# Engaging COEUR Principles to Achieve Higher Impact in Student Learning through a Campus-Community Partnership with the Air Force Institute of Technology

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Maggie Varga, Chief Operating Officer, Southwestern Ohio Council for Higher Education (SOCHE)

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Sean is serving his third term as an elected member of the Board of Education for the Yellow Springs Public Schools, where he has been president, co-chaired the 2020 Strategic Plan, and served as the district's legislative liaison. He also serves on advisory committees and boards for several local and national organizations, including the Dayton Literary Peace Prize, Learn to Earn, International Leadership Association, Springfield Museum of Art, TEDxDayton, ThinkTV Public Broadcasting, and Wright-Patterson Air Force Base Community Partner Leadership Council.

Sean has published and presented extensively on higher education, collaboration, civic engagement, and talent retention. He is also a principle investigator for the Kettering Foundation on several research projects concerning the civic mission of higher education. A higher education advocate and voice for collaboration, he posts regularly at creightoncollaborative.com. Sean holds degrees from Marist College and New York University, and earned his PhD from Antioch University. He lives in the charming village of Yellow Springs with his wife, Leslee, and his five fun children, Liam, Maya, Quinn, Audrey, and Juliette.

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# Engaging *COEUR* Principles to Achieve Higher Impact in Student Learning through a Campus-Community Partnership with the Air Force Institute of Technology


**Abstract**

This work presents a preliminary thematic analysis of student benefits and student outcomes that are achieved in a summer undergraduate research program following the implementation of the Council of Undergraduate Research *Characteristics of Excellence in Undergraduate Research* (*COEUR)* principles in a campus-community partnership. Our partnership between the Air Force Institute of Technology (AFIT) and Southwestern Ohio Council for Higher Education (SOCHE) engages principles described in *COEUR* to enrich undergraduate student research experiences in Science, Technology, Engineering, and Mathematics (STEM) fields in the AFIT Summer Research Program. AFIT is located on Wright-Patterson Air Force Base, Ohio, and SOCHE is located off-campus in Dayton, Ohio.

Since 2012, SOCHE and AFIT, a graduate school in engineering and applied science devoted to defense-focused research-based education, are partnering to transform student research experiences so that students can succeed in the 21st century STEM workforce. Students in the Summer Research Program are selected by AFIT Faculty Advisors to perform research in 12-week internships. Students are referred to as SOCHE interns because SOCHE is the government contractor and employer of the 40-50 students who participate annually. As the students' employer, SOCHE is able to assess the experiences of the students.

The two research questions we are asking in this paper are, "How do students describe the benefits of their research experiences, and how do these descriptions change during our transformation of the research experiences each year?" and the second question is "How do faculty describe the benefits of the research experiences for the students, and how do these descriptions change each year?" We employ applied thematic analysis of student surveys to develop answers to these research questions. Applied thematic analysis provides an inductive approach to analyze the qualitative data in a method that is systematic and rigorous according to Ohland and McNeil (2015) and Guest (2012).

In this partnership, SOCHE collects free-form student responses obtained in in-depth student pre-surveys and in-depth student post-surveys in 2012 (48 students, 18 responses to post-survey), 2013 (43 students, 8 responses to post-survey), 2014 (49 students, 33 responses to post-survey), and 2015 (34 students; 17 responses to post-survey). AFIT collects free-form

faculty responses in annual faculty advisor surveys in 2012 (21 faculty advisors; 13 responses), 2013 (16 faculty advisors; 9 responses), 2014 (13 faculty advisors; 11 responses), and 2015 (19 faculty advisors; 6 responses). Our study is identifying themes in the student responses regarding their self-identified benefits and outcomes, and themes in the faculty responses regarding the benefits and outcomes of the students. Our approach is to categorize the benefits according to the rubric[2] of Seymour *et al*. (2003), namely: (i) Personal/professional; (2) Thinking and working like a scientist; (3) Skills; (4) Clarification, confirmation, and refinement of career/education goals; (5) Enhanced career/graduate school preparation; (6) Changes in attitudes toward learning and working as a researcher; (7) Other benefits, including a good summer job and access to lab equipment. In 2015, SOCHE introduced five new initiatives. These initiatives address the two student concerns provided in 2014 student post-surveys regarding housing and computer access.

In conclusion, we are excited to have the opportunity to transform the student research experiences in the AFIT Summer Research Program. We are encouraged by student responses to initiatives that we are introducing each year. Since 2012, the initiatives include a joint orientation with SOCHE and AFIT (2013), creation of student cohorts (2013), weekly seminar meeting with outside presentations of general interest (2013), poster session (2013), weekly drop-in sessions offered by SOCHE at AFIT (2014), and a student village concept (2015). In 2016, the village concept introduced by SOCHE is planned again, and SOCHE will be on-site at AFIT for two or more days per week. Working together, we are excited to continue to transform the student research experiences.

## Introduction and Background

This work presents a preliminary thematic analysis of student benefits and student outcomes that are achieved in a summer undergraduate research program at a government institution following the implementation of the Council of Undergraduate Research *Characteristics of Excellence in Undergraduate Research* (*COEUR)* principles in a campus-community partnership.[1] *COEUR* presents best practices that "support and sustain highly effective undergraduate research environments." As described in *COEUR*, these practices focus on (1) Campus mission and culture; (2) Administrative support; (3) Research infrastructure; (4) Professional Development opportunities; (5) Recognition; (6) External funding; (7) Dissemination; (8) Student-centered issues; (9) Curriculum; (10) Summer Research Program; (11) Assessment Activities; and (12) Strategic Planning. This paper focuses on the summer research program and student benefits and student outcomes with the use of the seven benefit categories[2] described by Seymour *et al*. in 2003 are: (i) Personal/professional; (2) Thinking and working like a scientist; (3) Skills; (4) Clarification, confirmation, and refinement of career/education goals; (5) Enhanced career/graduate school preparation; (6) Changes in attitudes toward learning and working as a researcher; and (7) Other benefits, including a good summer job and access to lab equipment.

This paper describes student benefits and student outcomes obtained through a partnership between the Air Force Institute of Technology (AFIT) and Southwestern Ohio Council for Higher Education (SOCHE).[3,4] An analysis of the assessment and lessons learned are described. The research program engages principles described in *COEUR* to enrich undergraduate student research experiences in Science, Technology, Engineering, and Mathematics (STEM) fields in the AFIT Summer Research Program. AFIT is located on Wright-Patterson Air Force Base, Ohio, and SOCHE is located off-campus in Dayton, Ohio.

Since 2012, SOCHE and AFIT, a graduate school in engineering and applied science devoted to defense-focused research-based education, are partnering to transform student research experiences so that students can succeed in the 21$^{st}$ century STEM workforce.[5-8] Students in the Summer Research Program are selected by AFIT Faculty Advisors to perform research in 12-week internships. Students are referred to as SOCHE interns because SOCHE is the government contractor and is the employer of the 40-50 students who participate annually. As the students' employer, SOCHE is able to assess the experiences of the students.

The AFIT Summer Research Program includes a joint orientation session, formation of student cohorts, weekly seminar series, and a Poster Session.[5-6] The joint orientation takes place at the beginning of each summer with SOCHE leaders, DOD project leaders, and AFIT faculty. The formation of student cohorts takes place through encouragement of student camaraderie in social activities and STEM-based games. The weekly seminar series includes outside presentations of general interest, such as a lab tour, social lunches, resume workshop, poster creation workshop, and Kayak trip. The Poster Session is held toward the end of the summer and provides an optional opportunity for students to develop their communication skills. In the Poster Session, participating students prepare posters and explain their research to a panel of judges. In 2015, SOCHE made changes to address two student concerns regarding housing and computer access that students mentioned in 2014 student post-surveys. First, SOCHE created a "Student Village" for out-of-town and out-of-state students by partnering with Wright State University (WSU). In this village, a negotiated fixed rate for three months was offered to students for a furnished apartment with all utilities included. In 2015, 14 of the 34 interns took advantage of this opportunity. Providing nearby housing at an affordable cost near the base is important because students participating in civilian summer undergraduate research programs such as NSF Research Experience for Undergraduates (REUs) often have housing available on campus. Since the AFIT Summer Research Program is located at the AFIT campus, which is located on an Air Force base, nearby housing is not available to the students. The nearest university is Wright State University, which has entrances about one to two miles away; students typically need a car to purchase supplies, groceries, and drive to work each day.

Second, in 2015, SOCHE established a full-day presence on-site at AFIT each week. This role is that of a coordinator to answer student questions regarding computer access and provide information regarding transportation, housing, salaries, and summer activities. This role is very important because SOCHE is the students' employer, since the students are government contractors. This role is intended to increase student satisfaction with their research experiences, and the coordinator receives favorable feedback from the students. Because each student is selected individually by AFIT faculty (not by SOCHE), any additional participation by underrepresented students is decided by individual faculty members and is not related to additional presence by SOCHE on the AFIT campus. In 2015, SOCHE was available at AFIT each Wednesday from 9am until 5pm.

Third, SOCHE worked with AFIT to obtain "Smart ID" cards for students. In addition, SOCHE personalized a formal meet-and-greet with each student on the student's first day and student's last day of the internship. On the student's first day, the student is welcomed, shown to the work location, given an individual tour of AFIT, and is introduced to his or her Faculty Advisor; on the last day, the SOCHE Director thanks each student for participating in the program. In 2015, SOCHE also reached out to all student interns from the time they are hired until they return to their home schools. This personal outreach includes personalization of transportation arrangements for out-of-town and out-of-state students as well as providing a phone number to call with any questions and concerns.

## Motivation

This project is motivated by several reports published by the National Academy of Sciences (NAS). In 2004, the NAS prepared a groundbreaking report entitled *The Engineer of 2010: Visions of Engineering in the New Century*.[9] In this report, the NAS identifies key attributes that engineers in the 21$^{st}$ century are expected to exhibit to ensure their success and the success of the engineering profession. The key attributes are listed as: **strong analytical skills**, **practical ingenuity**, **creativity**, **communication**, **business and management**, **leadership**, **high ethical standards**, **professionalism**, **dynamism**, **agility**, **resilience**, and **flexibility**, and becoming **lifelong learners**. The NAS also prepared reports entitled *The Engineer of 2010*, *Rising Above the Gathering Storm*, and *Examination of the U.S. Air Force's Science, Technology, Engineering, and Mathematics Workforce Needs in the Future and Its Strategy to Meet Those Needs*.[9-13] One statement is that "a strong U.S. science and engineering workforce is of clear interest to the DOD, as the capability of producing superior technology is essential for future national security."[14] In order to develop a strong science and engineering workforce for the DOD, the federal government and U.S. Air Force offer several opportunities to undergraduates. These are listed briefly here, with references: "Research Experiences for Undergraduates" (REU) program sponsored by the National Science Foundation,[15] SMART Scholarship Program,[16-17] National Defense Science and Engineering Graduate (NDSEG) Fellowship program,[18] Air Force Summer Research Program (the subject of this paper),[4] Year-round internship program,[19] Pathways Internship Program,[20] PALACE Acquire,[21] Summer Faculty Fellowship Program,[22] Air Force Office of Scientific Research (AFOSR) Awards to Stimulate and Support Undergraduate Research Experiences (ASSURE),[14] NSF Federal Cyber Service Scholarship for Service (SFS) Program,[23] Oak Ridge Institute for Science and Education (ORISE).[24]

Our project is transforming the AFIT summer research program to expose undergraduate students in STEM fields to research opportunities at a DOD institution of the federal government and to future educational opportunities at this institution. By participating in the summer research program at AFIT, the students become motivated to graduate with STEM degrees and acquire skills so that they become successful engineers in the 21st century. In addition, the summer research program exposures undergraduate students at civilian institutions to unique opportunities so that the students develop research capabilities and skills that are aligned with the workforce needs of the Air Force.

## Overview of the Partnership

The partnership comprises the LEADER Consortium,[25] Air Force Institute of Technology (AFIT), and Southwestern Ohio Council for Higher Education (SOCHE). As described in our prior work,[5-8] the LEADER Consortium is funded by an ADVANCE Institutional Transformation Award from the NSF Award #0810989 since 2008 and is a partnership of four institutions of higher education in the Dayton region: the Air Force Institute of Technology, Central State University, University of Dayton, and Wright State University.

As described in our prior work, the Air Force Institute of Technology (AFIT) is a purely graduate-level institution, and as such, it is one of the few institutions offering graduate-level ABET-accredited degrees. AFIT's faculty members are approximately composed of 50% military faculty and 50% civilian faculty, and they are expected to conduct research programs in the same manner as civilian schools. AFIT's mission is to advance air, space, and cyberspace power for the Nation, its partners, and our armed forces by providing relevant defense-focused technical graduate and continuing education, research, and consultation. In 2011, the Carnegie Foundation identified AFIT as a doctoral/research institution for the first time in recognition of the doctoral education productivity with strong research activity in Science, Technology, Engineering, and Mathematics disciplines. Students perform research with faculty in six departments: Aeronautics and Astronautics, Electrical and Computer Engineering, Engineering Physics, Mathematics and Statistics, Operational Sciences, and Systems and Engineering Management.

The Southwestern Ohio Council for Higher Education, or SOCHE, is a 501c3 non-profit organization. Formed in 1967, SOCHE is a regional consortium of 20 colleges and universities in southwest Ohio. SOCHE's mission is to be "the collaborative infrastructure for higher education, helping colleges and universities transform their communities and economies through the education, employment, and engagement of more than 120,000 students in southwest Ohio."[3,4] In addition to providing internships, the organization manages a comprehensive portfolio of programs and initiatives to support higher education in the region.

## Transforming the AFIT Summer Research Program - Review

We now review the transformation of the AFIT Summer Research Program, which is described in detail in our 2015 journal article,[5] *Enriching Undergraduate Research at the Air Force Institute of Technology Through COEUR Principles*, in Council of Undergraduate Research Quarterly on the Web, and conference publications at American Society of Engineering Education Annual Meeting in 2013,[8] 2014,[7] and 2015.[6]

## Why a Transformation was Undertaken

The transformation was undertaken because, as described in our 2013 paper at American Society of Engineering Education,[8]

> *AFIT [lacked] many components of standard STEM research programs…, such as those at institutions funded through programs such as the National Science Foundation Research Experience for Undergraduates which we [used] as models to which we aspire to upgrade the AFIT program. A standard STEM summer program briefly consists of the following broad steps:*
>
> *First Component: Students are recruited,*
> *Second Component: Students form cohorts,*
> *Third Component: Students participate in research*
> *Fourth Component: Students develop presentations,*
> *Fifth Component: Students work on resumes, and*
> *Sixth Component: Students prepare poster sessions.*
>
> *As of summer 2012, the AFIT Summer Research Program lacked all components except the first component (recruiting) and the third component (research).*

At the same time, as described in our conference publication at ASEE in 2013,[8]

> *"[technical] capabilities have always been critical to the missions and roles of the U.S. Air Force in military operations, and these capabilities are rooted in science, technology, engineering, and mathematics… For a variety of reasons, concerns have arisen over the future of both the military and civilian contingents of the Air Force's STEM workforce. Emerging mission areas, particularly in the space and cyber domains, are expanding the need for new technical skills and expertise… A growing percentage of science and engineering graduates in the United States are foreign citizens and thus ineligible for the security clearances that many jobs in the Air Force and in the aerospace industry require. The existing STEM workforce is aging, with many individuals nearing retirement. Women and minorities are underrepresented in most S&E educational pursuits at a time when they constitute the majority of college students and therefore the majority of the future workforce. The market for STEM-educated U.S. citizens is becoming much more competitive."*

As we described previously,[8]

> *The motivation for our project stems from Recommendation 6-6a* [of Reference 13] *which states that the "Air Force should periodically access the capability of AFIT to help meet projected future requirements for STEM-degreed personnel by providing selected officers and civilians with educational opportunities leading to the award of a STEM degree. In addition, the STEM personnel decision support model should include a sufficient number of military and civilian AFIT student positions to enable use of these AFIT opportunities."* [12] *Recommendation 6-6a was developed in response to Finding 6-6 that states that "[the] Air Force Institute of Technology currently offers a number of degree, certificate, and short-course programs (and could potentially offer additional programs) that would increase the number of STEM-degreed officers available to meet Air Force STEM needs. In particular, the AFIT resident school offers graduate STEM education programs that address problems of unique importance to the Air Force; comparable programs are not available at civilian institutions."*
>
> *Our project, in response to Recommendation 6-6a exposes a pool of STEM undergraduate students to research opportunities and future educational opportunities at AFIT. This exposure thereby increases the number of civilian students who are participating directly in exciting and dynamic research opportunities at the forefront of basic scientific knowledge and also have the potential to contribute to the development of advanced technology of interest to the Department of Defense. This pool of STEM-educated students has the opportunity through the Summer Research Program to develop unique capabilities and current skills that are aligned with the workforce needs of the Air Force.*
>
> *In 2012, a formal assessment tool was distributed to the students for the first time to measure the impact of the research experience. Also in 2012, a formal assessment tool was distributed to the Faculty Advisors of the students for the first time to measure the research experience of the students from their advisors' perspective. Following the student survey results in the 2012 Program, we identified the following four broad needs expressed by the students: (1) A desire for mentors with increased organization and communication among SOCHE, AFIT, and the students; (2) A desire for increased interactions with other students; (3) A desire to improve their CV or resume at the beginning of the program; (4) A desire to gain engineering experience, skills, and confidence in research.*

## The Transformation Process

Starting in the 2013 Program,[6]

> *Four new voluntary components* [were implemented] *in response to the student needs. Because of government restrictions, the participation of students in the components is voluntary, and students were encouraged to participate by SOCHE. These transformational components are: (A) A joint orientation process with SOCHE and AFIT Project Leaders; (B) Student cohorts through social activities and STEM-based games;*

*(C) A weekly seminar meeting with outside presentations of general interest; and (D) A Poster Session so that students can present the engineering experiences they have gained. Selected students were awarded "Posters of Excellence" Certificates in a poster competition.*

**Demographics of the Students and How the Students are Selected**

Students apply to the SOCHE internship program from early February through May 1st each year at the SOCHE internship website, www.socheintern.org.[4] Each student submits an unofficial transcript, a resume, and three references. A list of students who apply before the May 1st deadline is compiled by SOCHE and is sent to interested AFIT faculty who interview and select the students. The faculty members then select students and inform SOCHE which extends an offer to each student. Students work between May 1st and September 30th each year at AFIT and coordinate their summer schedules with the AFIT faculty members.

Students are U.S. citizens and are primarily attending civilian institutions in the state of Ohio and states in the Midwest. As described on the SOCHE website, students are typically majoring in Aeronautical Engineering, Astronautical Engineering, Electrical and Computer Engineering, Mechanical Engineering, Nuclear Engineering, Systems Engineering, Computer Science, Materials Science, Mathematics, Operations Research, and Physics.

As described in our paper[8] published in 2013 in the Proceedings of the American Society of Engineering Education Annual Meeting, student demographics are:

*In the 2012 Summer Research Program, both undergraduates and graduate students participated in the Program: Sophomores (2), Juniors (5), Seniors (17), and Graduate Students (2). The participating students are from colleges and universities in Ohio (18), Indiana (4), Illinois (1), Tennessee (1), and Virginia (1). All of the student respondents are majoring in STEM fields: Computer Engineering (6), Electrical Engineering (7), Mechanical Engineering (5), Mathematics (5), Physics (1), and Engineering Physics (1). Over 10% of the participating students are female.*[8]

**Selectivity of the Program**

The program is selective. Each year, many more students apply than the number of available internships. The number of students who are applying to the program has increased since 2012.

**Sharing of Lessons Learned and Analysis of the Benefits and Results of the Program**

Two lessons learned are described[5] in our journal paper published in the *Council on Undergraduate Research Quarterly on the Web* in Spring 2015:

*First, the adjustments made in response to student feedback can be adapted by others running similar types of programs. For example, other programs might benefit from organizing a joint orientation among all stakeholders in a summer research program; forming student cohorts; arranging a weekly seminar; and organizing a poster session with recognition of the best posters. We are aware of a few similar components, such as poster* *sessions and seminars in some NSF-sponsored Research Experience for Undergraduate (REU) programs. Second, we learned that students respond eagerly to the opportunity to present their research in a setting open to participation of faculty, students, and staff. We are taking steps with SOCHE to encourage increased participation of students in future poster sessions. In this way, students who present their research through the poster session will increase their visibility as researchers and will be exposed to technical interactions with their colleagues, which is a fundamental experience in the ongoing professional development of the students.*[5]

*Of the students who responded to the question about their overall experience from the perspective of gaining non-technical but work-related experience (such as resume building and professional communication), 67 percent indicated that their experience was either "good" or "excellent" in the 2012 program, and 100 percent indicated that their experience was either "good" or "excellent" in the 2013 program. Thus the rating on this question improved from 3.7 in the 2012 program to 4.2 in the 2013 program. From the perspective of interacting socially and networking with their peers, 67 percent of the respondents rated the 2012 program as either "good" or "excellent," and 83 percent of the respondents rated the 2013 program as either "good" or "excellent." The rating thus increased from 3.7 in the 2012 program to 4.2 in the 2013 program on a 5-point Likert scale. Eighty-three percent of the respondents indicated that they would like to see "about the same" amount of professional programming and the same amount of social programming.*[5]

**Research Questions**

In this paper, the two research questions we are asking are, "How do students describe the benefits of their research experiences, and how do these descriptions change during our transformation of the research experiences each year?" and the second question is "How do faculty describe the benefits of the research experiences for the students, and how do these descriptions change each year?" Specifically, this paper employs applied thematic analysis of student post-surveys and faculty advisor post-surveys to develop preliminary answers to these research questions. Applied thematic analysis provides an inductive approach to analyze the qualitative data in a method that is systematic and rigorous.[26-27] In this paper, we present preliminary results obtained through the methods of applied thematic analysis to address these two research questions.

**Annual Surveys in Years 2012 - 2015**

The goal of our study is to identify themes in the student responses regarding their self-identified benefits and outcomes, and themes in the faculty responses regarding the benefits and outcomes of the students.

Student post-surveys are collected by SOCHE at the end of each summer program since the participating students are government contractors and employees of SOCHE. SOCHE collects free-form student responses obtained in in-depth student post-surveys in 2012 (48 students; 18 responses to post-survey), 2013 (43 students; 8 responses to post-survey), 2014 (49 students; 33 responses to post-survey), and 2015 (34 students; 17 responses to post-survey).

Faculty advisor surveys are collected by AFIT at the end of each summer since the participating faculty advisors are faculty at AFIT. AFIT collects free-form faculty responses in annual faculty advisor surveys in 2012 (21 faculty advisors; 13 responses), 2013 (16 faculty advisors; 9 responses), 2014 (13 faculty advisors; 11 responses), and 2015 (19 faculty advisors; 6 responses).

As described previously, our approach is to categorize the benefits according to the rubric of Seymour *et al*.[2] These benefits were catalogued in a publication of the first findings from a three-year study of 76 student interviews that took place in 2000 at Grinnell College, Harvey Mudd College, Hope College, and Wellesley College. In this study, the research questions were fundamental questions "about the benefits (and costs) of undergraduate engagement in faculty-mentored, authentic research undertaken outside of class work."[2] The results[2] reported by Seymour *et al*. (Table 3 in Reference 2) list students' positive observations regarding their research experience and are focused on the students' "increased confidence" in a variety of areas. These observations include "in ability to do research," "in contributing real knowledge to science," "because of being taken seriously by others," "in general (i.e., in nonspecific statements)," "because of ability to do research," "because of ability to contribute to science," "because of increased understanding of the nature of science," "because of presenting research," "because of gain in writing skills," "in presenting/defending research," and "in being taken seriously by mentor and others."[2]

## Results and Findings: Researcher Observations

At the end of summer 2012, students expressed a feeling of disconnectedness from other interns in the program. To remedy this, we introduced the idea of student cohorts starting in 2013. The idea was to match students up in groups of 4 to 5 interns with similar interests, and to get them communicating so that they would have a peer support group they could rely on. To encourage this, we planned several STEM-themed games. The first of these was a scavenger hunt wherein each group earned points by finding research-related items such as a list of graduate scholarship opportunities, a copy of a school's promotion and tenure guidelines, or a highly-cited paper in the students' field. However, students proved to be more interested in forming peer networks than in playing the games. Due to the nature of the games, we could not make them a required part of the students' daily activities, and only a few students participated.

Far more students participated in other social networking activities such as the kayak trip and lunch gatherings. As such, the lesson learned from this activity is that it is better to simply provide the students with frequent brief opportunities to socialize and network than to artificially create group engagement. In 2014, the lunch gatherings were expanded from roughly every other week to once every week, and this setting was continued in 2015. The students participated much more readily in these lunches than in the games, and student comments about feeling disconnected from their peers dropped significantly.

**Results and Findings: Faculty Advisor Responses**

The faculty advisors' responses to the student research experiences in the program are also generally favorable each year. Faculty advisors write that the students were motivated and that their students produced results that will be published in journals and reports and that will be presented at briefings and conferences. The faculty advisors reported that their students performed a literature survey; collected data; operated hardware, performed data collection; performed data analysis; assisted graduate students; wrote code; learned how to test and develop simulation models; and learned how to design, build, and test hardware systems. The faculty advisors report that the students learned about simulation modeling, programming languages, and developed experience on real systems.

As result of the research experience, the faculty advisors wrote that the students had a better understanding of graduate research and experimentation, worked on Air Force problems, and gained experience working with hardware, software, and theoretical approaches to scientific research.

As an example, in 2015, one faculty advisor wrote that "The students came eager to learn." Another faculty advisor wrote that a student, following the summer research experience, "knows how to test and develop simulation models." A third faculty advisor wrote that a student "accomplished measurements" and "built simulations/code."

In 2014, one faculty advisor wrote that the student "has appreciation for what graduate school is like," and another wrote that a student was able to accomplish "an outstanding poster and presentation."

In 2013, one faculty advisor wrote that the student "experienced a variety of hands on application of what he learned in the classroom" and "learned how to research answers in areas [he] hadn't studied." Another faculty advisor wrote that "I enjoy seeing [the students] grow over the summer." Yet another faculty advisor wrote that the faculty advisor "got to mentor motivated undergraduates." A fourth faculty advisor wrote that "the students were highly motivated, skilled, and physically present throughout the workday. This enabled them to accomplish a lot."

In 2012, one faculty advisor wrote that the student "has now been accepted to graduate school and has applied to a summer program … to work on related research." Another faculty advisor wrote that "the work was good and the student showed great initiative." A third faculty advisor wrote "[the students] provided a lot of outside benefits to my classroom." Yet another faculty advisor wrote that "[the student] expanded my group's capabilities for gathering experimental data."

**Preliminary Results**

Preliminary analysis of the student post-surveys and faculty advisor surveys identifies student benefits and outcomes from the AFIT summer research program. Preliminary qualitative themes are shown in Tables I and II. These tables show the frequency of preliminary qualitative themes in student post-surveys and faculty advisor surveys, respectively, in 2012, 2013, 2014, and 2015. The themes are shown in red and are organized according to the seven benefit categories of Seymour *et al.*[2] In the first benefit category of "Personal/Professional," three preliminary themes identified from responses to the students about what was most helpful are: (i) real world experience and hands-on application of STEM education,' (ii) interacting in a professional work environment,' and (iii) developing collaborations/networking. In the benefit category of "Thinking and working like a scientist," preliminary themes are: (i) preparing a publication, report, or documentation; (ii) designing parts, perform experiments, testing; and (iii) presenting results at conference/briefing. In the benefit category of "Skills," preliminary themes are: (i) learning new software/developing algorithms and programs, (ii) organizing and analyzing data, and (iii) teamwork in the DOD.

**Lessons Learned: Research Question #1: "How do students describe the benefits of their research experiences, and how do these descriptions change during our transformation of the research experiences each year?"**

Regarding the benefit "Personal/Professional," the preliminary theme reported with greatest frequency each year is real world experience and hands-on application of STEM education (see Table I). Regarding the benefit "Thinking and working like a scientist," the theme reported with greatest frequency each year is designing parts, performing experiments, and testing. Regarding the benefit "Skills," the theme reported with greatest frequency each year is "Learning new software, developing algorithms/programs." Regarding the benefit, "Clarification, confirmation, and refinement of career/education/goals," the theme reported with greatest frequency each year is "Gaining understanding of working in the DOD." Regarding the benefit, "Enhanced career/graduate school preparation," the primary theme reported each year is 'will apply for scholarships and fellowships.' Regarding the benefit "Changes in attitudes toward learning and working as a researcher," the theme 'learning about what is expected in a research career' is reported each year with nonzero frequency. Regarding the benefit "Other benefits," the theme 'good summer job/experience' is reported each year.

During the transformation of the research experiences each year, the results show that the same themes are reported with the greatest frequency. In Table I, the theme reported with greatest frequency each year is shown in bold font (in the case of equal frequency, both quantities are shown in bold font). In 'Skills,' the theme reported by students with greatest frequency is "learning new software, developing new algorithms/programs' in all four years 2012 (72%), 2013 (37.5%), 2014 (55%), and 2015 (65%).

**Lessons Learned: Research Question #2: "How do faculty describe the benefits of the research experiences for the students, and how do these descriptions change each year?"**

Regarding the benefit "Personal/Professional," the preliminary theme reported with greatest frequency each year is real world experience and hands-on application of STEM education (see Table II). Regarding the benefit "Thinking and working like a scientist," the theme reported with greatest frequency each year is designing parts, performing experiments, and testing. Regarding the benefit "Skills," the theme reported with greatest frequency each year is "Learning new software, developing algorithms/programs." Regarding the benefit "Clarification, confirmation, and refinement of career/education/goals," the theme reported with greatest frequency each year is "Gaining insight into an engineering career." Regarding the benefit "Enhanced career/graduate school preparation," the primary theme reported each year is 'will apply for scholarships and fellowships.' Regarding the benefit "Changes in attitudes toward learning and working as a researcher," the theme 'learning about what is expected in a research career' is reported each year with nonzero frequency.

**Table I. Frequency of Preliminary Qualitative Themes in Student Post-Surveys**

| Year | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|
| **Themes and Seven Benefit categories presented by Seymour et al. (Lopatto 2004b, Seymour et al., 2003)** | Frequency (N=48; 18 responses to post-survey) | Frequency (N=43; 8 responses to post-survey) | Frequency (N=49; 33 responses to post-survey) | Frequency (N=34; 17 responses to post-survey) |
| **Personal/Professional – What was most helpful** | | | | |
| **-Real world experience and hands-on application of STEM education** | **0.44** | **0.25** | **0.24** | **0.41** |
| **-Interacting in a professional work environment** | 0.056 | 0 | 0.091 | 0.06 |
| **-Developing collaborations, networking** | 0.17 | 0 | 0.21 | 0.12 |
| **Thinking and working like a scientist– What was accomplished** | | | | |
| **-Preparing a publication, report, or documentation** | 0.17 | 0 | 0.15 | 0.24 |
| **-Preparing a grant proposal** | 0.056 | 0 | 0 | 0 |
| **-Designing parts, performing experiments, testing** | **0.33** | **0.25** | **0.36** | **0.35** |
| **-Presenting results at conference/briefing** | 0 | 0.125 | 0.061 | 0.24 |
| **-Performing literature survey** | 0 | 0 | 0.03 | 0 |

| | | | | |
|---|---|---|---|---|
| **Skills– What was accomplished** | | | | |
| **-Learning to use new equipment** | 0.056 | 0 | 0.15 | 0 |
| **-Learning new software, developing algorithms/programs** | **0.72** | **0.375** | **0.55** | **0.65** |
| **-Organizing and analyzing data** | 0.17 | 0.25 | 0.18 | 0.18 |
| **-Learning about computers** | 0.056 | 0 | 0 | 0.06 |
| **-Teamwork in the DOD** | 0.17 | 0.25 | 0.12 | 0.06 |
| **Clarification, confirmation, and refinement of career/education/goals– What was most helpful** | | | | |
| **-Gaining insight into an engineering career** | **0.11** | 0.25 | 0.061 | **0.06** |
| **-Gaining understanding of working in the DOD** | **0.11** | **0.375** | **0.15** | **0.06** |
| **Enhanced career/graduate school preparation– -I have applied or will apply for scholarships and fellowships** | | | | |
| **-Will apply for scholarships and fellowships** | **0.28** | **0.625** | **0.45** | **0.35** |
| **Changes in attitudes toward learning and working as a researcher– My internship prepared me for a research career** | **0.22** | **0.50** | **0.33** | **0.06** |
| **-Learning about what is expected in a research career** | | | | |
| **Other benefits (a good summer job, access to lab equipment) – Additional information** | | | | |
| **-Good summer job/experience** | **0.33** | **0.625** | **0.36** | **0.35** |

Table II. Frequency of Preliminary Qualitative Themes in Faculty Advisor Surveys

| Year | 2012 | 2013 | 2014 | 2015 |
|---|---|---|---|---|
| **Themes and Seven Benefit categories presented by Seymour et al. (Lopatto 2004b, Seymour et al., 2003)** | Frequency (N=21; 13 survey responses) | Frequency (N=16; 9 survey responses) | Frequency (N=14; 11 survey responses) | Frequency (N=19; 6 survey responses) |
| **Personal/Professional** | | | | |
| **-Real world experience and hands-on application of STEM education** | **0.46** | **0.33** | **0.45** | **0.17** |
| **-Interacting in a professional work environment** | 0.08 | 0.22 | 0 | 0 |
| **-Developing collaborations, networking** | 0 | 0 | 0 | 0 |
| **Thinking and working like a scientist** | | | | |
| **-Preparing a publication, report, or documentation** | 0.23 | 0.44 | 0.09 | 0.5 |
| **-Preparing a grant proposal** | 0 | 0 | 0 | 0 |
| **-Designing parts, performing experiments, testing** | **0.62** | **0.78** | **0.55** | **0.67** |
| **-Presenting results at conference, briefing** | 0.08 | 0 | 0 | 0 |
| **-Performing literature survey** | 0 | 0 | 0.18 | 0 |

| | | | | |
|---|---|---|---|---|
| **Skills** | | | | |
| **-Learned to use new equipment** | 0.31 | 0.11 | 0 | 0 |
| **-Learned new software, developed algorithms, programs** | **0.77** | **0.89** | **0.82** | **0.67** |
| **-Organized and analyzed data** | 0.23 | 0.22 | 0.09 | 0.33 |
| **-Learned about computers** | 0.23 | 0 | 0 | 0 |
| **-Teamwork in the DOD** | 0.23 | 0.11 | 0 | 0 |
| **Clarification, confirmation, and refinement of career/education/goals** | | | | |
| **-Gained insight into an engineering career** | **0.31** | **0.22** | **0.45** | **0.33** |
| **-Gained understanding of working in the DOD** | 0.08 | 0 | 0.09 | 0 |
| **Enhanced career/graduate school preparation** | | | | |
| **-Will apply for scholarships and fellowships** | **0.46** | **0.44** | **0.45** | **0.50** |
| **Changes in attitudes toward learning and working as a researcher** | | | | |
| **-Learning about what is expected in a research career** | **0.23** | **0.11** | **0.54** | **0.33** |
| **Other benefits (a good summer job, access to lab equipment)** | | | | |
| **-Good summer job/experience** | 0 | 0 | 0 | 0 |

## Discussion

Both students and faculty reported the preliminary themes 'obtained real world experience and hands-on application of STEM education,' 'designing parts, performing experiments, testing,' 'learning new software, developing algorithms, programs' with greatest frequency. Regarding clarification, confirmation, and refinement of career/education/goals, students reported the theme 'gaining understanding of working in the DOD' with greatest frequency, whereas faculty advisors reported the theme 'gaining insight into an engineering career' with greatest frequency.

These benefits provide students with several of the attributes that are identified in the 2004 report entitled *The Engineer of 2020: Visions of Engineering in the New Century*. Specifically, these themes provide students with the key attributes of **strong analytical skills**, **communication**, **professionalism**, and opportunities to become **lifelong learners**.

Through the transformation of the AFIT summer research program, we are providing opportunities to students to help them acquire skills to become successful in the 21st century. One outcome for the DOD is that by exposing STEM undergraduate students to research opportunities at AFIT, students will be motivated to graduate with bachelor's degrees in STEM fields. Another outcome is that the students will acquire these skills to help them succeed in their careers. A third outcome is that the students will develop unique capabilities and current skills that are aligned with U.S. Air Force workforce needs.

## Future Work

Since many of the participating students are freshmen, sophomores, and juniors, after a few years we are hoping to identify which of the participating students have graduated with STEM degrees. Many are still enrolled in their undergraduate programs. The possibility of an alumni survey has been discussed, and there is a need to reach out to students, although some students do not update their contact information after participating in the program.

Recognizing this need, we are in the process of preparing a grant proposal to obtain additional resources to reach out to alumni, collect this data, and obtain an analysis of the extent to which these desired outcomes are achieved in this project. Data collected from alumni of the program can then be compared with data collected from alumni of the program in 2012 (the baseline year). Questions we will answer will include "Do participants have better retention rates than similarly situated students?"

## Conclusions

The preliminary applied thematic analysis presented in this paper is intended to identify preliminary themes in the student benefits and student outcomes as self-reported by students in annual post-surveys. The thematic analysis identifies preliminary themes in the student benefits and outcomes as identified from the annual faculty advisor surveys. These results provide input into continuing to develop best practices for the AFIT summer research program to improve student research experiences.[28,29]

Students report 'real world experience with hands-on application to STEM' with highest frequency in their Personal/professional development. Students report 'designing parts, performing experiments, testing' with highest frequency in their growth toward Thinking and Working like a scientist. Students report 'learning new software, developing algorithms/programs' with highest frequency in their Skills list.

In conclusion, we are excited to have the opportunity to transform the student research experiences in the AFIT Summer Research Program. We are encouraged by student responses and faculty advisor responses to initiatives that we are introducing each year. Since 2012, the initiatives include a joint orientation with SOCHE and AFIT (2013), creation of student cohorts (2013), weekly seminar meeting with outside presentations of general interest (2013), poster session (2013), weekly drop-in sessions offered by SOCHE at AFIT (2014), and a student village concept (2015). Looking ahead to the program in the summer of 2016, the student village concept is planned, and SOCHE plans to be on-site at AFIT for two or more days per week. Working together, we are excited to continue to transform the student research experiences.

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