paper, "Triangulating Coding Bootcamps in IS Education: Bootleg Education or Disruptive Innovation?" Waguespack, Babb, and Yates compare education from a coding bootcamp with education received from an Information Systems college. They observe that coding bootcamps operate with no oversight by a government or standard accrediting organization (Waguespack et al, 2018). This lack of oversight causes a large quantity of anecdotal statements about the effectiveness of these bootcamps without reliable data to support or refute the anecdotal evidence. Waguespack, Babb, and Yates noticed common variables

present in both positive and negative anecdotal reviews: quality and focus of curriculum, technical training and knowledge of instructors, number of full-time versus part-time instructors, quality of instruction, emphasis on realistic group projects, and availability of mentorship and tutoring for students. The paper also states, “It is fair to say that bootcamps are dedicated to providing the maximum of ‘knowing how’ … with virtually no attention to ‘knowing why’ (Claxton, 1997)!”. This statement causes concern because effective cyber security professionals require “knowing why” to effectively reason and solve problems.

“Triangulating Coding Bootcamps in IS Education: Bootleg Education or Disruptive Innovation?” primarily compares a coding bootcamp with the education one might receive to earn a college degree in Information Systems. The identified strengths of bootcamp approach include the immense focus on specific, marketable skills and technologies. The authors concluded these coding bootcamps produce mixed results. The authors attribute the mixed results to a lack of oversight and the present terrain of many providers with a wide range of standards or no standard (Waguespack et al, 2018). Waguespack, Babb, and Yates posit the greatest weaknesses of coding bootcamps are these mixed results and lack of standardization and accreditation. The authors concluded a bootcamp can supply valuable skills to a student, and universities should consider integration of this innovative approach to formalize it and capitalize on its advantages (Waguespack et al, 2018).

In their paper, “Barriers Faced by Coding Bootcamp Students”, Thayer and Ko interviewed 26 coding bootcamp students and published their analysis of the interviews using the Communities of Practice framework. The paper points out that coding bootcamps largely serve a different population than traditional college education: those seeking a change in career field (Thayer and Ko, 2017). Thayer and Ko sought not to assess the effectiveness of coding

bootcamps, but to identify obstacles faced by students of these bootcamps such as low confidence, external pressures, and interactions with other students. Those interviewed included current and former coding bootcamp students representing eight bootcamps and a wide range of stages from beginning the bootcamp to post-completion. The researchers found an initial group of bootcamp students and used stratified snowball sampling to find several more participants for the study. The sample of 26 students included diversity in gender, ethnicity, age, and sexual orientation (Thayer and Ko, 2017). The researchers developed semi-structured interviews with 25 questions divided into the following sections: background, decision to attend a coding bootcamp, change in views and goals, and perception of their experience in relation to others.

The researchers found several challenges the bootcamp students faced. Several participants in the study expressed concerns over not understanding why they passed or failed job interviews and the reluctance of interviewers to share their decision process (Thayer and Ko, 2017). This lack of feedback made it difficult for students to plan how to improve themselves. Students cited real-world work experience as a difficult requirement that internships could help them overcome (Thayer and Ko, 2017). The work experience provides potential employers with additional credentials aside from the bootcamp itself. To find opportunities that fit them well, participants emphasized the importance of networking with their peers (Thayer and Ko, 2017). These professional connections allow peers to make honest, well-informed recommendations based on their shared experiences and common knowledge learned from the bootcamp. Participants mentioned interview skills and, more broadly, communication skills as a valued quality that employers wanted to see in candidates (Thayer and Ko, 2017). Recruiters seek candidates with impeccable communication skills because every job requires working with others to accomplish a shared goal.

In addition to these formal boundaries, participants discussed many informal boundaries involving knowledge and identity. Regarding knowledge, participants addressed the difficulty of "learning to learn" or knowing how to teach oneself new programming languages or libraries by reading from existing documentation. Participants discussed the identity issue of imposter syndrome (Thayer and Ko, 2017). Several of the bootcamps encouraged students to call themselves "web developers" as early as the first week at the bootcamp on the premise that others would not see the students as web developers unless they called themselves web developers. This approach made several students uncomfortable because they felt they had not yet earned the title (Thayer and Ko, 2017). On the barrier of social divide within a bootcamp cohort, several participants expressed difficulty integrating groups of less experienced students with more experienced students. Despite this common divide, participants also described a close-knit team and new friends made at the bootcamps (Thayer and Ko, 2017). Some participants noticed a bias in who instructors spent more time with (Thayer and Ko, 2017). This bias could give some students an unfair advantage over others.

In her thesis "Can You Hack It? Validating Predictors for IT Boot Camps", Courtney Gear measured self-efficacy of students as they progressed through a coding bootcamp. Her study considered several cohorts from the same bootcamp. Her thesis measures student success in terms of self-efficacy and explores whether several predictors accurately predict the success or failure of a student in the bootcamp. She discusses the use of valid predictors in the participant selection process to accept participants expected to perform the best (Gear, 2016).

The study had tested four hypothesis or predictors. The first stated that higher scores on a logic test predict greater success in the bootcamp than lower scores (Gear, 2016). To test the validity of this predictor, Gear performed a correlation analysis to test for a correlation between

student self-efficacy scores and the scores on the logic test. She followed up on statistically significant correlation results with a series of linear regression analyses to determine if self-efficacy scores may depend on logic test scores. These analyses indicated a statistically significant prediction, supporting the hypotheses that higher logic scores predict success in the bootcamp (Gear, 2016).

The second predictor stated holding an associate degree predicts greater success in the bootcamp than having less formal education than an Associate's degree. Gear divided participant data into two categories: data for participants with an associate degree or higher, and data for participants with less than an associate degree. Next, Gear conducted a point-biserial correlation to examine the relationship between student self-efficacy scores and amount of formal education and noticed a significant, negative correlation. She concluded, contrary to her second hypothesis, less education predicts higher student self-efficacy scores (Gear, 2016). Gear posits this result indicates a Dunning-Kruger effect, where those with less competence cannot accurately assess their own incompetence, leading to higher self-efficacy scores.

The third predictor stated applicants who scored higher on a "webpage simulation" will be more successful in the bootcamp than those who scored lower. The thesis did not clearly describe what the webpage simulation task entailed but explained that the simulation intended to measure the experience with software development of an applicant and their willingness to learn new skills. A correlation analysis showed no correlation between webpage simulation scores and student self-efficacy scores (Gear, 2016). This could indicate the webpage simulation is a poorly designed method to evaluate applicants.

The fourth predictor stated higher scores on an interview predict greater success than lower interview scores. A correlation analysis showed no statistically significant correlation

between interview scores and self-efficacy scores (Gear, 2016). Imprecise data may influence this result. The interviewer assessed applicants as either “meets expectations” or “exceptional” and 95% of the population received a score of “meets expectations”. Finer granularity in rating applicants from the interview could supply more interesting data to study.

Gear discusses her results and data further. She explains self-efficacy measures how well students feel they perform, and her sample lacked objective indicators of performance. She suggests instructor scores as an objective source of performance data. A distinction between students with computer science or similar degrees and students with unrelated degrees could enable a better evaluation of her second hypothesis. She identified the extreme range restriction in predictor scores as a limitation of her study (Gear, 2016). She concluded that future work should also include objective measurements of student success and try to collect a sample size greater than the sample of 104 students she worked with.

Section 2.2 – Learning Theories

This section describes several learning theories. These theories provide guidance on ways to analyze the ACE program and its components. When suggesting improvements to the ACE program and general principles to create an effective cyber security bootcamp, these learning theories inform the suggestions to augment staff and intern feedback.

2.2.1: Gamification

Gamification applies mechanics from games to enrich a learning experience. The application of game mechanics encourages students to try persistently to solve a problem despite setbacks and challenges they may face along the way. This tenacity parallels a player playing a game until they win, but instead a student keeps trying until they complete their objective.

Completion of the objective implies the student achieved the desired learning outcome (David, 2016).

Gamification as a learning theory highlights several common game mechanics essential to cultivate the positive effects of gamification for the learner. The suitable application of each of these mechanics can ideally create a learning experience as engaging and fun as a game the learner might play solely for entertainment (Huang and Soman, 2013).

One of these mechanics insists a game must never present a player with an impossible challenge. The player needs to know a solution exists, otherwise they may give up and prematurely conclude no solution exists. At this point, the player no longer tries to complete the challenge. They feel the effort is not worth their time due to the uncertainty of ever arriving at a solution. To apply this mechanic to education and training, the student should never receive an impossible task from an instructor. An impossible task may demotivate the student and fuel a negative mindset, making them feel that they will never learn the desired outcomes of the lesson (Huang and Soman, 2013).

The game should also give specific goals with an obvious indicator of completion. If a player gets too broad of a goal, the player may not understand the task they need to complete or what steps they may need to take to progress. Without an obvious sign of completion, a player may not know how to tell if they solved a problem or if they need to do something more. Likewise, a learner needs a clear, specific objective and a way of knowing whether they succeeded or not. Failure to provide this indicator can cause uncertainty that damages learner self-efficacy (David, 2016; Huang and Soman, 2014).

Games supply positive feedback to incentivize player success. This positive feedback can take the form of points, experience/abilities, or in-game currency. These rewards for completing

goals serve the dual purpose of indicating success to a player and allowing the player to earn something of perceived value for their efforts. Providing similar positive feedback to a learner rewards their success learning new skills and topics while incentivizing them to continue to learn more and explore concepts they learned further in depth (David, 2016; Huang and Soman, 2014).

Throughout a game, an epic, inspiring story keeps players engaged. The story provides context for the tasks the player must complete and the goals they must reach. A story also makes the game entertaining, capturing the attention of the player and keeping them curious to see what happens next. When applied to learning, an epic, inspiring story may help learners remember concepts or add substance to topics that would otherwise feel dry. The success or failure of the learner may affect events in the story, further incentivizing the learner to succeed (Hamari, Koivisto, and Sarsa, 2014).

2.2.2: Bruner Spiral Curriculum

The Bruner Spiral Curriculum assumes an instructor can teach any subject if they use the right structure and presentation of the material (Bruner, 1960). The best structure and presentation may vary depending on the subject and intended audience, but Bruner shares some general guidance in his spiral curriculum theory. The spiral curriculum uses three key principles: cyclical return to the subject, increases in complexity, and a relationship between old learning and new learning (Bruner, 1960; Harden and Stamper, 1999).

The first principle of the Bruner Spiral Curriculum is a cyclical return to the same topic. Information gets reinforced and solidified each time students revisit the topic. This reinforcement helps students retain the information and increase their depth of understanding of the topic. The "Spiral" in "Bruner Spiral Curriculum" comes from this cyclical examination of the topic (Howard, 2007).

The second principle is an increase in complexity each time a student revisits the topic. Increasing the complexity with each visit allows students to build off their existing knowledge and learn more about the topic while reinforcing earlier learning. The increase in complexity at each visit should follow a logical progression from simple to complicated concepts. Breaking a topic into segments based on complexity implicitly separates the topic into visits in alignment with the first principle of the Bruner Spiral Curriculum (Lohani et al, 2005).

The third principle is a relationship between earlier learning and new learning. Bruner emphasizes the importance of a logical flow from one visit of a topic to the next. By supplying new learning within the context of old information, students can better understand depths of a topic previously outside of their reach. This relationship encourages learners to apply earlier knowledge to later objectives and adds structure to the logical progression from simple to complicated concepts (Lohani et al, 2005; Harden and Stamper, 1999).

The Bruner Spiral Curriculum is not without disadvantage. Although a course can apply the spiral curriculum at a smaller scale in short timespans, proper long-term reinforcement requires revisiting a topic over periods of one year or more. This makes the spiral curriculum less relevant for shorter courses like bootcamps. Attempting to teach a broad curriculum in a short time presents another issue. Greater time spent revisiting a topic reduces the total breadth of topics one may cover. This issue with time becomes compounded when a return to a familiar involves reviewing and relearning information a learner forgot (Masters and Gibbs, 2007).

2.2.3: Zone of Proximal Development

In his Zone of Proximal Development theory, Vygotsky posits any task fits within one of three categories: something the learner can do unaided, something the learner can do with aid,

and something the learner cannot do. Figure 2-1 Shows an illustration of these three categories. The zone of proximal development encompasses the second category, tasks the learner can do with aid. Maximal learning occurs when the learner successfully completes tasks within their zone of proximal development until they can complete the tasks without aid. The exact zone of proximal development of an individual is unique to them (Vygotsky, 1986; Zone of proximal development, 2009).

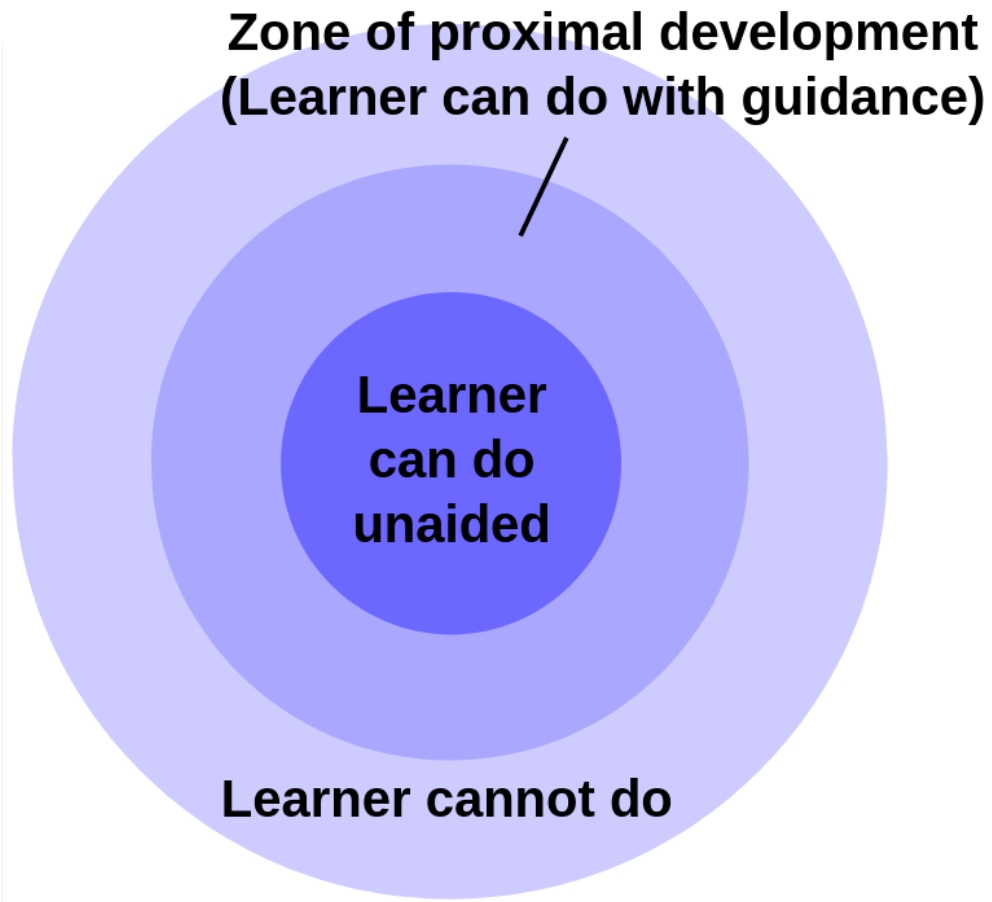

Figure 2-1: This figure illustrates the three categories of tasks for a learner (Dcoetzee, 2012).

The zone of proximal development theory describes the availability of and interaction with more knowledgeable peers or instructors as crucial for the learner. The learner requires aid from these more knowledgeable peers to complete tasks within the zone of proximal development. This aid with more knowledgeable peers may come in the form of focused

questions and positive encouragement. If the learner completes a task without interacting with more knowledgeable peers, the task did not truly belong in the zone of proximal development. Without the more knowledgeable peers, the learner cannot complete tasks within the zone of proximal development per its definition. Interaction with more knowledgeable peers enables maximal learning for the learner (McLeod, 2012, 2018; Vygotsky, 1986).

Scaffolding provided by instructors supports the learner. Instructors need to consider several factors to create effective scaffolding. Careful selection of tasks is one such factor. The task be of appropriate difficulty to fit within the zone of proximal development of the learner and ensure the learner uses the material they need to learn. After selecting a task, the instructor must anticipate errors the learner may make to guide the learner down the path which leads to optimal learning. Instructors must consider the emotional support that may contribute to more effective learning. Such emotional support may include making sure a learner does not let failure discourage them or sharing positive feedback when a learner succeeds. The instructor must also make choices of when and how to apply scaffolding (Cherry 2019; Wood and Wood, 1996; Wise and O'Neill, 2009).

2.2.4: Project-based Learning

Project-based learning presents the learner with an open-ended task they must complete. Learners may complete the task on their own or in teams. The task is open-ended in the sense that no single correct solution exists. The learner must apply critical thinking and problem-solving skills to develop a solution that satisfies every necessary requirement without violating any constraint that they must adhere to such as a project deadline (*Buck Institute for Education*, 2019).

The task comes from a real-world problem to provide the learner with an authentic application of the content and skills new to them. Solving the problem usually requires knowledge of multiple subjects. This requirement is a side effect of presenting learners with a real-world problem, rather than an artificially contrived problem created with the sole aim of teaching the unfamiliar content and skills. Presenting a real-world problem engages the learner by showing the practical application of the new material. The learner sees firsthand how it can help them solve relevant problems in their future (*Edutopia*, 2019; *Buck Institute for Education*, 2019).

Project-based learning emphasizes learner independence and inquiry. Instead of following guidance from an instructor, the learner or team of learners must investigate the problem on their own. During this investigation, the learners may ask an instructor focused questions or perform their own research until they reach a conclusion. Through this process, the learners develop critical thinking and problem-solving skills (*Edutopia*, 2019).

Open-ended projects come with two major drawbacks. If learners lack needed prerequisite knowledge of other subjects, they may not have the building blocks they need to construct a solution. The learner may find themselves unable to bridge the gaps in their background knowledge and never make it to the material the instructor intended to teach with the open-ended project. Working with teammates who have diverse background knowledge may alleviate this shortfall if the teammates can teach each other enough to set a foundation they can work from. The second major drawback is time commitment. Projects also consume much more time for learners and instructors. The broader scope gives learners a large solution space to search, and when they arrive at a solution the instructor cannot quickly check it against an

answer key because open-ended problems could have many solutions, even solutions never seen by the instructor (*Khan Lab School*, 2019; *Edutopia*, 2019; *Buck Institute for Education*, 2019).

2.2.5: Fixed/Growth Mindsets

In her theory on fixed and growth mindsets, Dweck claims that whether a learner believes in their ability to learn directly affects their ability to learn. This belief differs from self-efficacy in an important way: the mindset Dweck refers to represents the extent to which one believes in their capability to learn any new skill or knowledge, whereas self-efficacy represents the extent to which one believes in a specific portion of their existing skills or knowledge. A mindset encompasses assumptions one makes about the source of their talents and the effect of things such as arduous work and failure on the development of those talents. Dweck described two mindsets: the fixed mindset and the growth mindset (Dweck, 2012).

A learner in a fixed mindset assumes their inherent traits such as character, intelligence, and creative ability are static and cannot change in a meaningful way. One with a fixed mindset may try to maximize their utilization of their existing skills instead of stretching themselves to improve their assumedly static natural strengths and weaknesses. When one with a fixed mindset faces failure, they may view it as a devastating demonstration of their lack of talent or a sign that they were not meant to succeed at whatever they failed (Dweck, 2012).

A learner in a growth mindset assumes that with challenging work and earnest effort they can change the traits one with a fixed mindset considers static. One with a growth mindset assumes they developed their skills and talents through work and effort to learn, not by taking advantage of some natural talent that made them inclined to do well. When faced with failure, one with a growth mindset thrives on the challenge and sees an opportunity to grow and expand their abilities (Dweck, 2012).

Those with an open mindset may put in extra time and effort to achieve more ambitious goals one with a fixed mindset may dismiss as out of reach. Instead of accepting failure, one with an open mindset tries to find the root cause and improve themselves. The growth mindset often cultivates success in learners. One can encourage a growth mindset by actively telling learners they can learn, acknowledging effort, and approaching weakness and failure in a positive way to help one learn how to improve (Dweck, 2012).

2.2.6: Andragogy

Most learning theories focus on childhood learning but remain applicable to adult learning. By contrast, andragogy explicitly focuses on adult learning and the differences in how people learn as adults from how they learned as children. Andragogy acknowledges that adults have more life experience and background they consider as they try to learn something new.

Knowles makes six assumptions about factors that motivate adults to learn (Knowles, 1984):

1. Adults need to understand the reason they should learn something.
2. Experience with success and failure supply the basis for learning activities.
3. Adults must accept responsibility for their education decisions and desire involvement in the planning and evaluation of their education.
4. Adults feel motivation to learn information immediately relevant to their work or personal lives.
5. Adults learn best from problem-centric instruction rather than content-oriented instruction.
6. Internal motivation affects adults more strongly than external motivation.

Andragogy introduces seven principles of adult learning. The first principle states that adults must want to learn. Adults learn most effectively when they possess strong internal motivation and excitement to acquire new skills and knowledge. Wanting to learn includes wanting some freedom to direct the learning to meet self-identified needs (Smith, 1996, 1999, 2010; *Canadian Literacy and Learning Network*, 2014).

The second principle states that adults will only try to learn what they feel they need to learn. This principle relates to the first, fourth, and sixth assumptions Knowles made about adult motivation to learn. If an adult does not understand why they should learn something or it does not feel relevant to them, they will lack internal motivation, the most important form of motivation for an adult to learn. Andragogy emphasizes this practical approach to learning as one of the major differences between adult learning and childhood learning (*Teaching Excellence in Adult Literacy*, 2011; *Canadian Literacy and Learning Network*, 2014).

The third principle states that adults learn by doing. This principle is not unique to adult learning; children also learn by doing. Andragogy highlights the difference that learning by doing plays a more vital role for adults. Active practice and participation help integrate components into a coherent whole the learner can retain after the learning finishes (*Canadian Literacy and Learning Network*, 2014; Culatta, 2018).

The fourth principle states that adult learning focuses on problem solving. Children may learn knowledge and skills sequentially so they may apply them later, whereas adults often start with a problem and work to learn the necessary skills and information to develop a solution. Adults experience deeper learning when participating in a meaningful engagement to solve a realistic, relevant problem. The adult learner benefits from a more elaborate, longer lasting, and

stronger representation of the new knowledge when learning this way (*Teaching Excellence in Adult Literacy*, 2011; *Canadian Literacy and Learning Network,* 2014).

The fifth principle states that experience affects adult learning. Adults and children differ in the amount and impact of their life experience and the effect of that experience on their learning. Relevant experience can help reinforce related new learning and expand a preexisting base. However, prior knowledge that conflicts with new learning can degrade the learning process by making it more difficult to incorporate the new learning (*Canadian Literacy and Learning Network*, 2014).

The sixth principle states that adults learn best in informal situations. Children often follow a standard curriculum with formal requirements and timelines. Adults assess the value and necessity of content and its contribution towards a goal or solution to a problem. This informal assessment also considers the individual needs of the learner and meaningful impact of learning content. Performing these evaluations and learning in a collaborative environment with peers actively participating in the learning process makes it more efficient (Culatta 2018; *Canadian Literacy and Learning Network*, 2014).

The seventh principle states that adults want guidance and consideration as equal partners. Adults want to accept responsibility for their learning and confer with instructors for guidance. They do not want instructors to blindly tell them what to do. Adults figure out what helps them learn and what does not and try to optimize their learning by doing what works for them (*Canadian Literacy and Learning Network*, 2014).

Section 2.4 – Current Structure of the ACE

This section describes elements of the ACE program mentioned in feedback, evaluated with respect to education theories, and mentioned in suggested improvements. Except for the

final subsection, each subsection covers one element of the ACE program. The final subsection combines the elements from the previous subsections into a timeline to illustrates the day-to-day experience of an ACE intern. The description in this section reflects the 2019 iteration of the ACE. It does not include intended changes for the 2020 ACE class, the next iteration of the ACE at the time of writing.

2.4.1: Research

In preparation for each summer, the ACE staff request research project proposals from organizations across the Department of Defense and the contractor who facilitates the ACE program. The ACE staff accept proposals for projects most suitable for ACE interns to complete during the summer. Teams of six to twelve interns each work on one of the research problems and develop a solution or other deliverable throughout the 10-week internship.

Research mentors responsible for each project work with the team of interns assigned to their project. The mentors come from the organizations who proposed each project. The ACE interns benefit from the guidance and expertise shared by their research mentor through the course of the project.

These research projects provide interns with a real-world problem to solve in the cyber security field. ACE interns learn how to create and execute a research plan to solve an open-ended problem. At the conclusion of the ACE, each research team gives a formal briefing to describe their research problem and the solution they developed. After the final research presentations, the research mentors collect project deliverables and deliver them back to their organizations. The organization of each research mentor often employs the deliverables within a few weeks of the conclusion of the ACE.

2.4.2: Leadership

The ACE includes weekly military leadership seminars. A retired Air Force colonel leads the seminars, which explore case studies of remarkable events and relevant examples of leadership in the engineering field. Each case study takes a close look at the root causes of success and failure. Open-ended discussions during each case study develop critical thinking skills.

Interns travel to Gettysburg, Pennsylvania where the retired colonel uses Gettysburg National Military Park as the context for leadership lessons and links between the historic conflict and challenges faced by modern cyber leaders. The brief excursion allows the interns to shift focus from technical content to leadership and character development without the distraction of research and the weekly challenge problem. The battlefield tour follows the conflict chronologically, stopping at several sites to share stories of how leaders handled novel situations and interacted with their men. Each story emphasizes enduring lessons and concepts that prepare the interns for future roles as cyber leaders.

2.4.3: Lecture and "Challenge Problem"

Each week, interns attend a six to eight-hour lecture from a subject matter expert from academia, government, or industry. Each expert covers a different cyber security topic. The lecturer teaches necessary background and the latest knowledge on their topic in great depth. A different lecturer each week often results in a variety of presentation styles and structure. At the end of each lecture, the lecturer reveals the "challenge problem" for the week.

Each expert designs an open-ended challenge problem with the expectation interns will spend an estimated 40 to 60 hours over the next week devising a solution. The interns solve each weekly challenge problem in teams of three and individually author technical reports to

document and communicate their solution. These reports must follow a strict writing guide intended to facilitate clear, concise technical writing. The weekly challenge problem requires hands-on application of the knowledge and skills covered in the weekly lecture. The lecturer sometimes remains available during the week to answer questions from interns or provide clarification.

These weekly lectures and challenge problems provide the academic/education component of the ACE program. The ACE staff decide what topic interns learn about each week and solicit appropriate experts to present the lecture and develop a suitable challenge problem. Due to the evolving nature of the cyber security field, the selection of topics changes each year to maintain a modern and relevant curriculum. Table 2-1 and Table 2-2 show the weekly academic lecture and challenge problem topics for the inaugural ACE class and the 2019 ACE class, respectively.

Week and Topic	**Content**
1. Legal Issues	Internet laws and cybercrime, the Fourth Amendment of the US Constitution, search and seizure of data, rights and privacy issues, government versus private workplace, search warrants and wiretap laws, the PATRIOT Act
2. Security Policies	Establishing and implementing security policies, confidentiality integrity and availability considerations, identifying vulnerabilities and threats, establishing disaster response and recovery procedures
3. Cryptography	Mathematical basis for data encryption, substitution ciphers and the Data Encryption Standard, private-key and public-key

	cryptography, key distribution and trusted authority, digital signatures
4. Computer Security	Operating systems and file system security, passwords and one-way hashes, user-space administration, archiving and back-up strategy, intrusion detection, disaster response and recovery
5. Digital Forensics	Procuring and analyzing digital evidence, preserving the chain of custody of digital evidence, recovering hidden data on hard drives, classifying file systems, analyzing slack and sector data, recovering lost clusters
6. Network Security	TCP/IP packet format and vulnerabilities, protocol and implementation flaws, buffer overflow, denial-of-service attacks, distributed attacks, email, domain name system, web servers
7. Steganography	Data hiding in images, classifying steganography algorithms and tools, categorizing vessel capacity, detection and recovery of hidden data, digital watermarking, streaming media steganography, multilingual steganography
8. Network Defense	Host and network security, firewalls and periphery intrusion detection systems, bastion hosts, network monitors and traffic analyzers, network logfiles, detecting anomalous behavior, network recovery

9. Wireless Security	Wireless local area networks, wireless encryption protocols, war driving
10. Next-generation Cyber Security	Next-Generation Internet Protocols IPv6, embedded systems, 3G cell phones and personal data assistants

Table 2-1: This table shows the weekly academic lecture and challenge problem topics from the inaugural ACE class of 2003 (Jabbour and Older, 2004).

Week and Topic	**Content**
1. Fundamental Mission Analysis	The lecture provides the requisite background in Access Control Logic and Certified Security by Design for the Interns to execute a novel challenge problem: to devise and verify the authentication and authorization CONOPS for a UAV payload controller. The payload controller is a system to release a weapon within a kill box within mission timing, by means of transmitting, receiving, and executing a valid release command, in order to contribute to accomplishing an air interdiction mission. Interns will use an access-control logic to describe and verify the authentication and authorization CONOPS.
2. Agents and Evasion	Lecture will start with an introduction of network designs utilizing a defense in depth strategy leveraging antivirus, IDS/IPS, and firewalls to protect hosts. Interns will be introduced to the history, theory, and technology behind these tools, and how they are leveraged in home and enterprise networks. Interns will be introduced to remote access tools such as meterpreter and their use on Windows systems. The corresponding challenge problem will consist of Interns circumventing four (4) example networks and defense systems of increasing security posture to enable remote access. This lecture also serves as first introduction to offensive cyber operations.

3. Network Protocols and Attack Surface	Students will be introduced to fundamental network protocols such as ARP, DHCP, DNS, NTP, and TCP/IP. Each protocol's data structure and implicit trust model will be examined in depth. Students will learn to exploit the protocols fundamental assumptions and flaws to execute an array of spoofing and denial of service attacks. The challenge problem will consist of programmatically executing a variety of these on a test range.
4. Code-Level Attacks	The lecture will cover code-level attacks primarily involving memory corruption through buffer overflows and memory information leaks. The lecture will guide the students through a set of hands-on exercises that introduce exploitation concepts and modern protections. All material used in this course is derived from publicly available sources.
5. Logic and Lexicon of Operational Design and Art	The purpose of these lectures and exercises is to foster an awareness of the 'logic and lexicon' of cyber operational planning. Interns will determine how to achieve cyber effects to compel an enemy to bend to our will by designing a cyber-operations plan enabling our national command authorities to deter and defeat adversaries.
6. Covert Communications	This lecture will introduce interns to the theory and practice of covert communications in cyber operations. Interns will learn about the ability to use urgent pointers, DNS, HTTP, HTTPS, and SMB as covert channels. Interns will successfully exfiltrate a file of an infected host while avoiding detection from network defenders while using a covert communication channel.
7. Reverse Engineering	The two-part lecture is a crash course in reverse engineering, cyber-forensics, and actionable threat intelligence principles. Interns will be introduced to x86 machine language, executable file formats, and obfuscation methods such as "packing", "obfuscation," and "anti-debugging/anti-disassembly. The corresponding challenge

	problem will be analysis of a captured malware and investigation to compromise of the computer system.
8. Planning and Reconnaissance	This lecture is intended to provide instruction on network reconnaissance and pivoting. The topics covered are network fundamentals, reconnaissance, network enumeration, wireless networks, network attack, credential mining, privilege escalation, and pivoting. The course focuses on the fundamentals with interactive examples and provides a challenge problem that covers many of the topic areas addressed during the lecture.
9. Introduction to Hardware Security	This lecture examines the fundamental architecture of modern processors and considers their underlying design assumptions. These assumptions are considered in the context of cyber security with an emphasis on where speculative execution, shared resources or other indirect coupling has led to unexpected vulnerabilities. Mitigations to these architectural flaws are discussed and the trade space governing the balance of security and performance when implementing these fixes is explored.

Table 2-2: This table shows the topic of each weekly academic lecture and challenge problem for the 2019 ACE class (*2019 Curriculum Schedule*, 2019).

2.4.4: Lab Exercises

Each week, interns attend a 4-hour lab session. In contrast to the academic lectures, the lab sessions provide hands-on training to interns. Although these sessions contain some new knowledge by necessity, they primarily focus on teaching technical skills to impart new capabilities. The interns can use these new capabilities to generate effects during future exercises throughout the summer. Table 2-3 shows the topic and content for each weekly lab from the 2019 ACE.

Week and Topic	**Content**

1. "Concord Dawn"	Concord Dawn meets its education and training objective through a strongly integrated multi-domain operation executed in air, ground and cyberspace. Participants support an air strike on a High Value Target through gathering and interpreting intelligence, developing a plan to achieve mission objectives, and executing that plan as part of a time phased mission.
2. None	No lab due to the Gettysburg trip.
3. Code Hardening	Code-level hardening consists of activities undertaken by software developers, code reviewers, or testers to produce secure source code. In the Code Hardening exercise, students explore code-level hardening by mitigating Perl and PHP vulnerabilities of a web application to prevent input-based attacks such as cross-site scripting and SQL injection.
4. Code-Level Attacks	The Lab consists of a scenario in which the student must apply the knowledge from the Code-Level Attacks lecture to successfully attack a system. All material used in this course is derived from publicly available sources.
5. Privilege Escalation	The privilege escalation lecture covers one to two specific privilege escalation techniques focused on chroot jail breakouts and hypervisor escalation. The Lab has students perform hands-on debugging and exploitation of the Venom vulnerability using the gdb debugger. Students are required to compose shell code and inject it into heap memory to exploit the Venom vulnerability.

6. Adversary Tactics	This intense course immerses students in a simulated enterprise environment, with multiple domains, up-to-date and patched operating systems, modern defenses, and active network defenders responding to Red Team activities. We will cover several phases of a Red Team engagement in depth: user profiling and phishing, host enumeration and "safety checks", advanced lateral movement, sophisticated Active Directory domain enumeration and escalation, persistence (userland, elevated, and domain flavors), advanced Kerberos attacks, data mining, and exfiltration.
7. Reverse Engineering	Interns will learn to utilize reverse engineering software such as IDApro and Ollydbg along with additional analysis tools to bypass techniques such as packing, obfuscation, and anti-debugging/anti-disassembly. Using these skills, intern will analyze a malware sample and discover ways to block its command and control.
8. SCADA	The SCADA lab covers the fundamentals of SCADA systems, using physical hardware as examples to understand security and vulnerabilities of these devices. The students will learn about specific network protocols used to talk to these devices, the software architectures that sit on top of these devices, discover vulnerabilities within the devices, and exploit these vulnerabilities to understand the impact to these SCADA systems.
9. Meltdown	This lab will provide interns with a conceptual and hands-on appreciation for the meltdown attack in specific and hardware attacks in

	general. A review of germane computer architecture details such as caching, branch prediction, and out of order execution will be conducted. Interns will then learn and implement cache reading as a side channel, exploit out of order execution to read protected memory, and optimize the attack through memory conditioning and shell code.

Table 2-3: This table shows the weekly lab topics and content from the 2019 ACE program (*2019 Curriculum Schedule*, 2019).

2.4.5: Weekly Mission Operations

The ACE staff divide the interns into three teams before their arrival. Each team represents a fictitious nation-state with unique national interests, assets, and territorial claims. Every week, each nation-state team must complete a series of objectives during an hour-long, cyber-physical mission with simulated physical components such as aircraft. The missions parallel escalating tension between the nation-states throughout the internship until the final mission, which sparks a greater conflict leading into the capstone exercise.

The weekly missions require a blend of the leadership, planning, tradecraft, and knowledge the interns accumulated to successfully complete a military-style mission with clearly stated objectives. After the mission ends, the interns remain split into their nation-state teams to debrief. The debrief includes a self-assessment and discussion of lessons learned. Whether a team succeeds or fails their mission may impact their future missions.

2.4.6: 8-mile Run

The ACE requires a weekly 8-mile run to promote physical fitness and support team building through shared adversity. Dr. Devendorf, director of the ACE program at the time of writing, sums up the activity in this way:

> "Running, like the ACE, is an intrinsically individual activity, but along the way our peers give a shout of encouragement, a high five, or simply presence when we have difficulty so that we can achieve things we thought impossible."

2.4.7: Capstone Exercise

The capstone exercise takes place over two days at the Stockbridge test site. The site covers 300 acres of land, with 24 remote pad sites with minimal shelter supporting power and fiber network connections scattered about. Each pad site comfortably supports a maximum of three occupants. During the ACE capstone, each pad site network connects it to the ACE battlespace.

The ACE battlespace hosts the weekly mission operations and simulated vehicles on a simulated internet network completely isolated from the real internet. Throughout the summer, the mission operation requirements included infrastructure setup for each team to communicate when geographically separated from teammates.

The interns learn that the map of their nation-states is an aerial photograph of the Stockbridge test site with national borders and infrastructure such as airbases and supply depots overlaid. Each nation-state team self-organizes into smaller flights of three members. Each flight deploys to a pad site within the national borders of their nation. The flights must communicate with the rest of their nation through the communication infrastructure they set up throughout the summer.

The final weekly mission operation sparks a mock war between the nation-state teams. The ACE staff give each nation a desired end state and a series of missions to achieve the desired end state. The missions include challenges solvable with the knowledge and skills learned over the summer. The missions also integrate cyber and kinetic warfare. For example, a mission may

require a nation-state team remove the threat of a surface-to-air missile site via cyber means to allow aircraft to enter the area and bomb supply depots replenishing the weapons of the enemy nation.

At the conclusion of the Capstone exercise, the ACE staff compare the end state of the exercise to the desired end state of each nation and declare a winner. A debrief from the ACE staff follows to share insight on the exercise and events from the all-knowing staff perspective. Following the staff debrief, the interns meet in their nation-state teams to do a team debrief. The ACE staff divide themselves among each nation-state team to offer guidance during the team debrief if needed.

2.4.8: Summary and Weekly Schedule

This section summarizes each of the components of the ACE program by assembling them into a weekly schedule that portrays the experience of an ACE intern during a normal week of the ACE program. Exceptions to this schedule include the week of the Gettysburg trip and the final week of the ACE when the capstone exercise takes place.

Monday morning interns turn in their report for the last challenge problem no later than 0800. Starting at 0800, selected teams of three who solved the challenge problem together give 15-minute briefings on their solutions. Questions from the ACE staff, lecturer from the previous week, and other interns follow each briefing. After the intern briefings conclude, usually around 0930, interns report to the academic lecture. The new subject matter expert for the week introduces themselves and proceeds with the academic lecture. The interns get an hour lunch break at whatever time the lecturer chooses. After the lunch break, the lecture reconvenes and continues until completion anywhere from 1700 to 1900. The lecturer concludes by introducing

the weekly challenge problem. Independent of the lecture and challenge problem, each nation-state team receives instructions and requirements for the weekly mission operation.

Tuesdays begin with research at 0800. Interns work in their research project teams with their research mentor all day. Many research mentors allow flexibility with the structure of the day, such as the timing and duration of breaks and lunch, provided the interns remain productive. Research time ends at 1700. At this point, interns often use the evening to begin the challenge problem and start drafting their reports.

The 8-mile run begins Wednesday morning at 0730. Interns collect an ACE poker chip from a container at the 4-mile mark and deposit them into a glass jar when they finish. The glass jar fills throughout the summer to visibly show the distance the interns covered as a team. Every intern and ACE staff must complete the course by 0900. For the remainder of the day, the interns split into two groups. The first group works on their research projects for the first half of the day while the second group attends the weekly lab activity. The second half of the day the groups switch; those who researched in the morning attend the lab activity in the afternoon, and those who attended the lab activity in the morning work on their research projects for the remainder of the day.

For Thursdays, interns remain split into the same two groups. From 0800 to 1200, one group works on research projects in the morning while the other attends the weekly leadership workshop. In the afternoon from 1300 to 1700, the group who worked on research projects in the morning attends the leadership workshop and the group who already attended the leadership workshop works on their research projects for the remainder of the day.

Interns all work on their research projects Friday from 0800 to 1600. At 1600, interns divide into their nation-state teams and execute the weekly mission operation. Each team

completed any preparation for the mission operation in the prior evenings. The mission execution ends at 1645 and the interns debrief among their teams until 1700. The ACE staff sit in on the team debriefs to share the mission outcomes and, if necessary, steer the debrief in a productive direction.

This description of a week in the ACE summarized several of the different components of the ACE program. Each component provides unique data and artifacts from the interns. The next chapter discusses current methods employed by the ACE staff to assess effectiveness of the ACE program with the currently available data and artifacts.

Chapter 3 - Current Methods of Assessment

This chapter begins with a high-level view of intern evaluation in the ACE program as described in the ACE syllabus. The sections following the high-level view visit each evaluation instrument to investigate how the ACE staff use it to evaluate interns.

Section 3.1 – High-level View

The ACE staff evaluate the degree to which interns achieve course objectives. The information and artifacts used in this evaluation include written reports, oral presentations, hands-on lab exercises, the weekly 8-mile run, and a final staff assessment at the end of the program. At the end of the ACE program, every intern receives a stratification based on their final grade in every program component. This stratification reveals a class ranking, and the top ten percent of ACE interns graduate with the distinction of Distinguished Graduate. Table 3-1 shows the nine graded components of the ACE program and their weighting in the final grades.

Evaluation Instrument	Evaluation Mechanism	Weight
Challenge Problem Report	Grading Rubric	20%
Challenge Problem Evaluation	Staff Assessment	5%
Challenge Problem Presentation	Grading Rubric	5%
Lab Execution	Grading Rubric	10%
Research Progress	Research Mentor Assessment	10%
Weekly Operation	Group Score	10%
Staff Evaluation	Staff Assessment	20%
ACE Run	Run Rubric	10%
ACE Capstone	Final Score	10%

Table 3-1: This table shows the graded components and their weighting in final grades.

The ACE staff evaluate academic assignments with standardized rubrics. Each rubric contains a total of 100 points possible for each assignment. The total points earned on an assignment correspond to a letter grade in accordance with Table 3-2. To graduate the ACE, an intern must earn at least a Satisfactory grade (60%) in every program component.

Letter Grade	Meaning	Percentage
A-, A, A+	Exemplary	90-100
B-, B, B+	Proficient	75-89
C, C+	Satisfactory	60-74
C-	Substandard	56-59
F	Unsatisfactory	0-55

Table 3-2: This table shows the meaning of each range of point values and their corresponding letter grade.

Section 3.2 – "Challenge Problem"

3.2.1: Presentation

Each week, the graduate assistants schedule three teams of three to present their solutions to the challenge problem to the entire ACE class and staff. Each presenting team gets 15 minutes for their presentation, followed by five minutes to answer questions from the audience. The presentations must follow a template with the following seven sections: problem statement, background, assumptions, tools and techniques, solution, risk assessment, and references / works cited.

After the five-minute question period, the ACE staff share feedback and constructive criticism with the presenters. Feedback often covers items such as slide layout, word choice, and

general presentation etiquette. The ACE staff assign a score based off their assessment of the presentation.

3.2.2: Report and Evaluation

Each week, every intern writes a technical report to document and communicate the solution their team of three came up with for the weekly challenge problem. The ACE staff created a standard rubric for grading these reports. See Appendix B for a copy of a blank challenge problem report rubric. The rubric allocates 60 points to the solution itself and 40 points to the writing and clear communication of the solution.

To grade every report without fully saturating the limited time of the graduate assistants, the graduate assistants employ a peer grading system. During the academic lecture, the graduate assistants grade the papers of every intern who presented their solution that week (around nine interns, or three teams of three) to establish a standard and clarify their expectations for the reports from that week. Next, the graduate assistants anonymize the ungraded reports by removing the cover page, which contains the name of the author, and assigning each report a number.

In the evening, the graduate assistants meet with the interns who presented that morning. The graduate assistants discuss any unique elements of the previous challenge problem and how to grade them in the reports. After reading over their papers and asking any questions, the presenters from that morning grade the anonymized ungraded reports from the previous week at their convenience. The graders must return all graded reports by noon that Thursday. The graduate assistants remain available to address questions or concerns the graders may have.

After the graders return the graded reports, the graduate assistants reunite the papers with the matching cover pages. The graduate assistants return each graded paper with its cover page

and a filled in grading rubric to the original author. The grading rubric contains a field the grader must print their name in so an intern who wishes to dispute their grade may first consult with the original grader to understand why the grader gave the assigned grade. After discussing the grade with their grader, if any disagreement remains the report author may consult with a graduate assistant. The Challenge Problem Evaluation component covers honest grading and providing constructive feedback on the rubric and annotated in graded papers.

Section 3.3 – Lab Exercises

The ACE staff request each lab instructor to produce their own rubric with a total of 100 points for use in grading their lab exercise. The variety and uniqueness of each lab exercise makes a single, standardized lab rubric impractical and too inflexible for this application. A graduate assistant helps the lab instructor during each lab exercise. Together, the lab instructor and graduate assistant fill in the lab rubrics to grade each team as they progress through the exercise.

Section 3.4 – Research

To evaluate the contributions each intern makes to their assigned research project, the ACE staff turn to the research mentors. The mentors observe each intern on their research team while working with them throughout the summer. The ACE staff provide the research contributions rubric in Appendix D and ask each research mentor to fill one out for each intern on their research team on a weekly basis. Research mentors may pursue other means of evaluating interns on their research team and incorporate their assessment into the research grade for each intern. For example, a mentor may meet privately with each intern to discuss their contributions, the team, and the research project.

Section 3.5 – Weekly Operation

During each weekly mission operation, the ACE staff act only as observers until the exercise ends. The interns seek guidance and clarification from a designated marshal for their nation-state team, who they contact through infrastructure they create on the ACE battlespace. The interns self-divide themselves into three rooms, one for each nation-state team. The ACE staff all begin in a staff-only room together at the start of the exercise to ensure everything gets off to a smooth start. After resolving any issues, throughout the exercise a member of the ACE staff may visit any of the nation-state teams in their rooms to observe the exercise from the perspective of the interns or follow up on any anomalies the ACE staff notice.

At the conclusion of each mission operation, the ACE staff convene to analyze the end state of the exercise. The ACE staff determine a point value for each mission and reward points to each nation-state team qualitatively based on the degree to which the exercise end state parallels the desired end state reflected by the mission objectives. These points accumulate throughout the summer and a scoreboard publicly displays the score of all teams at any time. The ACE staff may speak to a team after their debrief if the staff have anything to add or share based on their observations.

Section 3.6 – Staff Evaluation

At the end of the ACE program, the staff collectively evaluate each intern. The staff evaluation exists with the intent to provide a wholistic assessment of each intern that captures elements not visible in the other artifacts graded throughout the ACE program. See Appendix C for a copy of the staff evaluation rubric. The staff evaluation rubric contains two sections: ACE Core Tenets and Attitude and Conduct. The ACE Core Tenets section contains one subsection

for each part of the ACE motto: No Excuse, No Extension, No Exception. The Attitude and Conduct section contains one subsection for each tenet.

The No Excuse subsection allocates 25 points to quantify the degree to which an intern takes responsibility for their actions and whether they learn from the outcome. The No Extension section allocates 25 points to assess the adherence to deadlines and punctuality demonstrated throughout the summer. The No Exception section allocates 20 points an intern may consequently lose for breaking the ACE code of conduct or violation the Rules of Engagement for an exercise. The Attitude and Conduct sections each allocate 15 points to quantify the impact an intern had on themselves and others.

Section 3.7 – ACE Run

The grading for the ACE run follows the ACE run rubric in Appendix A. The rubric allocates 20 points to Distance Travelled, with full points awarded for completing the entire 8-mile course before the 0900 deadline. The rubric awards the next 40 points on a linear scale, where completing the run in 58 minutes or less earns the full 40 points and completing the run in a time over the 90-minute limit earns no points. An intern earns the final points by finishing before the 0900 deadline, irrelevant of total time taken or distance travelled.

The assessment of the ACE run emphasizes on-time performance by placing an equal focus on finishing faster than the required 90-minute time and finishing before the 0900 deadline. The heavy weight on finishing before the 0900 deadline also deters interns from causing unnecessary delay to the next activity since the interns must all wait for everyone to finish. The designer of the run rubric accommodated interns who must train before they can complete the full 8-mile course in the required time.

Consider the case of an intern who knows they cannot complete the full 8-mile course in 90 minutes. The intern may accept the option of starting early at 0700, so they have 120 minutes to finish. If that intern completes the entire course and returns before 0900, they still earn 60 points, a minimal passing score. The intern must show improvement each week and eventually complete the run in under 90 minutes at least once to graduate, but the distribution of points in the rubric accommodates such an intern by giving them a chance to improve without immediately failing them from the program due to a poor run.

Section 3.8 – Capstone Exercise

The ACE staff score the Capstone event in a way like they score the weekly operations but modified to suit the two-day exercise. The same scoreboard used throughout the summer begins with the scores each team accumulated from each weekly operation. Throughout the capstone exercise, teams must complete mission objectives to progress towards their desired end states. Completion of each objective earns points that the scoreboard adds to their team score. Other lines of effort such as destroying enemy aircraft and military installations also earn points. At the end of the capstone exercise, the nation-state with the most points (and, consequently, closest to the desired end state of their nation) wins.

Chapter 4 - Observations and Assessment of 2019 ACE

This chapter enumerates available data collected during the 2019 ACE course. Each section describes the information gathered on each component of the ACE and conclusions drawn from the data. The chapter ends with a conclusion on the overall effectiveness of the ACE based off the observations and assessments from each section.

Section 4.1 – Research

The research mentors evaluated each member of their research teams according to the ACE research rubric. The ACE staff received two complaints about the weekly evaluation with the research rubric. The first complaint expressed concern that the wording and structure of the rubric makes it suitable for assessing a final research deliverable, but unsuitable for assessing a project in progress, especially for the earlier weeks of research. The second complaint insisted assessing every intern every week is too frequent when the research mentors only see their team for at most 20 hours each week. A precursory look at the research grades of different research teams reveals each research mentor may have taken a different approach to grading their team or interpreted the research rubric differently. These differences cause a visible variance in grade trends across different research teams. Figure 4-1 shows the average research grade of every intern each week over the course of the ACE. Figure 4-2 shows the average of the variance of grades assigned each week for each research project. The following subsections look at the grades broken up by research team. Research teams 3 and 4 experienced the greatest variance in research grades assigned to each intern. These larger variances indicate the research mentors for research teams 3 and 4 assigned the same research grade to more than one intern less frequently than the other research mentors.

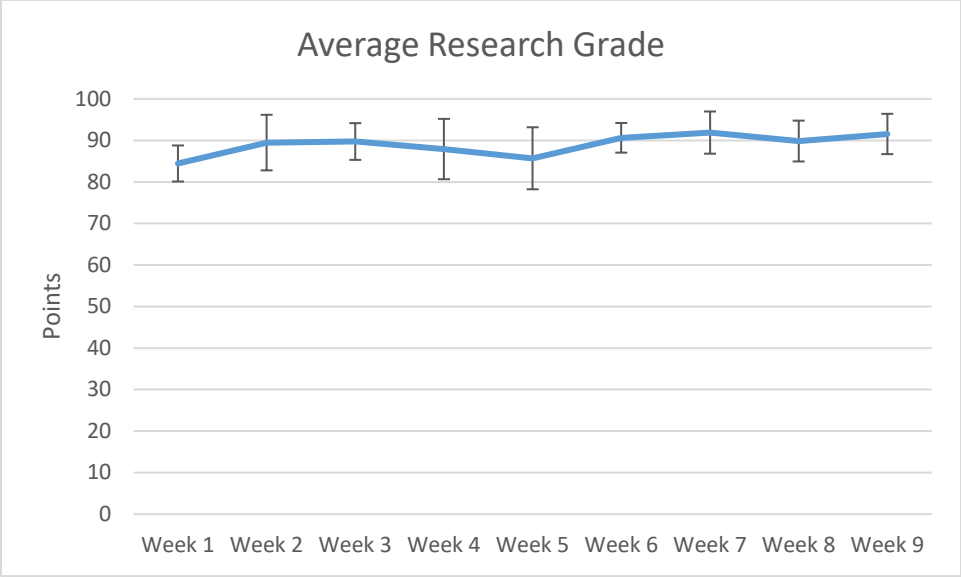

Figure 4-1: This figure shows the average research grades for each week with error bars showing one standard deviation in either direction.

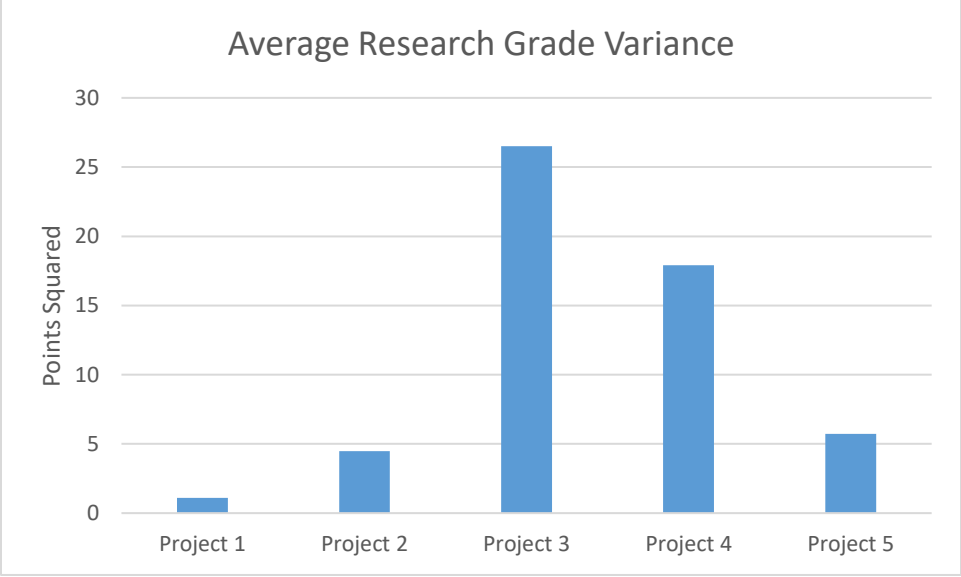

Figure 4-2: This figure shows the average variance in research grades for each research project.

4.1.1: Research Team 1

Seven of the surveyed interns come from the research team this study labels Research Team 1. Figure 4-3 shows the research grades of each surveyed intern from Research Team 1

throughout the summer. Every intern received an identical grade each week except for intern 3 on week 8, who received a slightly lower grade than their peers. The otherwise identical grades suggest that their research mentor assessed the team instead of each individual intern. The research mentor may have used the team score as a baseline and deducted points if they observed unproductive use of time, which may be the case for intern 3 in week 8. Grading the team as a whole in this manner makes sense on its own but does not capture the intent of assessing the contributions of each individual intern.

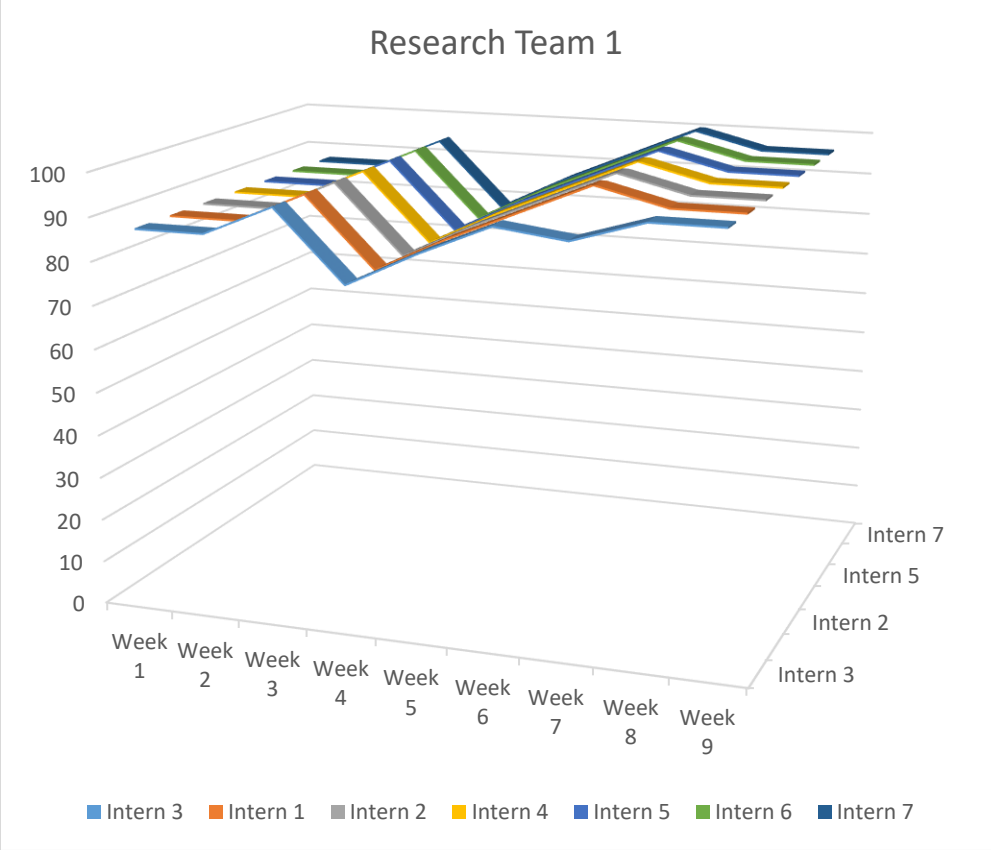

Figure 4-3:This figure shows the research grades of Research Team 1 throughout the summer.

4.1.2: Research Team 2

Five of the surveyed interns come from the research team this study labels Research Team 2. Figure 4-4 shows the research grades of each surveyed intern from Research Team 2

throughout the summer. In the first few weeks, interns 8 and 15 received identical grades and interns 12, 14, and 17 received a separate set of identical grades. These two distinct sets of identical grades suggest the interns formed two cliques, one more productive than the other, and the research mentor assessed each clique as a single unit. From week 5 onwards, the grades converged and each intern on the team received almost identical grades for the remainder of the summer. This convergence could indicate the cliques merging at this time, and the research mentor accordingly assessing the entire team as a single unit.

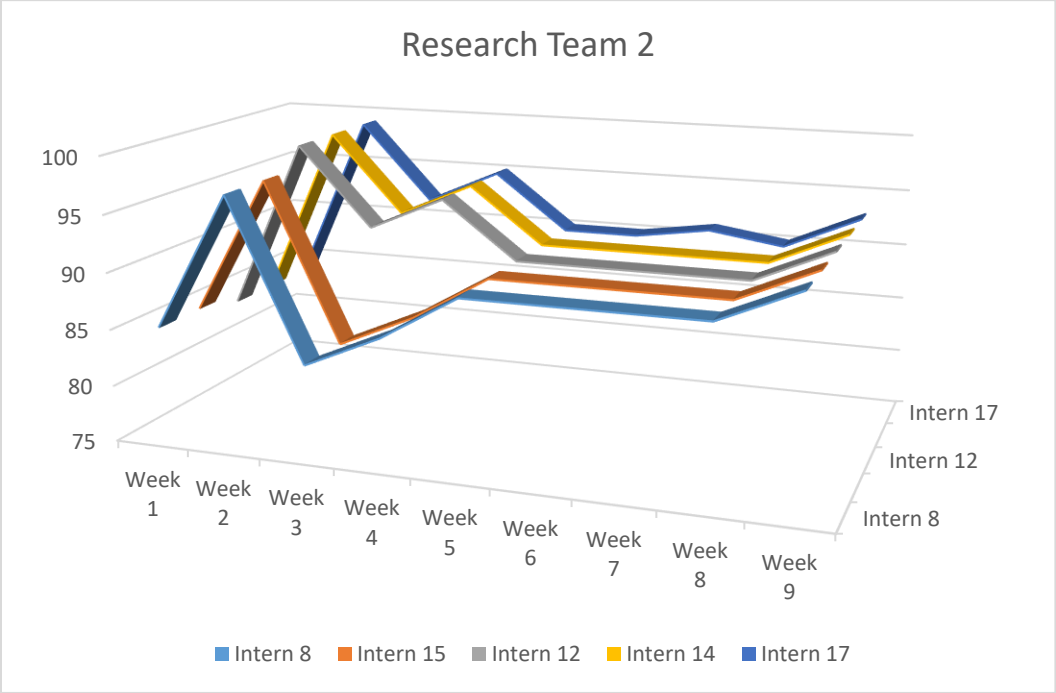

Figure 4-4: This figure shows the grades of each intern from Research Team 2 over the summer.

4.1.3: Research Team 3

Seven of the surveyed interns come from the research team this study labels Research Team 3. Figure 4-5 shows the research grades of each surveyed intern from Research Team 3 throughout the summer. Based on research grade similarities, it appears the interns in Research Team 3 also formed cliques. Unlike Research Team 2, the research mentor did not assign interns

of the same clique mostly identical grades; although grades within a clique follow similar trends from one week to the next, minor variances set the interns apart from one another. The major distinction of the clique containing interns 13, 16, and 18 from the other interns is the sharp drop in grades at week 5, which the clique recovers from in week 6. Research team 3 experienced the greatest variance between team member research grades each week on average as shown in Figure 4-2. Based on this high variance, it appears the research mentor for Research Team 3 tried to assess interns individually as desired by the ACE staff.

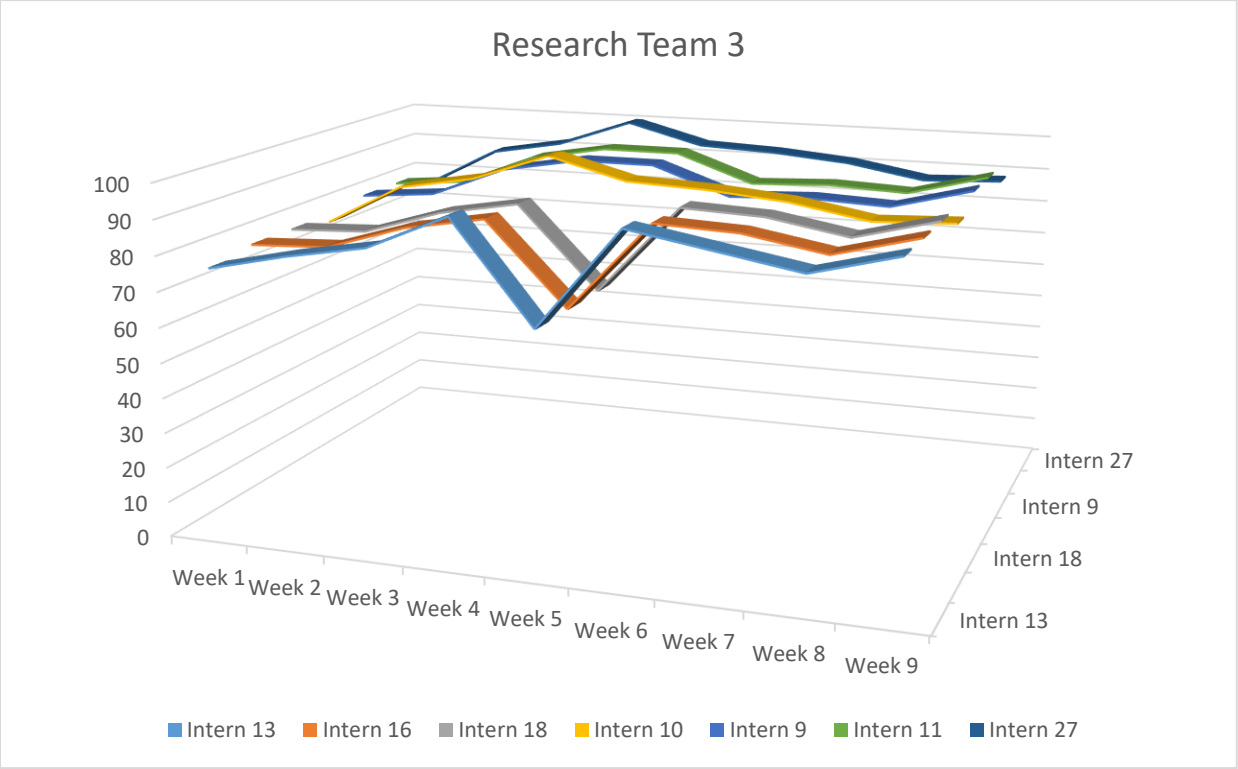

Figure 4-5: This figure shows the research grades for Research Team 3 over the summer.

4.1.4: Research Team 4

Five of the surveyed interns come from the research team this study labels Research Team 4. Figure 4-6 shows the research grades of each surveyed intern from Research Team 4 throughout the summer. The first two weeks, every intern from Research Team 2 got the same

research grade each week. After the second week, interns 23 and 24 continued to get a matching set of grades each week but the grades of the remaining interns on Research Team 4 diverged from one another. Overall, it seems the research mentor for Research Team 4 followed the intent of assessing each individual intern. Two interns contributing equally to a single line of effort could explain the identical grades between interns 23 and 24.

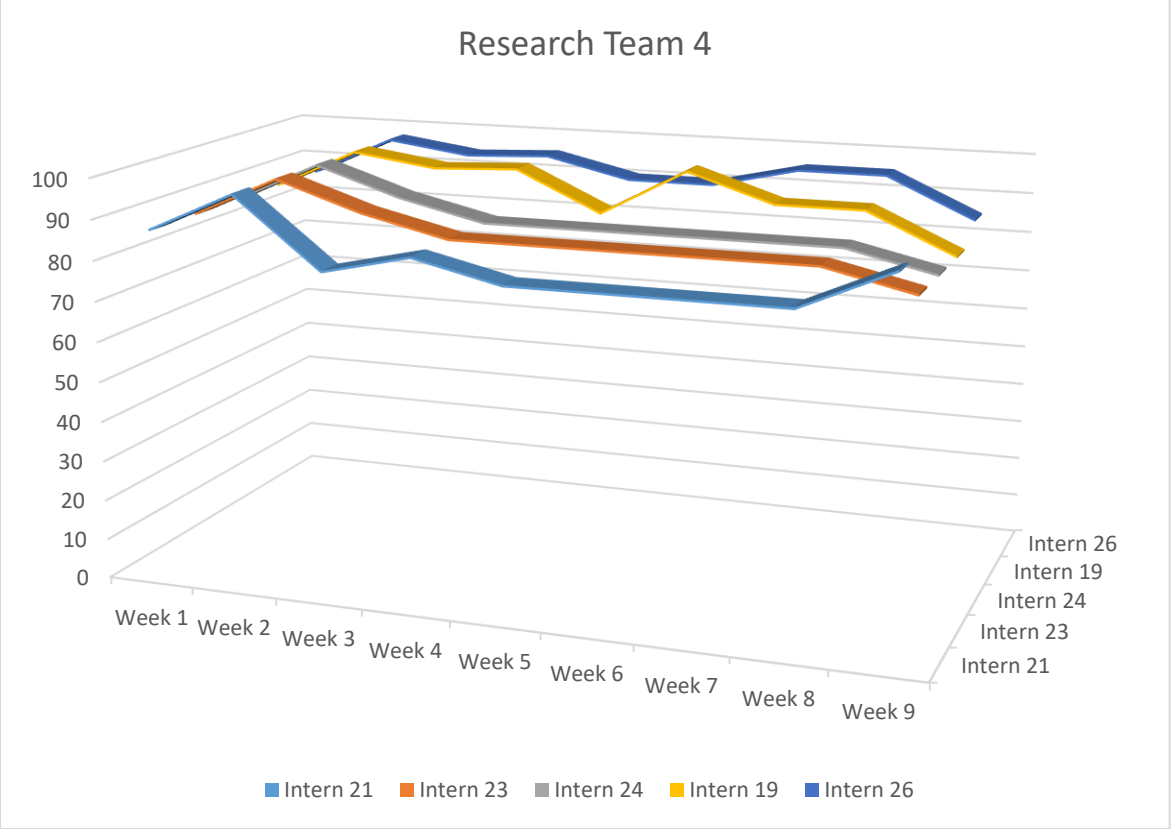

Figure 4-6: This figure shows the research grades for Research Team 4 throughout the summer.

4.1.5: Research Team 5

Three of the surveyed interns came from the research team this study labels Research Team 5. Figure 4-7 shows the research grades of the surveyed interns from Research Team 5 throughout the summer. Each week, every intern from Research Team 5 received the same research grade with two exceptions: weeks 6 and 8. For week 6, intern 20 received a higher

grade than interns 22 and 25, who both received the same grade. For week 8, intern 25 received a much higher grade than interns 20 and 22, who each received the same grade. These deviations from the norm of assigning all three interns the same grade may indicate the research mentor assessed the entire team based on their research progress, but on occasion used research grades to reward an intern for exceeding expectations that week.

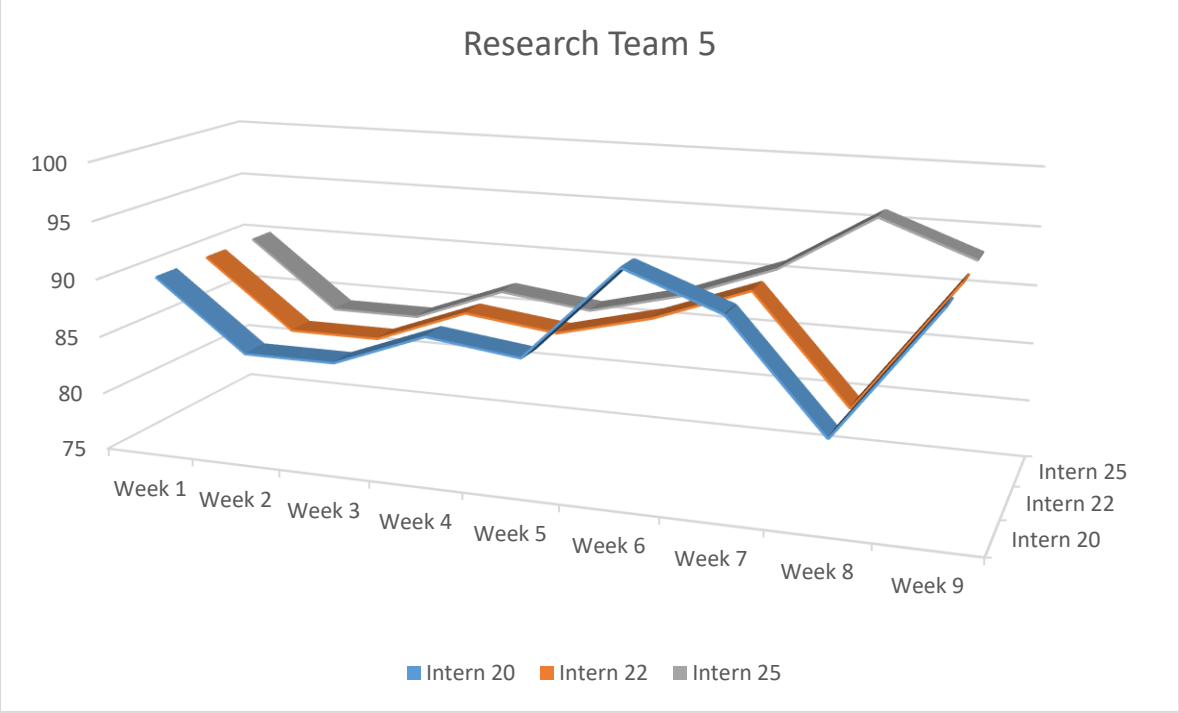

Figure 4-7: This figure shows the research grades for Research Team 5 over the summer.

Section 4.2 – Leadership and Teamwork

This section shares observations from the ACE staff about each of the three nation-state teams, East, West, and Central. The East and West teams represent traditional nation-state entities, whereas the newly introduced Central team resembles insurgent forces seeking independence from the East and West nations. A few weeks into the ACE, the ACE staff appoint

two interns from each team as commander and deputy of their team. These observations come from a compilation of notes recorded by the ACE staff and graduate assistants during or shortly after spending time with each team.

4.2.1: East Team

15 interns made up the East team. Each of the four graduate assistants spent time with the East team and recorded notes on their observations. Subjective comments in notes from the graduate assistants indicate the graduate assistants perceived the East team as having a "strong work ethic", "respect for one another", and "tenacity when faced with adversity".

Three graduate assistants who spent time with the East team during their preparation for the weekly mission operations mentioned the team performed Rehearsal of Concepts (ROC) drills prior to every operation starting in week 4. According to these graduate assistants, the East team would rehearse their plan several times with changes to the scenario in each iteration. When a graduate assistant asked why they prepared in this way, an intern on the East team answered that they incorporated changes with each iteration to test their contingency planning. No graduate assistant observed another nation-state team perform a full rehearsal of a weekly mission operation prior to its execution.

Throughout the summer, several graduate assistants and members of the ACE staff sat in on the East debriefs that followed each weekly mission operation. The staff notes for debriefs from the second half of the summer report the East team identified problems, root causes, instructional fixes, and lessons learned on their own without prompting from the ACE staff or graduate assistant in the room. The graduate assistant and staff notes from East debriefs also indicate the team remained internally focused on ways the team could have met their objectives under the given circumstances instead of blaming external factors for their failures.

Two graduate assistants observed a team-building session the East team organized for themselves. Prior to the team building session, the East commander had asked every intern on the team to fill out an anonymous online form with one strength and one weakness for each member of the team (including themselves) for review by the entire team during the session. The East commander stated the purpose of the team building session was to help everyone on the team understand their strengths and weaknesses and create personal goals for improvement. Both graduate assistants present described the anonymously submitted strengths and weaknesses as "professional" and "productive". The two graduate assistants who attended the session also reported at least four interns on the East team said they felt the team building session accomplished its goals. No other nation-state team held a similar team building session that the graduate assistants knew of.

The ACE staff and graduate assistants noticed another unique thing the East team did. The West and Central commanders always acted as leader during the weekly mission operations. The East team let a different teammate act as leader each week. During a debrief, a member of the ACE staff asked the East commander why their team rotated leaders for the weekly operation. The East commander said they wanted to give everyone on the team experience with leadership and followership, so every member understood both roles.

4.2.2: West Team

18 interns made up the West team, the largest nation-state team of the 2019 summer. The graduate assistants admitted during an ACE staff meeting that they felt as if they spent the least amount of time around the West team. When asked why they felt this was the case, the graduate assistants speculated that the West team always seemed to have a negative attitude and this

negativity deterred the graduate assistants from actively seeking the team out to ask if they needed anything like they said they frequently did with the East and Central teams.

The graduate assistants speculate one of the primary causes of the negative attitude they observed stemmed from an interpersonal conflict between two members of the West team. According to the notes from the graduate assistants, they became aware of this conflict the second week of the summer but did not address it to see if the two interns could work it out. Every graduate assistant indicated in their notes a drop in overall morale of the West team beginning within one week after the interpersonal conflict started.

According to the graduate assistants, both interns involved in the conflict asked for a mediated discussion with a graduate assistant present to try to resolve the conflict. Three of the four graduate assistants were present for the discussion but only one led the conversation according to the notes from the three present graduate assistants. In their notes, the graduate assistants agree that the source of the conflict was differing measures of success. Although both interns expressed a desire to succeed in the program, the discussion revealed one measured success as the quantifiable points and grades earned on assignments and the other did not care about grades as much but measured success in terms of self-efficacy.

After the discussion, the graduate assistants all noticed and recorded improvements in the West team morale. According to the notes from two graduate assistants, the commander and deputy of the West team had a conversation with them about their team morale. In the conversation, the commander and deputy explained that they spent several hours discussing ways to improve the team morale and asked if the graduate assistants had any advice. The graduate assistants suggested the commander and deputy act positively towards their teammates, setting an example the team might follow.

In the following two weeks leading up to the capstone exercise, two graduate assistants wrote that the morale of the West team appeared to increase. At the same time, observations from the ACE staff noted the staff did not see improvement in the teamwork of the West team these last couple of weeks. In an informal discussion, the graduate assistants speculated the increase in morale without an accompanying improvement in teamwork could lull the west team into a false confidence for the capstone exercise.

4.2.3: Central Team

The last 9 interns composed the newly introduced Central team. The new Central team played the role of insurgents seeking independence from the established nations of East and West. This new and unique role gave the opportunity to examine the outcomes of a smaller team size for a nation-state team.

One of the graduate assistants reported seeing the Central team cross-training teammates. The graduate assistant asked what they were doing, and one of the members of the Central team answered that they decided to each teach at least one teammate how to do their job, so the unavailability of one teammate would not cripple their team. The graduate assistants did not notice any other team cross-train in this manner.

In an informal discussion between all four graduate assistants reflected in one of their notes, the graduate assistants unanimously agreed the Central team had the best morale out of the three nation-state teams. The graduate assistants speculated the Central team had exceptional morale based off observations that their team made sure everyone had fun no matter what they were working on. Three of the four graduate assistants specifically mentioned an appreciation for the sense of humor the Central team had.

In their notes, the graduate assistants often refer to "shenanigans," the term they used for any action the Central team took to incite conflict between the East and West teams. The graduate assistants mention examples such as political propaganda condemning each nation the Central team sent to The ACE Observer, the official news website of the ACE battlespace. Another example mentioned by two graduate assistants involved the Central team stealing sensitive information from the East and West teams regarding their plans for a weekly mission operation. According to the graduate assistants, the Central team created a new website on the ACE battlespace called "WikiCheeks" (a play on "WikiLeaks") where they posted the information they stole from the East and West teams.

One week after the WikiCheeks leak, one of the graduate assistants reported that the West team refused to discuss their plan for the weekly mission operation with the graduate assistant. When the lead graduate assistant asked the West team why they did not want advice from the graduate assistant, the West team claimed the only way the information on WikiCheeks could have gotten leaked was if a graduate assistant deliberately shared it. The lead graduate assistant assured them the graduate assistants would never intentionally share sensitive information with another team because their role is to support every team equally. According to the notes from the lead graduate assistant on this encounter, the Central shenanigan still damaged the trust between the West team and the graduate assistants.

Section 4.3 – Lecture and "Challenge Problem"

Each week the interns turned in technical reports documenting their solution for the weekly challenge problem. The graduate assistants graded some of the reports and the interns anonymously peer graded the rest. The graduate assistants recorded the grades before returning the reports to their original authors. In addition to the graded weekly challenge problem report,

the ACE staff collected optional, anonymous feedback from the interns on each lecture. The feedback followed the lecture feedback form in Appendix E.

4.2.1: Challenge Problem Report Grades

The graphs of the report grades and their variance in Figure 4-8 and Figure 4-9 show two major anomalies: the fifth and seventh challenge problem reports. In general, the report grades showed an overall increase as the interns gained experience writing. Figure 4-8 shows the average report grades for each challenge problem report. It depicts the general upward trend in report grades throughout the summer. Figure 4-9 shows the variance in grades for each report. The variance graph emphasizes the anomalous grades for the seventh challenge problem report.

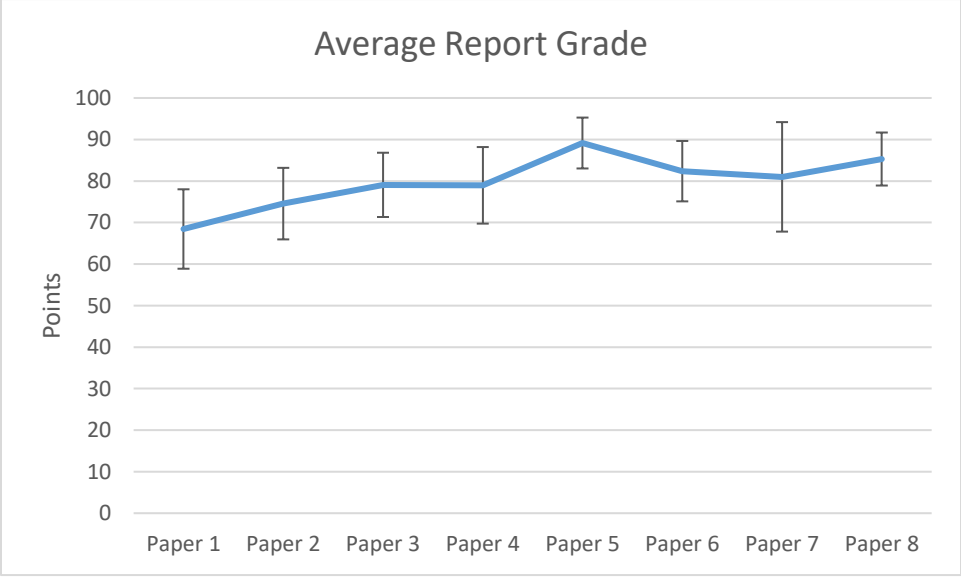

Figure 4-8: This figure shows the average grade of each challenge problem report with error bars indicating one standard deviation in either direction.

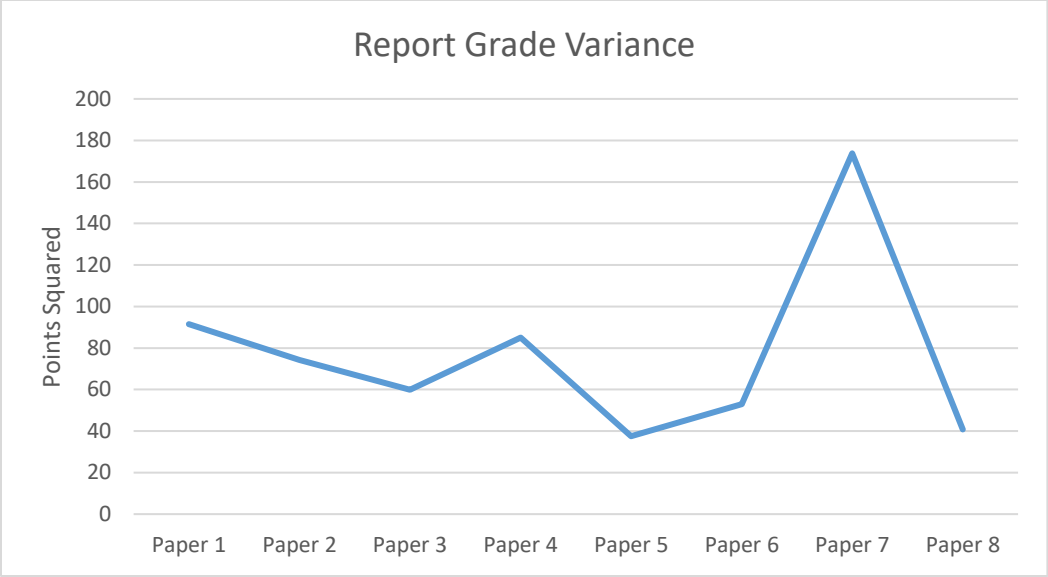

Figure 4-9: This figure shows the variance in report grades for each challenge problem report.

On the fifth report, all except for three of the surveyed interns earned exceptional grades of 87% or higher. Figure 4-8, the graph of average report grades, shows report 5 as a global maximum. Intern 10, who earned the lowest score on the fifth report with 66%, scored uncharacteristically low that week; their next two lowest report grades were 73% and 81%. Personal factors such as a choice to focus more heavily on other tasks or hinderance from a distraction external to the ACE could account for their atypical score.

Two possibilities that could explain this anomaly of exceptional grades on the fifth report for most surveyed interns include a lecture and instructor who taught their topic with clarity or a topic and challenge problem easier than the other topics and challenge problems. The topic of the fifth week was identifying enemy centers of gravity and creating a cyber campaign plan to effectively target those centers of gravity in varying stages of warfare. The cyber campaign plan covered higher-level content at a strategic level of operations as opposed to the lower-level technical topics covered in other weeks. This difference could remove the edge interns with a stronger technical background had on the more technical topics. A leveled playing filed explains

the similar grades. A talented instructor could have caused the uncharacteristically high grades on the report, but if one assumes the topic change was the only major difference between the fifth week and other weeks this result could indicate variations in background knowledge among the interns heavily influence success on the challenge problems and reports.

The report grades of surveyed interns showed massive variance on the seventh report, as shown in Figure 4-9. The ACE staff can eliminate inconsistencies in peer grading as an explanation for the variance because the lecturer requested to read and grade every report for their topic. Since the same person, a subject matter expert on the topic, graded every report this week the week 7 reports received the most consistent grading.

The seventh report went with a lecture and challenge problem on reverse engineering, with the challenge problem asking interns to reverse engineer a real malware sample to determine its capabilities and vectors to infect other machines. Due to the length of the lecture and large volume of content, the lecturer took two days instead of one to teach the interns about reverse engineering. The ACE staff planned for the extra day after the same lecturer teaching the same topic earned a reputation for keeping the interns in the Monday lecture until 8:30pm the prior summer.

The large variance indicates some interns potentially understood the topic very well, but others may have understood it very poorly even after two days to cover it. For interns with less background knowledge, the graduate assistants speculated the volume of new knowledge and technical depth acted as barriers to a thorough understanding of the topic. If correct, this speculation supports the previous indication that background knowledge of the topic covered heavily influences success or failure on the weekly challenge problem report.

4.2.2: Feedback from Interns

Each week, the ACE staff invited interns to share feedback on the most recent academic lecture by submitting an optional, anonymous lecture feedback form (reproduced in Appendix E) with their challenge problem report. The lecture feedback form asks interns 10 questions. Questions 1.1 through 1.5 ask open-ended questions such as "What impressed and/or interested you the most?" or "What would you improve about today's lecture?". Questions 2.1 through 2.5 asked interns to rate their agreement with five statements on a scale from 1: strongly disagree to 5: strongly agree. For example, question 2.1 measures intern self-efficacy by asking interns to rate their agreement with the statement "I have a strong understanding of material presented".

The number of interns who voluntarily provided feedback varied from week to week. Week 6 received the most intern feedback, with 36 lecture feedback forms submitted. For weeks 2 and 3, no intern submitted a lecture feedback form. When the graduate assistants asked about the lack of feedback for those weeks in a casual, informal conversation the interns all expressed the same sentiment: they felt that they did not have enough time to complete the workload the ACE placed on them and the optional, anonymous lecture feedback easily fell to their lowest priority. After weeks 2 and 3 the interns felt more capable of managing their time and workload, so more interns participated in the lecture feedback. Week 7 represents an outlier where only three interns provided lecture feedback, and of the three only two filled in questions 2.1 through 2.5.

The ACE staff found most answers to questions 1.1 through 1.5 unhelpful. Interns often neglected to answer them, instead preferring selecting answers to questions 2.1 through 2.5. When interns did answer questions 1.1 through 1.5, the ACE staff described the answers as simple and not specific to the weekly topic or lecturer, such as "more breaks would have

helped". Some feedback forms showed an exception to this trend and provided feedback that the ACE staff found insightful. The ACE staff suspect the same intern filled out every lecture feedback form with insightful answers to questions 1.1 through 1.5 because in each week with an insightful feedback form, the insightful form was the only one written in green pen.

The remainder of this section focuses on the answers to questions 2.1 through 2.5 and includes several correlation analyses. Questions 2.1 through 2.5 asked interns to select a number between 1 and 5 which best represents their agreement with each statement. A response of 1 meant "strongly disagree" and 5 meant "strongly agree". Table 4-1 lists the statements for questions 2.1 through 2.5.

2.1	I have a strong understanding of the material presented.
2.2	Materials provided were of high quality.
2.3	The lecture followed logical flow that enabled learning.
2.4	The information was well explained/taught.
2.5	Sufficient amount of time was spent covering new topics.

Table 4-1: This table reproduces the statements for questions 2.1 through 2.5 on the lecture feedback form.

Next, Table 4-2 shows the average response to each question for each week and the number of participants who provided lecture feedback that week. The lowest average response for each week appears in bold. The table excludes weeks 2 and 3 because no intern provided lecture feedback those weeks. According to notes recorded by the graduate assistants, two graduate assistants asked a group of interns (the notes did not indicate the size of the group) why no one provided lecture feedback these weeks. Two of the interns in the group answered similarly, indicating that they felt that they did not have enough time to complete all their tasks

for the week and the optional lecture feedback fell to their lowest priority. The remainder of the group expressed agreement with the sentiment that they felt they did not have time to fill out lecture feedback forms. Only three interns provided lecture feedback in week 7. It is not known why so few interns provided feedback this week.

Question	Week 1	Week 4	Week 5	Week 6	Week 7	Week 8
2.1	3.62	3.98	**4.19**	4.37	**4.5**	4.33
2.2	4.15	4.63	4.61	4.57	**4.5**	4.46
2.3	4.04	4.26	4.58	4.31	**4.5**	4.58
2.4	3.92	4.18	4.55	4.34	5	4.5
2.5	**3.46**	**3.42**	**4.19**	**4.14**	5	**4.29**
Participants	26	31	31	36	3	25

Table 4-2: This table shows the average response to each question and number of participants for each week, with the lowest average response in each week in bold.

The lectures received generally favorable feedback from interns who submitted lecture feedback forms. According to this data, interns most often expressed the least agreement with the statement in question 2.5 about enough time spent to cover new information. Despite this expressed desire to spend more to become comfortable with new topics, the interns still generally reported agreement with the statement in question 2.1, which measures their self-efficacy for the weekly academic lecture topic.

Table 4-3 shows a correlation matrix calculated with every set of responses to questions 2.1 through 2.5. These correlation coefficients indicate a moderate to strong positive correlation between every pair of questions from this set. These strong correlations indicate the questions all measure details of the same broad concept: perceived quality of a lecture. The answers to question 2.1, which measured intern self-efficacy, most strongly correlated with the answers to

question 2.5 which asked if the intern felt they spent enough time covering new information. This result reveals the factor most closely linked to how well an intern feels they understood material is whether the intern felt they had enough time to adequately cover material new to them. Conversely, this result could also mean even if an intern did not feel they understood a new topic well they still felt confident enough they could learn it given more time.

The highest correlation coefficient links questions 2.3 and 2.4. Questions 2.3 and 2.4 measured whether an intern thought the information "followed [a] logical flow" and whether the information was "well explained". This result indicates interns who felt that the information was well explained also tended to feel that the information followed a logical flow. Reviewing the two questions shows they seem to ask nearly the same thing, so combining questions 2.3 and 2.4 into one question could make the survey shorter without degrading the usefulness of the feedback.

The lowest correlation coefficient in the matrix links questions 2.2 and 2.5. Question 2.2 asked if the intern felt the lecturer provided materials with a high quality and question 2.5 asked whether interns felt they spent enough time on new information. The moderate correlation shows interns who felt the given time sufficed to learn new information also generally felt that the lecturer provided high quality materials or, alternatively, if the lecturer provided poor quality materials the time to learn new information did not suffice. Despite the moderate correlation between answers to these two questions, questions 2.2 and 2.5 ask about different aspects of the lecture and their specificity could help the ACE staff identify the reason interns did or did not learn well from a lecture.

Although one should expect some correlation between answers to questions about the shared topic of perceived quality of a lecture, the degree of correlation can indicate the

usefulness of a question compared to another question. Too high of a degree of correlation, as we saw with questions 2.3 and 2.4, could mean the questions are too similar and one may not be more useful than the other. Even if questions have some correlation, they can still ask about qualities specific enough to provide helpful feedback and identify reasons for the reported perceptions of lecture. Questions 2.2 and 2.5 show an example of questions with some correlation but specific enough to provide useful results.

	2.1	*2.2*	*2.3*	*2.4*	*2.5*
2.1	1				
2.2	0.63	1			
2.3	0.54	0.67	1		
2.4	0.60	0.72	**0.83**	1	
2.5	0.70	**0.50**	0.65	0.67	1

Table 4-3: This table shows the correlation matrix calculated form every set of answers to questions 2.1 through 2.5 on a lecture feedback form with the strongest and weakest correlation coefficients in bold.

Table 4-4 shows the average response between all questions 2.1 through 2.5 for each week and the number of participants who shared lecture feedback for that week, excluding weeks where no intern shared lecture feedback and the outlier week 7 when only three interns shared lecture feedback. From the remaining values, a calculation of the correlation coefficient between the average answer to questions 2.1 through 2.5 and the number of participants yielded a correlation coefficient of 0.29. This correlation coefficient shows a very weak positive correlation between the feelings of an intern towards a lecture and the likelihood they shared lecture feedback. Although the correlation coefficient indicates the quality of a lecture may play a role in the likelihood an intern provided feedback, the low value suggests other factors more heavily influenced whether an intern provided feedback for a given week. This measurement also

faces the issue of selection bias. In weeks where fewer interns shared lecture feedback, the interns who did not provide feedback may have refrained from doing so because they felt very differently about the lecture compared to the interns who provided feedback.

	Week 1	Week 4	Week 5	Week 6	Week 8
Average response	3.84	4.09	4.43	4.35	4.43
Participants	26	31	31	36	25

Table 4-4: This table shows the average response for all questions 2.1 through 2.5 for each week and the number of participants who shared lecture feedback for that week.

Table 4-5 shows the average reported self-efficacy score and the average report grade for each week where interns shared lecture feedback. A correlation coefficient calculation between the average score and average reported self-efficacy yields a correlation coefficient of 0.75. This correlation coefficient shows a strong positive correlation between the average self-efficacy score and average report grade each week. The positive correlation shows that self-efficacy scores reported by the interns who provided feedback accurately represent their understanding of the subject most of the time. This result shows no evidence of a Dunning-Kruger effect, contrary to Gear's observations of the coding bootcamp (Gear, 2016).

	Week 1	Week 4	Week 5	Week 6	Week 7	Week 8
Average score	68.44	78.96	89.15	82.37	81	85.30
Self-efficacy	3.62	3.97	4.19	4.37	4.5	4.33

Table 4-5: This table shows the average self-efficacy score and average report grade for each week interns provided lecture feedback.

Section 4.4 – Lab Exercises

The ACE staff did not grade the lab exercises according to plan. Several factors caused this deviation. Due to misunderstandings and poor communication, many lab instructors did not provide a rubric for their lab exercise. Some instructors did provide a rubric, but there was not always a graduate assistant available to assist the instructor and assess the interns with the rubric. A graduate assistant did grade the first lab exercise as intended, but the graduate assistants never recorded the grades in the master gradebook because they were still finalizing their process for keeping track of intern grades.

This lack of grade information and the absence of intern feedback on the lab exercises results in insufficient data to make a worthwhile assessment of this component of the ACE. The only data that remains consists of personal recollections from staff interactions with interns and lab instructors. Although these recollections provide interesting insight into the thoughts and feelings of specific interns, they are too sparse and do not provide a solid foundation to draw meaningful conclusions. Whether any meaningful conclusions can be drawn from this information is a topic for future work.

Section 4.5 – Weekly Mission Operations

The three nation-state teams had unique experiences with each weekly mission operation. This section describes the experience of each team at the beginning of the summer, in the middle of the summer, and in the final weeks that led up to the capstone exercise. This analysis relies on observations by the ACE staff and graduate assistants because no one recorded the scores from each week. No one recorded the scores each week because no grade used the mission operation and capstone points as a metric to assign a score until after the capstone ended.

The ACE staff designed the first mission with the intent to ease interns into using the software library shared with them for command and control of their simulated unmanned aerial vehicle (UAV) assets. Each team needed to launch one UAV, fly it to a predetermined location, leave it there for a short time period, then return it to a friendly airbase to land and refuel. Every team failed this first mission. According to staff notes from the debriefs, the interns on every team expressed that they underestimated the value of planning and preparing for the mission ahead of time. The notes from the graduate assistants show that at least one graduate assistant observed the East and Central teams retrying the failed mission even though they could not earn any points or credit from it. In a conversation with a graduate assistant, a member of the West team said they left their team debrief feeling defeated but resolved to come back and execute the next mission perfectly. The second mission operation went much better for every team according to an internal ACE metric. The ACE staff designed the mission operations to gradually become more complex but remain somewhat symmetrical between teams for the first half of the summer.

In the middle of the summer, the graduate assistants reported that they frequently saw interns planning and preparing for the weekly mission operations. Two graduate assistants and at least one member of the ACE staff noticed the West team became “obsessed” with earning points and appeared to lose focus on the mission objectives. This suggests that potentially the points system used for weekly mission operations did not promote team effectiveness and completion of objectives.

The ACE staff and graduate assistants observed a cycle where the West team would not earn the maximum possible amount of points, become more focused on points, earn even fewer points, and then place an even greater focus on earning points. During these cycles, the graduate assistants noted that they saw the West team spend their time in team meetings discussing ways

to maximize points earned and neglecting to discuss ways to improve their effectiveness as a team. One of the graduate assistants wrote that in hindsight, the graduate assistants missed an opportunity to intervene and encourage the West team to use their failure as a learning opportunity to improve their teamwork.

In the final weeks leading up to the capstone exercise, the East team successfully completed the most mission objectives out of all three nation-state teams. The Central team maintained the best situational awareness out of all three nation-state teams by an internal ACE metric. The graduate assistants observed the Central team use their situational awareness to create fog and friction to disrupt and disorient the East and West missions. The ACE staff and graduate assistants saw improvement in the West team but still felt they were behind the East and Central teams in working cohesively.

Section 4.6 – ACE Run

Each week, interns participated in the 8-mile ACE run. Interns received a grade based on the run rubric in Appendix A. The interns received no grade for the week 3 run because this run took place in Gettysburg. The ACE staff excepted the Gettysburg run from the requirements in the run rubric and only required completion. The ACE staff only required completion with the intent of making the run more reflective in nature without the pressure of a deadline. The following analysis do not consider week 3 due to the absence of run grades for the week. This section also excludes data from interns who became injured and did not run every week. Figure 4-10 shows the weekly average run grade throughout the summer.

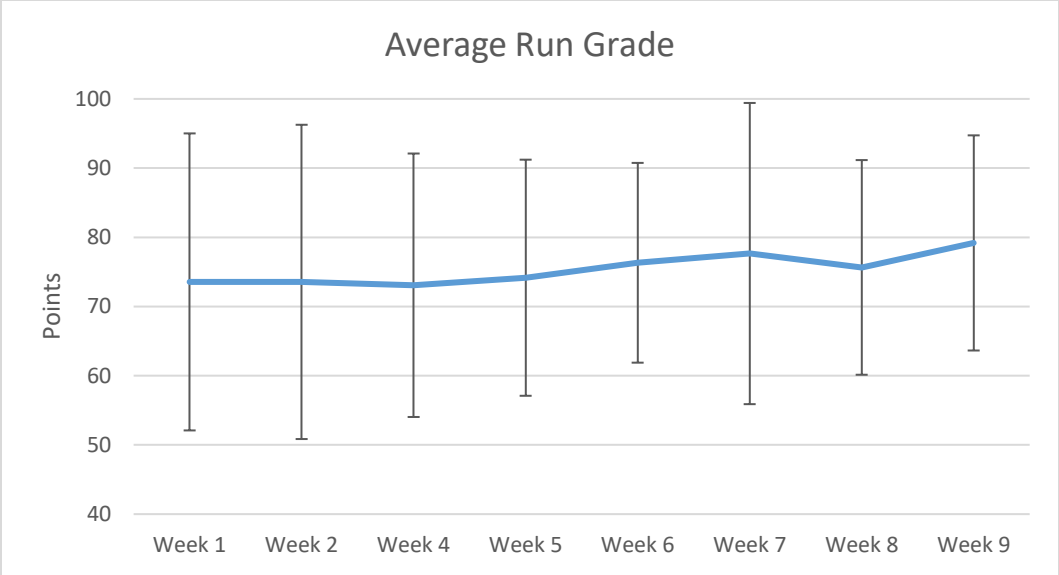

Figure 4-10: This figure shows the average of all intern run grades for each week with error bars showing one standard deviation in either direction.

The run grades show most interns improving their run time throughout the course of the summer. The run grades on their own do not reveal much in terms of whether the ACE met its objectives, but the remainder of this section performs correlation analyses to see if run scores correlate with other measured data.

A calculation of the correlation coefficient between report grades and run scores revealed a correlation coefficient of 0.12. This result indicates no significant correlation exists between report grades and run scores. The calculation for that correlation coefficient considered every report grade and run grade pair from a given week for a given intern, excluding weeks where the interns did not get graded on the run or a challenge problem report.

Table 4-6 shows a correlation matrix between the average report grade, average run score, and final staff evaluation earned by each intern. The correlation shows a different but similarly insignificant correlation coefficient for the average run score and average report grade compared with the correlation coefficient calculated from individual report grade and run score

pairings. The correlation coefficient between average run score and staff evaluation, 0.42, reveals a fairly weak positive correlation between the average run score earned by the intern and the perception the ACE staff have of that intern at the end of the summer according to the final staff evaluation. This correlation could indicate the staff show slight preference towards interns who perform well on the run during staff evaluation. It could also indicate an unknown factor could make some interns both better runners and better in the eyes of the ACE staff. Of those two possible explanations, if the first is correct then that explanation indicates the staff evaluation provides less value as an evaluation mechanism because in some cases a part of what it evaluates overlaps with the qualities already evaluated and reflected by the run scores.

	Average Run Score	*Average Report Grade*	*Staff Evaluation*
Average Run Score	1		
Average Report Grade	-0.14	1	
Staff Evaluation	**0.42**	0.23	1

Table 4-6: This table shows the correlation matrix calculated with the average report grade, average run score, and final staff evaluation of each intern.

Table 4-7 shows the correlation matrix computed with every tuple of the report grade, research grade, and run score for a given intern and week. The correlation coefficients all suggest no correlation exists between the run score, research grade, or report grade for each week. The absence of any correlation indicates these three grades measure independent qualities in every intern.

	Run	*Research*	*Report*
Run	1		
Research	0.04	1	

Report	0.07	0.09	1

Table 4-7: This table shows the correlation matrix with correlation coefficients for every tuple of report grade, research grade, and run grade for a given intern and week.

Section 4.7 – Capstone Exercise

The 2019 ACE concluded with the two-day capstone exercise. According to the ACE staff, the capstone this year went differently than any previous year since the ACE introduced the exercise in 2015. Going into the capstone, the Central team began in the lead with the most points. The East team followed behind. The West team began the capstone with a negative point value that resulted from their failures in weekly mission operations, especially an operation when they allowed one of their simulated UAVs to bomb an imaginary animal hospital resulting in fictitious civilian casualties. In prior years the scoreboard remained visible during the capstone so interns could get feedback on their missions. When the ACE staff discussed the failures of the West team and their obsession with earning points on the scoreboard, the staff decided to hide the scoreboard from the interns during the capstone. The ACE staff said they hoped removing the scoreboard would give West an opportunity to focus on their mission objectives instead of their score and recover from their prior failures. The staff also said they decided removing the scoreboard makes the exercise more realistic because in a real war, a nation has no oracle to tell them whether they did something right or wrong. The ACE staff and graduate assistants told the interns about this change in advance, so they knew not to expect to see the scoreboard during the exercise.

Once the smaller groups of two to four interns were deployed to their remote pad sites at the Stockbridge test location, nation-state teams prioritized establishing communications between their pad sites and communication with their marshal, a member of the ACE staff who tasks them with missions. The ACE staff took notes of events during the capstone such as when

teams first established communications. The Central team got their communications up and contacted their marshal first. The East team quickly followed. The West team soon had communication with every pad site except one. Unable to send anyone to help the dark pad site, the West team contacted their marshal to inform them of the situation and began executing missions. The ACE staff immediately sent a graduate assistant to verify the pad site did not have any network or infrastructure issue out of scope of the exercise. The graduate assistant confirmed the pad site functioned as expected, so according to capstone notes the ACE staff elected to give the interns at that pad one hour to establish communications with their team before the staff would step in to help.

The East team demonstrated excellent command and control over their UAV assets according to an internal ACE metric. Despite their control over their UAVs, they ACE staff saw them face many difficulties in other aspects of their missions. According to staff and graduate assistant observations, they primarily had trouble with missions that required integrating cyber effects with kinetic effects to progress towards their objectives. As one example in notes from a graduate assistant stated, one mission required intelligence the team could exfiltrate from the network of one of the fictitious companies on the ACE battlespace, but the East team tried to execute the mission without searching for additional intelligence and did not complete the objectives. The graduate assistant speculates the East team would have succeeded with the intelligence to support their mission execution.

According to capstone notes, the West team eventually made contact with their last pad site. The West marshal noted that each West pad site focused on its own line of effort, and in the opinion of the marshal these lines of effort did not share enough information with their commander to let the commander effectively lead and direct them in a joint effort to accomplish

their mission objectives. The ACE staff and graduate assistants speculated the poor communication and teamwork of the West team degraded their capability to complete their missions.

Notes from the Central marshal indicate the marshal thought the Central team experienced some disorientation from the fog and friction introduced in the capstone exercise. They initially accomplished some of their mission objectives but completed fewer objectives as the exercise progressed according to capstone notes. The desired end state for the Central team required the East and West nations end the exercise too weak to prevent the Central regions from declaring independence from the nations of East and West. By an ACE internal metric, the Central team was not considered to have the required forces to support a declaration of independence, so the Central mission objectives intended to maximize the opportunity for the East and West forces to destroy each other. As stated by the team commander in the debrief, interns on the Central team misunderstood this intent and acted off the impression they needed to strike blows against the East and West forces themselves. The ACE staff speculate that this misunderstanding prevented the Central team from making notable progress after their initial successes.

On the second day of the exercise, the East and West teams each neutralized one surface to air missile (SAM) site in the enemy nation, according to the capstone notes. These openings in the air defense system of each nation granted the opportunity to send bombers to destroy enemy infrastructure such as airfields, weapon manufacturing centers, and supply depots. By an ACE internal metric, the strikes did not significantly impact the balance of power between the two nations. Each nation only lost the infrastructure near one of their several SAM sites. At the end of the exercise, the balance of power and regions of influence measured by an ACE internal

metric remained nearly identical to at the start of the exercise. According to a post-capstone battle damage assessment East and West both lost several UAVs, but plenty remained. In order to declare a winner, the ACE staff continued to score the teams during the exercise even though the interns could not see the scoreboard. At the end of the exercise, the ACE staff determined the Central and East team scores hardly varied from their starting values. The score of the West team remained negative. The ACE staff did not expect this result at all.

The ACE staff declared no winner. The staff also decided not to show the interns the final scores because according to capstone notes no staff member felt that the low scores accurately portrayed how the interns performed despite their failures to meet mission objectives. During the exercise debrief with everyone in the same room, the ACE staff explained these reasons for not declaring a winner, but instead of revealing the low scores reflected their assessment that the scores did not accurately reflect performance in the exercise. Then the interns split into their nation-state teams to do a team debrief. At least one member of the ACE staff sat in on each team debrief.

According to notes from the graduate assistant who sat in on the West team debrief, the West team opened their debrief with remarks that they performed exceptionally well during the exercise and could not have done anything better. The graduate assistant reported they stepped in to indicate the team should try and find ways they could have improved. According to the graduate assistant, one of the interns insisted they executed the exercise flawlessly. In their notes, the graduate assistant describes an uncomfortable debate in which the graduate assistant made several points that shattered the belief the West team did well. The graduate assistant also described a feeling of relief when some of the members of the West team guided the debrief to an internally focused reflection that everyone said they learned from.

According to notes from the Central marshal and the graduate assistant in the Central debrief, the Central team began their team debrief feeling frustrated and blamed their marshal for the misunderstanding about the intent to maximize opportunity for the East and West nations to destroy each other. Their marshal wrote that they admitted to some poor communication to the team but asked them to focus inwardly on what they could have done better despite the poor communication because sometimes unclear communication or directions are part of the fog and friction of war. According to the notes from the graduate assistant, the remainder of the Central team debrief went well and they identified several lessons learned and points to reflect on.

Section 4.8 – Conclusion

The ACE states its objective as developing the next generation of cyber security leaders. To assess the effectiveness of the ACE at meeting this objective, we define a cyber leader as someone who exemplifies three traits: technical excellence, impeccable communication, and superb teamwork whether as a leader or a dynamic subordinate. We also consider the capstone exercise as a sort of final assessment where the interns get the opportunity to demonstrate these three qualities and show off the skills they learned throughout the summer.

The 2019 ACE interns demonstrated technical excellence in several ways throughout the summer. According to the research mentors, every research project produced an exemplary deliverable. The research deliverables demonstrate the ability of the interns to analyze and solve a real-world technical problem. The grades interns received on their weekly challenge problem reports show their technical excellence with each of the weekly topics. Their completion of the weekly lab exercises proves their ability to apply theory in practice to generate effects. These grades and observations confirm the interns graduated the ACE with technical excellence.

The interns exhibited impeccable communication in nearly everything they did during the ACE. The technical reports for the weekly challenge problems required clear, concise written communication to document their problem, assumptions, and solution well enough another could replicate it. The interns also gave presentations on their challenge problem solutions and delivered a final research presentation to the entire ACE class, ACE staff, government scientists, and defense contractors. The ACE staff did not record grades for any presentation, but by the end of the summer the ACE staff agreed the interns showed markedly improved communication skills. In less formal settings, nearly every component of the ACE required communication with a team. These observations attest to the impeccable communication demonstrated by the interns.

Nearly all aspects of the ACE required successful teamwork from the interns. The interns solved the weekly challenge problems in small teams of three, research problems in their research teams of approximately six to twelve interns, and the interns completed the weekly mission operations and capstone exercise in their nation-state teams of nine to eighteen interns. The interns met the challenge problems and research projects with success. The weekly mission operations went generally well for some nation-state teams, but quite poorly for others. When introduced with uncertainty, fog, and friction, the interns sometimes struggled to overcome those obstacles and complete their mission objectives. Considering this, the ACE interns demonstrated superb teamwork in some settings but not others.

The ACE 2019 capstone defied the expectations of the ACE staff. Despite their success in the more academic components of the ACE, the interns did not perform well in the capstone. Even the East and Central teams, who performed relatively well during the weekly mission operations, struggled to apply their technical excellence, communication, and teamwork towards strategic national objectives during the final two-day exercise. This performance was

uncharacteristic compared with previous capstone exercises. In 2017 and 2018, ACE interns integrated cyber and kinetic affects to enhance their warfighting effort. In 2019, the interns showed devastating capability with cyber or kinetic effects independently, but in the fog and friction of the capstone exercise found themselves unable to combine the two to complete their missions and win the mock war.

This assessment leaves no clear-cut answer to whether the ACE met its objective to develop the next generation of cyber leaders. The 2019 ACE interns undeniably left the program with newfound technical expertise and impeccable communication skills, two of the three traits in our definition of a cyber leader. The interns struggled with superb teamwork in some situations but showed it in others. In the final capstone exercise, no nation-state team got any closer to their desired end state.

Chapter 5 - Proposed Changes to Assessment Method

This chapter reviews the current methods used to assess the ACE and proposes changes to capture more useful data on the program. These proposed changes intend to facilitate assessment of the effectiveness of future iterations of the ACE program. These changes should also help the ACE staff identify more detailed ways to improve the program.

Section 5.1 – Challenge Problem

The current system for submitting and grading the weekly challenge problem reports works well according to at least two lecturers. A rubric and grade assigned for each challenge problem presentation an intern gives would provide more quantifiable information to assess the communication skills of each intern. The ACE staff would need to decide how heavily to weigh presentation grades in relation to the other grades received in the course. If every intern presents their solution to the weekly challenge problem an equal number of times, weighing one presentation to carry a weight equal to one paper may provide a place to start.

The analysis of lecture feedback revealed many weaknesses in the current system. The issue manifested itself in the absence of any lecture feedback for weeks 2 and 3. Making lecture feedback voluntary invites the possibility of receiving no lecture feedback or only receiving feedback from a self-selected fraction of the population that may not represent the whole well. Requiring the lecture feedback form from every intern every week supplies a more complete dataset representative of the entire population of interns.

The ACE staff rarely found answers to questions 1.1 through 1.5 helpful. Removing these questions and replacing them with a single optional, open-ended question at the end of the form asking for any additional feedback on how to improve the lecture would remove the saturation of unhelpful or generic answers observed in the 2019 lecture feedback. Simplifying the lecture

feedback form to ask only multiple-choice questions makes the form easier for the interns to fill out in a short amount of time. This change alleviates the concerns expressed by interns in the second and third weeks of the 2019 ACE about feeling they did not have time to fill out the lecture feedback forms.

The current lecture feedback form offered the option for participants to submit lecture feedback anonymously in the hope that interns would provide honest feedback without fear of any consequence for leaving negative feedback about a lecturer. Anonymous lecture feedback forms come with the downside of not being able to link a specific grade to a specific set of feedback. The ability to link feedback forms to report grades would allow more thorough correlation analysis. Instead of using the data in aggregate, such as comparing average of the set of report grades for a week with the average of a set of responses to a question on the lecture feedback form, the ACE staff could perform an analysis that considers each individual grade and the feedback responses from the intern who earned that grade. This link would also connect feedback from one week to the next, so the ACE staff could identify every lecture feedback form filled out by the same intern.

Requiring interns to include their names on lecture feedback forms reintroduces the threat of insincere feedback due to fear of repercussions from shared feedback. Instead, the ACE staff could devise a system to provide pseudonymity on the lecture feedback forms. As an example, the graduate assistants could put unique numbers on slips of paper in a hat. At in processing, the graduate assistants let each intern draw a slip of paper from the hat and instruct them to mark all their lecture feedback forms with that number. This links the forms to a single intern without revealing the identity of that intern. At the end of the summer, as a part of out processing, the graduate assistants ask each intern to reveal their secret number. The graduate assistants can then

replace the name of each intern in the gradebook with the secret number and destroy the record linking the number with the name of the intern. This process links the sets of grades to the sets of feedback and preserves pseudonymity for the interns once the graduate assistant destroys the information with the name and number of each intern. This solution assumes every intern either trusts the graduate assistant to destroy the information that links the lecture feedback to their name or does not care if the ACE staff can link lecture feedback to their name after the conclusion of the program.

The ACE staff use the solution to the weekly challenge problem and optional lecture feedback to assess whether a lecture successfully met its learning objectives. The lecture feedback uses only self-efficacy score to measure effectiveness. To complement the self-reported self-efficacy score, the lecture feedback form could include a short quiz with four or so questions about key points taught in the lecture. The ACE staff would need to make it clear the quizzes only assess whether the lecture met its learning objectives and do not get graded or influence interns during the ACE in any way. With this addition to the lecture feedback form, the ACE staff have three instruments to assess the effectiveness of a lecture: a self-efficacy score, a solution to a problem that involves the lecture topic, and the answers to the quiz questions.

Section 5.2 – Lab Exercises

The existing grading system to assess the lab exercises did not work in practice because no data was collected. If the ACE staff choose to grade the weekly lab exercises, a simple pass/fail system may accommodate the breadth and uniqueness of every lab exercise. To assess whether each lab exercise taught its desired learning outcomes, the ACE staff could incorporate the hands-on skills from lab exercises into other elements of the program such as the weekly mission operations and capstone exercise. Success or failure during the mission that incorporates

the skills from the lab would indicate whether interns learned and retained the skills the lab exercise taught.

Section 5.3 – Research

The current method for assessing interns during their research time provided inconsistent results. Due to the inappropriate scope of the research rubric for its application in grading interns weekly, research mentors interpreted the rubric differently and applied it to the interns on their teams in different ways. This variations in grading from one research mentor to another remove meaning from the research grades when comparing interns from different research teams.

Instead of grading every intern each week on their perceived contribution to the research project, the ACE staff could ask research mentors only to grade the final deliverable near the end of the summer. The existing rubric is well suited for grading a research project in this manner. This method of grading makes sense for a project-based component of the ACE and alleviates concerns that the research mentors did not get enough time with interns each week to produce meaningful feedback for the weekly research grades. By evaluating the research deliverable, the research grades would better capture an assessment of the technical problem-solving capabilities of the interns on each research team.

Section 5.4 – Weekly Mission Operation

A points system rewarded interns for completing objectives in the weekly mission operations. This system backfired when the enthusiasm of the West team turned into an obsession with earning the most points. In future iterations of the ACE, if the ACE staff decide to continue to use a points-based system they need to determine the objectives for each mission and their point values. When sharing the mission with the interns, the staff need to communicate

the objectives and point values in a way that clearly connects the points to the objectives to keep the interns focused on their mission objectives.

The current point system for scoring the weekly mission operations could work well if the rewarding of points aligns with mission objectives and the interns understand the relation between the two. In the 2019 ACE class, interns sometimes did not understand why they did or did not earn points at the conclusion of a weekly mission operation. The point system should clearly define objectives and the conditions required to meet them. As an alternative to a point system, the ACE staff could consider grading the mission operations as pass/fail where a team passes if they meet all objectives and achieve their desired end state.

Section 5.5 – Staff Evaluation

The ACE syllabus detailed a system and rubric for the staff evaluation, but this system did not work. Towards the conclusion of the 2019 ACE program, the staff became overwhelmed and did not schedule a time to meet and decide on staff evaluation grades for each intern. The staff realized they needed to perform staff evaluations the day before the ACE graduation ceremony in order to identify the distinguished graduates since the staff evaluations get counted in final grades. The staff member who created the staff evaluation system and rubric was absent this day. The handful of staff and graduate assistants present did not know about the rubric, so they devised an ad-hoc method to perform the staff evaluation and came to a consensus for the staff evaluation grade of every intern.

The ACE staff should prevent the neglection of the staff evaluation. All ACE staff should read and discuss the staff evaluation rubric before the ACE interns arrive so the staff have conceptual unity in the way they will grade the interns. For objective measurements mentioned

in the staff evaluation rubric, the ACE staff need a system in place from the moment the interns arrive to collect necessary information. As an example, the ACE staff should ask the graduate assistants to keep track of any intern who arrives somewhere late or misses something due to an unexcused absence so the staff can reference this record when performing the staff evaluation.

Section 5.6 – ACE Run

The ACE staff put much thought into the current method to assess interns on the 8-mile run. The current method of assessment excels at rewarding interns for achieving fast run times while maintaining reasonable expectations for anyone who needs to train to make the required 90-minute time. The balance of points allocated to returning before the deadline, completing the entire course, and the overall run time should remain as-is if the ACE staff wish to continue assessing the run in this manner.

Alternatively, the ACE staff could consider grading the run on a pass/fail basis. An intern who completes the full course in the required 90-minute time passes while an intern who does not complete the full course in 90 minutes fails the run for that week, and an intern must pass at least two runs to pass the overall run component of the program. This grading method does not reward interns who push themselves to improve their personal run time like the current method. On the other hand, without incentive to finish quickly, faster runners may feel motivated to stay with their slower teammates to motivate and encourage them. The ACE staff should decide which of these two assessment methods best matches the spirit of the ACE run.

Section 5.7 – Capstone Exercise

The ACE staff should assess the capstone exercise in a way consistent with the assessment of the weekly mission operations due to the close relationship between these two components of the ACE program. If the interns earn points for their weekly mission operations then suddenly find themselves without a scoreboard during the capstone exercise, the removal of a clear indicator of success may introduce unintended uncertainties. On the other hand, if the interns do not earn points from their weekly mission operations, the introduction of a point system for the capstone exercise could add unnecessary complexity and cause confusion. Imagine learning a new sport and training with the same team for weeks, but suddenly before the first real match against an opponent the rules or scoring system of the game change.

Aside from assessing the capstone exercise itself, the capstone grants an opportunity to assess the rest of the ACE program. The ACE staff can learn what interns retained from the program by heavily incorporating problems that require knowledge from the weekly academic lectures and lab exercises into the capstone missions and objectives. The capstone exercise then becomes a final assessment over as many topics from the summer as can fit in the exercise. This assessment measures not only technical knowledge but the ability to use it in a stressful situation to think critically and solve problems with strict deadlines.

The integration of topics throughout the ACE into the capstone exercise already happens to some extent. Some of the capstone missions do incorporate elements from a handful of lab exercises. If the ACE staff dedicate time and effort to expand this incorporation to include the weekly lecture topics and adapt the capstone exercise each year to follow the changes in weekly topics the capstone could become a significantly more powerful instrument to reveal which knowledge the interns mastered and what needed more instruction or hands-on training.

Chapter 6 - Analysis with Education Theories

This chapter analyzes the ACE with several education theories. Each education theory provides research-backed insight on what may make the ACE program more effective at meeting its learning objectives. These education theories also help identify things the ACE program does right and should continue doing.

Section 6.1 – Gamification

Gamification suggests applying mechanics from games to the ACE should enrich the learning experience of the interns. The ACE already employs some game mechanics, such as the points earned for weekly mission operations. The incorporation of additional game mechanics would strengthen the existing game mechanics and make the ACE program align more closely with the qualities of gamification.

The theory of gamification states the game must never present a player with an impossible challenge. In the 2019 iteration of the ACE, the staff never thrust an impossible task upon the interns. When interns reached an impasse, the graduate assistants assured them a solution existed for the task before them and often helped nudge them in the right direction. The alignment with this game mechanic could explain why the interns worked with such tenacity throughout the summer and refused to give up. To stay in agreement with this mechanic, future iterations of the ACE should never present interns with an impossible task.

Games should not only give players tasks guaranteed to be possible, but task with specific goals and an obvious indicator of completion. Some components of the ACE fit this quality much better than others. For example, some of the weekly mission operations gave specific sets of latitudes and longitudes a nation-state team needed to fly their UAVs to and hover for a specific time period. These specific goals came with an obvious indicator of

completion: the scoreboard increasing the score when a team completes their objective. Other components of the ACE did not fit this quality well. For one of the weekly challenge problems, the interns got access to the network of Stork Industries, a fictitious weapons manufacturer in the ACE battlespace. The problem challenged them to move laterally through the network and any networks connected to it to gather intelligence on weapons systems sold to the enemy nations-state teams. Not every machine on every network the interns could access contained intelligence, and the interns had no way to know for certain whether they had accessed every machine they could potentially get access to or found all the intelligence on the network. Many interns found making the judgment of whether they collected enough intelligence or needed to keep trying to find more very frustrating.

In the case of Stork Industries, telling the interns when they found every piece of intelligence defies realism. In a real situation with access to an unfamiliar network, no oracle exists to tell an operator whether they missed anything. To provide a clearer indicator of success without compromising realism, the Stork Industries challenge problem could include details on what the intelligence is needed for and how it will be used. This information would provide interns with the context they need to know how to decide whether they found enough information. The ACE staff should consider ways to revise similarly vague challenge problems to facilitate clearer indications of success.

Games supply positive feedback such as points, new skills/abilities, or in-game currency to incentivize player success. The weekly mission operations used a system of scoring points to quantify the success of each team and encourage friendly competition. The intelligence gathered from the Stork Industries network also represents a form of positive feedback interns received for their success. The ACE staff should discuss other ways the components of the ACE can provide

positive feedback when interns do well. One way could include expanding the mission operation and capstone point system to award points for other program components such as the run and lab exercises. Tying each weekly challenge problem into the weekly mission operations and ACE lore could offer the opportunities for interns to gather useful intelligence or tools like the challenge problem that involved Stork Industries.

An epic, inspiring story keeps players engaged in a game. The ACE places interns on nation-state teams with their own histories and national values: the West nation is made up of lumberjacks proud of lumber industry, and the East nation is composed of hunters who take pride in their fur trade. The source of conflict between the East and West nations focuses on the resources in forests: the East hunters want the forests for hunting grounds, and the West lumberjacks want the forests to chop them down. The ACE has another important element of any story: a setting. Appendix F shows a map of the land of ACE, with a border between the East and West nations and three forest regions marked. The map comes from an aerial photograph of the Stockbridge test site, with the red and blue dots marking the pad sites where interns get deployed during the capstone exercise. This map gets used throughout the summer. Its area is where the simulated UAVs fly during the weekly mission operations and interns can see the locations of their UAVs imposed on the map in visualization software provided by IronZone, a fictional defense contractor in the ACE universe.

The Stockbridge test site provides a physical setting for a story where the weekly mission operations take place. The ACE battlespace provides a virtual setting. The simulated internet hosts an array of websites for companies and organizations that exist in the ACE universe: Stork Industries, a weapons manufacturer; IronZone, producer of the UAVs used by both nations; SISI, a private intelligence company; Hergwerts, a university in the central region of ACE; The ACE

Observer, a news agency; Interdimensional Telecommunications, the internet service provider who maintains the network; and Plough Industries, a virtual private server provider who can deploy and host servers on the network for interns to use. These fictitious companies and the simulated internet on the ACE battlespace introduce several elements and characters that could interact in a story.

These elements get tied together in a story that guides the escalation of tensions between the East and West nations throughout the summer, but the potential to make this story an epic and inspiring one is underutilized. Currently the story only applies to the weekly mission operations and capstone exercise. Wrapping the other components of the ACE into this story could make it much more impactful and memorable. Getting the ACE interns more invested in this story raises a serious concern. The story divides the interns into two opposing nations with international relations far from amiable towards one another, especially as tensions rise leading up to the capstone exercise. The ACE staff and graduate assistants would need to keep a very close eye on things to make sure the interns do not become too invested in the East/West conflict and show animosity towards interns on the opposing team. The ACE staff could make the ACE run completely independent from the storyline and nation-state team identities. The shared experience of the run could be emphasized by the staff as something that unifies all the ACE interns to ensure the interns feel that bond more strongly than their association with one of the nation-state teams.

The ACE already has several elements of game mechanics. The ACE staff should expand on these mechanics to exploit their benefits. Making the story of tensions escalating between East and West more epic and inspiring could make the story more impactful and better aligned with the mechanics in gamification. The ACE staff should ensure the interns do not show

animosity towards interns on an opposing team by emphasizing the bond all ACE interns share, such as the shared experience of the ACE run.

Section 6.2 – Bruner Spiral Curriculum

The spiral curriculum lays out three key principles to maximize learning: cyclical return to the subject, an increase incomplexity with each return, and a relationship between old learning and new learning. Applying these principals to the ACE should help maximize intern learning during the summer. The spiral curriculum does have disadvantages one must consider in its application.

The first principle of the spiral curriculum involves a cyclical return to each topic. Currently, the ACE spends one week with an intense focus on a topic but may never return to that topic once the week passes. This structure allows for coverage of a broad range of topics with a new topic introduced each week, but according to Bruner this structure may not maximize retainment of learning with each topic. The ACE staff should find a way to revisit as many topics as possible, especially the more challenging topics to help interns learn and retain their new knowledge. The ACE staff could introduce at least one revisit to each topic by introducing the topic in one component such as an academic lecture, then visit the topic in another component such as a lab after the dedicated week for that topic has passed. If the ACE staff integrate most lecture topics into the final capstone exercise, the capstone could provide a third visit to the topic.

The second principle is an increase in complexity on each cyclical revisit of a topic. Once the ACE staff establish a means to revisit critical topics, they should design an increase in complexity into each visit. Returning to the example of a lecture topic revisited in a future lab, the lab instructor could expand and introduce some new knowledge not present in the original

lecture on the topic and apply it in the lab. This method would revisit the topic to strengthen the previously learned knowledge and increase the complexity to keep pushing the interns to learn new things. An integration into the final capstone exercise could introduce a slightly more complex revisit that puts the critical thinking and problem-solving skills of the interns to the test.

The third principle states a relationship must exist between old learning and new learning. The revisits to a topic in the ACE program could establish this relationship by revisiting a topic in a context like the context it was originally introduced in before shifting the same topic into a new, unfamiliar context. Applying old learning to newer objectives also helps form a strong relationship between old learning and new learning. For example, a lab exercise that expands on the topic it revisits could require an application of the same tools and techniques originally taught with the topic as a foundation from which the new learning builds onto when it increases in complexity.

Application of the spiral curriculum over a time period of 10 weeks can benefit learning, but proper long-term reinforcement requires revisiting a topic over periods of one year or more. This downside makes the spiral curriculum less effective for bootcamps than if it were applied to longer educational programs such as a four-year degree. The broad curriculum of the ACE also creates difficulties in making time to revisit topics without removing other topics and reducing the scope of the program. The option of revisiting topics introduced during one component of the ACE during another component may alleviate some of these challenges.

Section 6.3 – Zone of Proximal Development

The Zone of Proximal Development theory labels three categories of tasks: tasks the learner can do unaided, tasks the learner can do with aid, and tasks the learner cannot do. The second category, tasks the learner can do with aid, is the zone of proximal development. This

theory also describes the importance of interaction with more knowledgeable peers and instructors. The instructors should provide scaffolding to support the learner.

The ACE should try and place as many tasks in the zone of proximal development for as many interns as possible to maximize learning. The most challenging part of this goal lies in the reality that the boundaries of the zone of proximal development vary between individuals. The ACE staff have no way to determine where the zone of proximal development lies for every intern before they arrive. Despite this challenge, the ACE staff and graduate assistants can use their interactions with the interns and observations of their success, failure, and difficulty facing different obstacles to adapt and provide necessary assistance.

The ACE program does an excellent job making knowledgeable peers and instructors available for interns to interact with. As part of their full immersion in the program, the interns all live in the same dorm-like facility. This locality makes peers available on a near constant basis and the interns often exploit this locality to work together when solving problems. The ACE program houses the graduate assistants in the same facility where the rest of the interns live. This arrangement places knowledgeable instructors in a perilously inescapable position of availability to the interns at any time such as late in the evenings and on weekends. This availability is critical to the success of the ACE program because of the high volume of tasks that fall within the zone of proximal development and the resulting necessity of some form of aid.

The instructors provide scaffolding to the interns. Providing scaffolding involves anticipating errors an intern may make and guiding them down the path that leads to optimal learning. The path that leads to optimal learning is not necessarily the most direct path to the solution. Interns often learn from their failures, so if an instructor sees an intern going down an incorrect path with great learning potential the instructor may not stop them.

In the case of the graduate assistants, they often help the interns understand why something did not work to get the maximum learning from the experience before guiding them in the right direction. The graduate assistants excel at guiding interns down the path that leads to optimal learning for any topic they learned about during their summer of ACE because they know from personal experience what mistakes interns will likely make. The graduate assistants have a harder time with new topics they did not cover their summer of ACE.

The ACE staff should arrange a meeting between the graduate assistants and each lecturer so the lecturers can brief the graduate assistants on the challenge problem and mistakes they believe interns will likely make. This briefing would help the graduate assistants provide scaffolding for topics newly introduces to the ACE curriculum. The graduate assistants also provide scaffolding in the form of emotional support. The graduate assistants always make sure interns know everyone on the staff understands the ACE is a stressful and challenging program and interns can talk to the graduate assistants if they have any problems.

Section 6.4 – Project-based Learning

Project-based learning involves an open-ended task for a learner to complete on their own or as part of a team. The ACE heavily employs project-based learning in several places such as the research problems and weekly challenge problems. These projects let the interns learn while applying their critical thinking and problem-solving skills. This education theory specifies factors to maximize learning from projects.

The problem should come from a real-world problem to provide an authentic application of content. The ACE research projects come from real research proposals from across the Department of Defense and the final deliverables get put in use after the ACE ends. The ACE research projects engage interns by showing a practical application for the cyber security

concepts they learn. The weekly challenge problems sometimes come from a real-world problem, but not always. The ACE staff should encourage lecturers to make their challenge problems as realistic as possible.

A drawback of project-based learning is required prerequisite knowledge to solve an open-ended problem. The ACE program places interns on research teams so the interns can share their background knowledge with the team and bridge such gaps without slowing progress towards a solution. In the event no intern on a research team has enough prerequisite knowledge for the team to make progress, the research mentor for the research team can step in to get things rolling. The ACE program should continue using these strategies to minimize the impact of this drawback to project-based learning. This problem does not affect the weekly challenge problems because the academic lectures cover all new knowledge needed to solve the challenge problem.

Section 6.5 – Fixed/Growth Mindsets

The fixed and open mindsets describe how the belief of a learner in their ability to learn directly affects their ability to learn. A learner in the fixed mindset believes their inherent traits are static and cannot change in a meaningful way. A learner in the open mindset believes hard work and effort can lead to growth and meaningful change in the traits the fixed mindset considers static.

Observations of the time and effort ACE interns put into achieving ambitious goals suggest most interns likely had an open mindset. Graduate assistants often remind interns that failure is okay and even anticipated at times, but these reassurances can go even further to foster an open mindset. Instead of promoting the idea that interns should accept failure and keep going, the graduate assistants should promote the open mindset perspective that failure rewards the interns with a new and unique opportunity to learn and better themselves. Additional positive

feedback from the graduate assistants would help nurture and maintain an open mindset among interns. The graduate assistants should congratulate interns for effort, remind interns they can learn to overcome their obstacles, and approach weakness in a positive way. If the graduate assistants spot signs of an intern thinking with a closed mindset, they should speak with that intern and encourage a shift in perspective to an open mindset. Helping the interns maintain an open mindset should help them succeed.

Section 6.6 – Andragogy

Andragogy places a focus on adult learning and differences between adult learners and younger learners. Andragogy applies to every ACE intern because all ACE interns are adults. Applying the six assumptions Knowles makes assumptions about adult learning. From these assumptions derive seven principles of adult learning that may help the ACE staff improve the learning outcomes for ACE interns.

The first principle states that an adult must want to learn. The absence of a desire to learn makes an adult unreceptive to new information. The desire to learn includes a desire for some freedom to shape learning to meet self-identified needs. The ACE program assumes an intern applying for and accepting a position in the internship implies their interest in learning about the cyber security topics covered throughout the summer. Although the ACE follows a rigid schedule, the interns get some freedom to shape their learning. Interns can shape their learning by spending time with a graduate assistant covering any material they want to learn more about or recognize a need to strengthen. The interns can also utilize the ACE battlespace for hands-on activities outside of what the ACE prescribes to them as long as they do not violate a code of conduct.

The second principle emphasizes a practical approach to learning and the importance of internal motivation. Instructors throughout the ACE program should strive to communicate the relevance of their content to the interns and how the content will help the interns succeed or avoid failure. If the instructors accomplish this, the interns should feel more internal motivation to learn the new material.

The third principle states that adults learn by doing. This principle also places an importance on active practice and participation. The ACE includes several hands-on experiences such as the lab activities, weekly operations, and various projects. The interns also actively participate in discussions with their various teams. The ACE should continue this heavy application of hands-on learning.

The fourth principle states that adult learning focuses on problem solving. The research and weekly challenge problem components of the ACE focus extensively on problem solving. Planning for the weekly operations also requires problem solving in both operational planning and technical development of capabilities. The problem-solving components of the ACE suit this principle of Andragogy very well and the ACE staff should continue to use them.

The fifth principle states that experience affects adult learning. The interns first arrive at the ACE with different experiences. Some interns arrive with significantly more relevant experience than their peers. The interns with relevant background often grasp new but similar concepts well and use their understanding to help the other interns. The ACE staff currently send some prereading materials out a few weeks prior to the start of the ACE to try to give every intern a similar introductory foundation. The ACE staff should consider expanding the prereading or incorporate some introductory elements into the beginning of the ACE program to ensure every intern has experience that will enhance their learning during the summer.

The sixth principle states that adults learn best in informal situations. The ACE program follows a formal curriculum and schedule, but outside of that schedule interns find or create informal settings to convene and learn as they work on various tasks. These opportunities allow the interns to participate in a collaborative learning environment. The graduate assistants unknowingly reinforced this type of learning during the 2019 ACE course by socially hanging out with the interns and working with them during their informal collaborative sessions. The ACE staff and graduate assistants should continue to encourage informal collaboration sessions.

The final principle states that adults want consideration as equal partners. The dynamic between lecturers and interns resembles a formal relationship a college professor might have with their students. ACE graduate assistants more optimally fill the role of instructors who consider the interns as equal peers. The shared experience between the graduate assistants who recently went through the ACE program and the interns currently in the program creates a bond that places the graduate assistants in closer proximity to the interns and makes them more approachable. The graduate assistants understand what the interns experience and feel and can closely relate seeing as they went through the same things one year prior. This dynamic puts the graduate assistants and interns in a peer-like status to each other without compromising the authority the graduate assistants hold. The guidance and consideration as peers shown by the graduate assistants to the interns aligns with this last principle of Andragogy. The ACE staff should continue to encourage the graduate assistants to interact with interns in this dynamic and treat the interns as peers in their interactions with interns to the greatest extent appropriate.

Chapter 7 - Conclusion

The lessons learned from this case study of the ACE reveal important ingredients to a recipe for a successful cyber security bootcamp. A cyber security bootcamp should have a stated objective and create a formalized method to evaluate itself to determine whether it accomplishes its objective. The evaluation mechanism should consider the entire population of participants and use as many objective measurements as necessary to reliably evaluate the bootcamp. Subjective notes to complement the objective measurements can provide context and, if collected and coded properly, supply more data for analysis. Pseudonymous feedback from participants that the evaluators can link to other data such as grades on assignments would aid evaluators.

A cyber security bootcamp may incorporate game mechanics to enrich the learning experience. A fictitious but realistic setting for components of a bootcamp can provide context for realistic applications of new learning while keeping participants engaged. Any reward participants receive needs a direct, transparent relationship with an objective. Participants need some clear indicator of success and the bootcamp should keep the indicator consistent throughout its duration to facilitate learning. The bootcamp should use these and any other game mechanics in a manner that does not compromise realism to keep learning applicable outside the context of the bootcamp.

No matter what breadth of topics a bootcamp covers, the bootcamp should aim to revisit topics periodically to reinforce learning. Ideally, recurring topics should increase in complexity with each revisit. The bootcamp instructors should try to maintain a relationship between each visit of a topic to maximize learning. With each topic, the bootcamp should aim to place tasks in the zone of proximal development to the greatest extent possible. To address the zone of proximal development varying from one participant to another, instructors can maintain

flexibility and adapt to provide appropriate scaffolding to accommodate each participant. Teaching a foundation of background knowledge at the beginning of the bootcamp may help normalize the zones of proximal development of participants by giving each of them the same baseline of knowledge to grow from.

A cyber security bootcamp should use an open-ended project or problem as one component of teaching for as many topics as reasonable. Instructors should make the projects as realistic as possible to provide an authentic application of the new topic. The mitigation of issues with project-based learning such as time-consuming grading and gaps in participant background knowledge needs addressed by the bootcamp and its instructors.

A bootcamp should watch for signs participants may think with a closed mindset. Instructors should know how to encourage thinking with a growth mindset and positively reinforce participants when they show traits of a growth mindset. Keeping participants in the growth mindset helps their ability to learn. If the bootcamp intends to recruit adult participants, the bootcamp should take special considerations to maximize adult learning. The bootcamp should communicate the relevance of new topics so participants feel motivated to learn them. The instructors should incorporate hands-on learning activities and problem-centric lessons so participants can learn by doing and use the new learning to solve relevant problems.

The bootcamp should ensure the availability of knowledgeable peers and mentors. If the bootcamp successfully keeps tasks in the zone of proximal development, the participants will need to interact with these more knowledgeable peers to progress. The more knowledgeable peers should make themselves available in both formal and informal settings and treat the participants as equals.

A cyber security bootcamp should place a great emphasis on teamwork to produce graduates most capable of applying their new knowledge to solve problems, deliver capabilities, and produce other meaningful results. Placing participants on a team gives them a chance to practice and hone their teamwork skills. Although some groups naturally form effective teams, instructors and mentors should actively search for opportunities to provide mentorship to participants to help them work better as a team. Formal education on how participants can be dynamic subordinates and better leaders can equip the participants to learn the most from their experience working on teams during the bootcamp.

Chapter 8 - Future Work

This thesis assessed the 2019 iteration of the ACE program and used education theories to recommend ways to improve future iterations of the program. The ACE staff may decide whether to implement each change and the details of how to implement each change remain up to them. If the ACE staff choose to make changes based off the recommendations from education theories, they should continue to assess interns and analyze the results after the next iteration of the ACE to determine the impact the changes had. Knowing the exact impact of each individual change on the learning outcomes of the program could show interesting results if an analysis isolating each change proves feasible to conduct. Repeating an assessment and analysis of the program each year could help the program continually improve at a faster rate. Future assessments may also find better refinements to the assessment methods used to measure the success of the interns.

The application and selection processes determine the makeup of the population of ACE interns. In a prior ACE class, the ACE staff performed an informal experiment to test their ability to predict how successful a candidate will be in the ACE after reviewing their resume and conducting their application interview. During the discussion of a candidate after their interview, the staff recorded a number from 1 to 10 indicating a consensus of how well the staff felt the intern would perform in the program. At the end of the summer, the staff compared their prediction rating of each intern with the position of the same intern in the stratification generated from final grades. The ACE staff found no correlation between their predictions and the actual performance of the interns and several predictions severely deviated from the result in the final stratification. An in-depth analysis of the ACE application and selection process and the process

of accurately identifying predictors of success or specific qualities that make applicants a better fit for the program could help the ACE staff refine the selection process.

The ACE staff have the capability of assessing interns during the program, but a study that follows ACE alumni after they graduate from the program could shed some light on the longer-term impacts the ACE has on its alumni. Determining what information graduates retain and what information alumni found helped them the most could help the ACE staff modify the curriculum to focus on the most useful topics throughout the summer and strengthen the materials for the topics which alumni did not retain as well.

References

Older, Susan. Advanced Course in Engineering (ACE) - Cyber Security Boot Camp. Air Force Research Laboratory Information Directorate Rome Research Site, AFRL-RI-RS-TM 2008-16 Final Technical Memorandum. April 2008.

Jabbour, Kamal, and Susan Older. The Advanced Course in Engineering on Cyber Security: A Learning Community for Developing Cyber-Security Leaders. 2004.

David L, "Gamification in Education," in Learning Theories, https://www.learning-theories.com/gamification-in-education.html. January 26, 2016.

Huang, Wendy Hsin-Yuan; Soman, Dilip. A Practitioner's Guide to Gamification of Education. Research Report Series Behavioral Economics in Action. Rotman School of Management, University of Toronto. 10 December 2013.

Hamari, J.; Koivisto, J.; Sarsa, H. Does gamification work? A literature review of empirical studies on gamification. Hawaii International Conference on System Sciences. IEEE Computer Society. 2014.

Harden, R., and Stamper, N. What is a spiral approach to curriculum? Medical Teacher, 21(2): 141-143. 1999.

Howard, J. Curriculum Development. Elon University: Center for the Advancement of Teaching and Learning. 2007.

Lohani, V. K., Mallikarjunan, K., Wolfe, M. L., Wildman, T., Connor, J., Muffo, J., and Chang, M. Work in progress-spiral approach to curriculum to reformulate engineering curriculum. In Proceedings Frontiers in Education 35th Annual Conference. IEEE. October 2005.

Masters, K., and Gibbs, T. The Spiral Approach: implications for online learning. BMC Medical Education, 7(52). 2007.

Dweck, C. S. Mindset: The New Psychology of Success. Constable & Robinson Limited. 2012.

"Seven Principles of Adult Learning." Principles of Adult Learning, Canadian Literacy and Learning Network, web.archive.org/web/20140217103828/www.literacy.ca/professionals/professional-development-2/principles-of-adult-learning/. 2014.

Staff, TEAL Center. TEAL Center Fact Sheet No. 11: Adult Learning Theories. Teaching Excellence in Adult Literacy, web.archive.org/web/20171215125941/communitycolleges.wy.edu/Data/Sites/1/commissionFiles/abe/training/abe-ntt/mod-6-articles/ntt---module-6---fs-11-teal-center-adult-learning-theory-fact-sheet-air-logo-rev12-06-11.pdf. 2011.

Smith, M. K. ‘Andragogy’, the encyclopedia of informal education. https://infed.org/mobi/andragogy-what-is-it-and-does-it-help-thinking-about-adult-learning/. 2010.

Culatta, Richard. “Andragogy (Malcolm Knowles).” InstructionalDesign.org, www.instructionaldesign.org/theories/andragogy/. 30 November 2018.

Knowles, M. S. & Associates. Andragogy in Action. San Francisco: Jossey-Bass. 1984.

Zone of proximal development. In Penguin dictionary of psychology. Retrieved from Credo Reference database. 2009.

McLeod, S. A. Lev Vygotsky. Retrieved from https://www.simplypsychology.org/vygotsky.html. 5 August 2018.

McLeod, S. A. Zone of proximal development. Retrieved from www.simplypsychology.org/Zone-of-Proximal-Development.html. 2012.

Cherry, Kendra. “How Vygotsky Defined the Zone of Proximal Development.” Verywell Mind, Verywell Mind, www.verywellmind.com/what-is-the-zone-of-proximal-development-2796034. 31 July 2019.

Wood, D., & Wood, H. Vygotsky, tutoring and learning. Oxford Review of Education, 22(1), 5–16. 1996.

Vygotsky, L. Thought and language. Cambridge, MA: MIT Press. 1986.

Wise, A. F., & O'Neill, K. Beyond more versus less: A reframing of the debate on instructional guidance. Retrieved from http://psycnet.apa.org/psycinfo/2009-09809-005. 2009.

“Project-Based Learning.” Edutopia, www.edutopia.org/project-based-learning. Accessed November 2019.

“What Is Project-Based Learning?” PBLWorks, Buck Institute for Education, www.pblworks.org/what-is-pbl. Accessed November 2019.

“Project-Based Learning.” Khan Lab School, Khan Lab School, khanlabschool.org/academics/approach-learning/project-based-learning. Accessed November 2019.

Bruner, J. Process of education. Cambridge, MA: Harvard University Press. 1960.

Thayer, Kyle, and Andrew J Ko. Barriers Faced by Coding Bootcamp Students. University of Washington. 2017.

Gear, Courtney, "Can You Hack It? Validating Predictors for IT Boot Camps". All Theses, Dissertations, and Other Capstone Projects. Paper 635. 2016.

Waguespack, Leslie J, et al. “Triangulating Coding Bootcamps in IS Education: Bootleg Education or Disruptive Innovation?” Information Systems Education Journal (ISEDJ), vol. 16, no. 6, ISSN: 1545-679X. December 2018.

Dcoetzee. Zone of Proximal Development image. https://en.wikipedia.org/wiki/File:Zone_of_proximal_development.svg. 2012. Accessed 16 April 2020.

Appendix A - ACE Run Rubric

Name:		ACE Conditioning: 8 Mile Run		Date:	
		Grader:		Overall Score:	
	Criteria	**Unsatisfactory**	**Minimal**	**Proficient**	**Exemplary**	**Score**
PLANNING						
20%	**Distance Traveled** • Traversed ACE Course • Returned before designated cutoff • Progress towards allowed run time (usually 90 minutes)	• Less than full ACE course • Returned after cutoff (usually 0900) • No improvement towards completion	• Less than full ACE course • Returned prior to cutoff (usually 0900) • Minor progress to meet allowed run time	• Completed full ACE course • Returned prior to cutoff (usually 0900) • Good progress to meet allowed run time	• Completed full ACE course • Returned prior to cutoff (usually 0900) • Met allowed run time	
40%	**Overall Time** • Traversed ACE Course • Time to complete – linear scale	• Less than full ACE course • Time exceeds allowed run time (usually 90 minutes)	• Completed full ACE Course • Completed in 81-90 minutes	• Completed full ACE Course • Completed in 69-81 minutes	• Completed full ACE Course • Completed in 58-69 minutes	
40%	**Completion Time** • Time to complete	• Returned after to cutoff time (usually 0900)			• Returned prior to cutoff time (usually 0900)	
Comments:						

Appendix B - Challenge Problem Report Rubric

Name:		Lecture Rubric		Date:	
		Grader:		Overall Score:	

	Criteria	Unsatisfactory	Minimal	Proficient	Exemplary	Score
TECHNICAL CONTENT						
40%	**Content and Technical Solution** • Depth of analysis • Grasp of core concepts • Clarity	• Superficial treatment of the subject matter • Incomplete or incorrect presentation of concepts • Difficult to understand technical contribution	• Adequate treatment of the subject matter • Generally accurate presentation of concepts • Technical contribution is apparent from report	• Good treatment of the subject matter • Accurate presentation of concepts • Technical contribution is clear from report	• Exemplary treatment of the subject matter • Outstanding presentation of concepts • Technical contribution is clear, concise, and succinct	
20%	**Originality** • Novelty of proposed solution • Technical Feasibility	• Uninspired solution that lacks understanding of subject matter • Infeasible or impractical in proposed operational scenario	• Original solution that reflects moderate understanding of subject matter • Marginally feasible for proposed operational scenario	• Novel solution that reflects strong understanding of subject matter • Feasible for proposed operational scenario	• Exceptional unique solution that reflects flawless understanding of subject matter • Feasible for proposed operational scenario	
PROFESSIONALISM						
10%	**Report Structure** • Includes all required sections • Section completeness • Report cohesion and well structure	• Missing one or more report sections • Report sections lack critical components or information • Lacks cohesion and structure	• Contains all ACE report sections • Report sections include most required information • Good cohesion and understandable	• Contains all ACE report sections • Report sections include most required information • Good cohesion and understandable	• Contains all ACE report sections • Report sections include all required information • Cohesive, complete and understandable	
10%	**ACE Writing Guide Format and Style** • Writing Guide sections 3.1 and 3.2	• Significant deviation from style and format that reduces readability or cohesion	• Significant deviation from style and format but does not affect readability or cohesion	• Minimal deviation from format or style guidelines	• No deviations from format or style guides	
20%	**"Jabbourian" English** • Writing Guide sections 3.3 and 3.4	• Significant deviation from writing guide requirements • Core concepts difficult to understand	• Some deviation from writing guide requirements • Core concepts difficult to understand	• Minimal deviation from writing guide requirements • Core concepts well communicated	• No deviation from writing guide requirements • Core concepts crystal clear and well communicated	
Comments:						

Appendix C - Staff Evaluation Rubric

Name:		Staff Evaluation		Date:		
		Grader:		Overall Score:		
	Criteria	Unsatisfactory	Minimal	Proficient	Exemplary	Score
ACE Core Tenets						
25%	**NO EXCUSE** • Takes responsibility for actions/inaction	• Blames others or circumstances for unsatisfactory performance	• Generally takes responsibility for unsatisfactory performance	• Takes full responsibility for their actions	• Takes full responsibility for their actions and learns from the outcome	
20%	**NO EXCEPTION** • ACE Code of Conduct • Capstone Rules of Engagement (ROE)	• Multiple minor breaches of the Code of Conduct after counseling • Major breach of the Code of Conduct after counseling • Multiple minor or major ROE violations	• No additional issues following counseling for minor breaches • No additional issues following counseling for major breach • No additional issues following counseling for minor or major ROE violation	• Minor breach addressed via informal counseling • No major breaches • Minor ROE violation addressed via informal counseling	• No minor breaches • No major breaches • Inspires others to live up to the Code of Conduct • No ROE violations, promotes adherence to ROEs	
25%	**NO EXTENSION** • Timeliness of Assignments • On time for ACE events	• 2 late assignments • Multiple (4+) instances of documented tardiness	• 1 late assignments • 2-3 instances of uncoordinated tardiness	• 0 late assignments • 1-2 instance of tardiness	• 0 late assignments • Never tardy or coordinated with staff •	
Attitude and Conduct						
15%	**Attitude** • Impact on self • Impact on others	• Negative attitude undermines their learning • Negative attitude undermines learning of their peers	• Negative attitude degrades their ability to learn and grow • Negative attitude does not affect their peers	• Good attitude promotes personal growth and learning • Good attitude promotes growth and learning in others	• Paragon of positivity results in personal growth and learning • Inspires their peers to learn	
15%	**Conduct** • Impact on self • Impact on others	• Unprofessional conduct undermines learning and growth • Disruptive to entire class	• Professional conduct most of the time • Occasionally disruptive to the learning environment	• Professional conduct leads to positive learning experiences • Professional conduct supports a positive learning experience	• Consummate professionalism greatly enhances the ACE • Conduct promotes professionalism in their peers	
Comments:						

Appendix D - Research Rubric

Name:		Research Rubric		Date:	
		Grader:		Overall Score:	
	Criteria	**Unsatisfactory**	**Minimal**	**Proficient**	**Exemplary**	**Score**
TECHNICAL CONTENT						
40%	**Technical Objectives** • Depth of analysis • Grasp of core concepts • Clarity	• Superficial research product does not advanced the project objectives • Fundamental errors in the deliverables, diverts and degrades project progress • Difficult to understand the accomplishments	• Adequate research product makes some progress toward project objectives. • Fundamentally sound, some errors in nuanced concepts or applications • Reasonable to understand accomplishments	• Very good research that advances the project at or ahead of schedule • All work fundamentally sound and free of technical error • Straightforward to understand with appropriate figures, explanations or demonstration	• Outstanding research that significantly advances the project and opens additional avenues of inquiry • Fundamentally sound, free of technical error and demonstrates mastery of advanced concepts • Product ready for briefing or demonstration	
20%	**Level of Effort** • Task prioritization • Diligence	• Tasks not core or related to research objectives • Distracted during research hours, engaged in other activities	• Tasks related to research objectives • Present during research hours, mainly engaged on project	• Task high priority items with a critical path to meet research objectives •	• Exceptional unique solution that reflects flawless understanding of subject matter • Feasible for proposed operational scenario	
PROFESSIONALISM						
20%	**Completeness** • Includes all required sections • Section completeness • Cohesion and structure	• Missing one or more report sections • Report sections lack critical components or information • Lacks cohesion and structure	• Contains all required sections/components • Report sections include most required information • Good cohesion and readability	• Contains all required sections/components • Report sections include most required information • Good cohesion and understandable	• Contains all ACE report sections • Report sections include all required information • Cohesive, complete and understandable	
20%	**Delivery on Time** • Written materials provided • Code committed to repositories • On-time for presentations and meetings	• Written materials not provided by deadline • Code not committed to repository by deadline • Late or no show for presentations/meetings	• Written materials provided by deadline in required format • Code committed in repository by deadline • On-time for meetings/presentations	• Written materials provided with proof copies for review • Code committed to repository in appropriate branches • On-time and prepared to present or discuss at meetings/presentations	• Written materials on time and revised per mentor feedback • Code committed to repository in appropriate branches with comments • Prepared all materials required for successful meeting/brief prior to start	
Comments:						

Appendix E - Lecture Feedback Form

Note: Space to respond to questions 1.1 through 1.5 removed in this reproduction to fit on one page.

1. Overall Evaluation						
1.1	What impressed and/or interested you the most?					
1.2	What needed more explanation? Are you still confused about any topic that was covered?					
1.3	Describe one item that most effectively facilitated your learning during this lecture?					
1.4	What would you improve about today's lecture?					
1.5	Recommendations for the future / Any additional comments:					
2. Please rate your agreement with the following statements accordingly:						
2.1	I have a strong understanding of material presented:	1. Strongly Disagree	2. Disagree	3. Neutral	4. Agree	5. Strongly Agree
2.2	Materials provided were of high quality:	1. Strongly Disagree	2. Disagree	3. Neutral	4. Agree	5. Strongly Agree
2.3	The lecture followed logical flow that enabled learning:	1. Strongly Disagree	2. Disagree	3. Neutral	4. Agree	5. Strongly Agree
2.4	The information was well explained/taught:	1. Strongly Disagree	2. Disagree	3. Neutral	4. Agree	5. Strongly Agree
2.5	Sufficient amount of time was spent covering new topics:	1. Strongly Disagree	2. Disagree	3. Neutral	4. Agree	5. Strongly Agree

Appendix F - ACE Map