STEM Consulting Services

Computer Science Principles and Cybersecurity Pathway for Career and Technical Education

Program Evaluation

2019-2022

Final Report
December, 2022

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STEM Consulting Services
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Introduction

Science, technology, engineering, and mathematics (STEM) education continues to be of significant national interest within the United States and globally as the need for a STEM literate population and workforce increases every year. STEM education programming has been regularly studied over that period relative to a wide range of research interests. Particular to this project, computer science and the efforts required to ensure a representative IT and cybersecurity workforce will demand purposeful attention. This current project, Computer Science Principles and Cybersecurity Pathway for Career and Technical Education (CTE), aims to build those workforce pathways while purposefully addressing gender (male/female/non-binary) inequities.

Year 1 Findings

Year 1 Evaluation

09.15.20
(Reporting Period 10.01.19 – 9.30.20)

STEM Consulting Services (SCS) has provided information below to report on the implementation of the project: Computer Science Principles and Cybersecurity Pathway for Career and Technical Education. To date, evaluation efforts have included (a) evaluation plan modifications based on PI needs and U.S. Department of Education recommendations, (b) assistance in development and approval of IRB and data sharing agreements with Norfolk Public Schools (led by Co-PI D. Marshall), (c) initial data collection regarding pre/post test data for content and attitudinal instruments (d) initial data collection regarding mentors, (e) program leader interviews, and (f) artifact analysis and observations regarding programmatic implementation.

Accountability

Overall Project Implementation

Most portions of the project were observed to move forward despite Covid-related disruption. This is not an insignificant statement given the degree of disruption that occurred in both the K-12 and higher education environments. Programmatic elements that continued in both original and modified versions include:
## Goals/Objectives

<table>
<thead>
<tr>
<th>(Goal 1)</th>
<th>Activity</th>
<th>Assessment</th>
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</table>
| Increase the access for underrepresented high school students in STEM fields in computer science and cybersecurity by providing the CTE educational programming and informal learning experiences in local schools | 1. Introduction to Cryptography with Exercises module was developed and implemented (with Covid-related modifications) with high school students in their CTE course | a. number of courses per school  
b. number of students enrolled in CTE classes  
c. attendance of code nights and field trips  
d. focus interviews with CTE teachers  
e. Students AP Computer Science Principles Test  
f. Students IT Fundamentals Test and Qualtrics Attitudinal Section  
g. Students Cyber Fundamentals Test and Qualtrics Attitudinal Section |
| Develop, assess, and improve hands-on computer science and cybersecurity educational modules that can be easily integrated into a high school curriculum | 2. Hands-on Activities on Cryptography module was developed and implemented with elementary school students at the Family Night of Code | |

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<th>(Goal 2)</th>
<th>Activity</th>
<th>Assessment</th>
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| Demystify the field of CS and cybersecurity and build awareness for students and families of the new data-driven society, and of the need for a minimum level of computer science literacy for entry into the job market | 1. field trips to local companies that use CS and cybersecurity applications in their day-to-day activities - ranging from advanced manufacturing, banking, and healthcare (Field Trip (Unilever) (12.06.19))  
2. code nights involving parents and community (Family Night of Code (03.10.20))  
3. high school student participation in a competition such as the Great Computer Challenge and the National Youth Cyber Defense Competition  
4. STEAM Family Night (03.05.20) | a. pre-test and post-test at field trips  
b. pre-test and post-test at Code Nights  
c. pre-test and post-test at competitions  
d. Student Career Development Focus Group Interview Questions |

<table>
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<tr>
<th>(Goal 3)</th>
<th>Activity</th>
<th>Assessment</th>
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<tbody>
<tr>
<td>Develop and deliver professional training workshops to CTE high school faculty focused on computer science and cybersecurity</td>
<td>1. NPS Professional Development Day (08.26.20)</td>
<td>a. workshop evaluation survey</td>
</tr>
<tr>
<td>Establish professional development experience for high school CTE teachers through face to face and distance learning workshops</td>
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</tbody>
</table>
(Goal 4) Engage college students to serve as mentors and role models to the high school students
(Obj 4) None listed

| 1. None listed | a. focus interviews with high school students (mentees) |
|  | b. focus interviews with undergraduate and graduate students (mentors) |

The potential disruptive impact to implementation based on the institutional and state responses to Covid-19 cannot be overstated. Because instruction was altered in Spring 2020 at universities and K-12 in the middle of the semester, instructors (both university and high school) had to (a) make immediate adjustments to minimize negative impacts on students and (b) after school and collaborative peer activities were severely altered to conform with institutional safety policies or eliminated (e.g. spacing requirements, 51% F2F requirement for SACS, university students were no longer allowed in K-12 schools, etc.). These actions meant originally planned programmatic elements like the mentoring component could not move forward as originally planned and many could not be modified in a timely fashion. SCS recommends examining remote means of mentoring within child safety/digital safety guidelines provided by NPS and ODU until face to face meeting restrictions have been relaxed. Additionally, the nature and role of mentors in the project seems to be very broadly defined. SCS is working with the project leaders to establish and document fidelity in the nature of mentoring roles and relationships. Despite the extraordinary circumstances that Covid-related impacts have placed on grant-funded efforts that were designed for face-to-face contexts, the project team has managed to implement, at least in part, all programmatic elements.

**Effectiveness**

**Data Collection and Analysis**

Due to the challenges presented by Covid-related responses external to the project, data collection was severely impacted. This resulted in postponed collection of some interview data (rescheduled for Oct/Nov 2020), most notably Teacher Focus Groups and Mentors and concerns over the validity of test scores given the lack of fidelity in instruction based on significant changes to instructional modality in Spring 2020. As summer unfolded there remained considerable uncertainty with respect to instructional modality at both the university and K-12 levels. This uncertainty did not resolve until late August/early September of 2020. Data collection contexts that existed in public schools were also compromised as most went to complete remote learning options. Some school systems no longer accepted university student at all. The variability of this implementation meant any data collected would not be comparable to those collected in previous contexts and time points. Furthermore, the stresses that all parties were and are under for delivery of basic instructional services made some data collection an unrealistic pursuit.
We will analyze the attitudinal and content knowledge test data as planned using a quasi-experimental design in which the question of whether or not population dependent variable means (student content test scores and student attitudinal test scores) vary by case (teacher) across factor (intervention stage (i.e. Year 0 (comparison data/no intervention), Yr 1, Yr 2, Yr 3)). Additionally, the covariate of dosage (i.e. PD-related instructional experiences) received by students will be included in the analysis. We originally anticipated that with effective implementation means should increase from Year 0 to subsequent Years and that dosage will be positively associated with higher means.

Consequently, the evaluation-related data collection originally involving sources that consisted of:

1. Focus Group Interview Questions with CTE Teachers targeting pedagogy and including content analysis of instructional materials (1 data collection time point per year)
2. Student Career Development Focus Group Interview Questions (1 data collection time point per year)
3. Students AP Computer Science Principles Test (1 data collection time point per year)
4. Students IT Fundamentals Test and Qualtrics Attitudinal Section (2 data collection time points per year)
5. Students Cyber Fundamentals Test and Qualtrics Attitudinal Section (2 data collection time points per year)
6. Mentor Surveys (1 data collection time point per year)
7. Mentee Surveys (1 data collection time point per year)

We have the following data currently collected and a revised timeline for collection/analysis based on Covid-19 response.

Participant Overview:

1. Initial Demographics
   a. 340 students participated in 2 Computer Science classes, 1 Cyber security class and 4 after school clubs
   b. 26 students participated in more than 1 class and/or after school activity (08.3% of 314)
   c. 314 students participated in only one class and/or after school activity.
   d. Additional analysis is underway regarding descriptive statistics as part of variable development for additional statistical work

2. Focus Group Interview Questions with CTE Teachers targeting pedagogy and including content analysis of instructional materials (1 data collection time point per year)
   i. Oct/Nov 2020 collection planned (Covid delayed)
   ii. April 2021 collection planned
   iii. April 2022 collection planned
3. **Student Career Development Focus Group Interview Questions (1 data collection time point per year)**
   i. Oct/Nov 2020 collection planned (Covid delayed)
   ii. April 2021 collection planned
   iii. April 2022 collection planned

4. **Students AP Computer Science Principles Test (1 data collection time points per year)**
   i. April 2020 (collected; analysis in progress)
   ii. April 2021 collection planned
   iii. April 2022 collection planned

5. **Students IT Fundamentals Test and Qualtrics Attitudinal Section (2 data collection time points per year)**
   i. May 2020 (collected; analysis in progress)
   ii. Sept 2020 (collected, analysis in progress)
   iii. May 2021 collection planned
   iv. Sept 2021 collection planned
   v. May 2022 collection planned

6. **Students Cyber Fundamentals Test and Qualtrics Attitudinal Section (2 data collection time points per year)**
   i. May 2020 (collected; analysis in progress)
   ii. Sept 2020 (collected, analysis in progress)
   iii. May 2021 collection planned
   iv. Sept 2021 collection planned
   v. May 2022 collection planned

7. **Mentor Surveys (1 data collection time point per year)**
   i. Oct/Nov 2020 collection planned (Covid delayed)
   ii. April 2021 collection planned
   iii. April 2022 collection planned

8. **Mentee Surveys (1 data collection time point per year)**
   i. Oct/Nov 2020 collection planned (Covid delayed)
   ii. April 2021 collection planned
   iii. April 2022 collection planned

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**Impact**

**Dissemination Efforts**

Publications:
None to date

Presentations:

Websites:

1. https://sites.wp.odu.edu/odu-nps-cs-cybersecurity-pathway-for-cte/
2. https://github.com/muratkuzlu/ODU_CTE-RaspberryPi

Other:

1. Dr. Deborah Marshall received Gerald G. Day Excellence in Authorship Award for the Top Overall Article featuring Granby High School efforts in promoting inclusion of underrepresented groups in STEM pathways
2. Granby High School CTE Newsletters
3. Lunch & Learn

In the short amount of time the project has been implemented given typical project start-up needs and timelines and Covid-related impacts, the project team has managed to produce two presentations at two highly respected national conferences, developed and maintained three web resources, and provided regular outreach via Newsletters and Lunch and Learn meetings. Dr. Marshall was also recognized nationally for her published work at ITEEA. SCS has discussed with project leaders additional conference venues, including National Association for Research in Science Teaching (NARST) and the American Educational Research Association (AERA). Both conferences have SIGs/RIGs that are related to project foci and would expand dissemination. Given the timeline, the project team is exceptionally productive and impactful.

In summary, the project team appears to be making good progress towards achieving the stated objectives. Data analysis completion in Fall 2020 of Year 1 data will provide initial quantitative and qualitative evidence regarding efficacy across measures. Strong observational evidence exists for the implementation and impact of project elements as described above.
Year 2 Findings

Year 2 Evaluation

10.31.21
(Reporting Period 10.01.20 – 9.30.21)

Year 2 data collection followed the primary goals/objectives established in Year 1 of the project. STEM Consulting Services (SCS) has provided information below to report on the implementation of the project: Computer Science Principles and Cybersecurity Pathway for Career and Technical Education. To date, evaluation efforts have included (a) evaluation plan modifications based on PI needs and U.S. Department of Education recommendations, (b) assistance in development and approval of IRB and data sharing agreements with Norfolk Public Schools, (c) initial data collection regarding pre/post test data for content and attitudinal instruments (d) initial data collection regarding mentors, (e) program leader interviews, and (f) artifact analysis and observations regarding programmatic implementation.

Accountability

Overall Project Implementation

Most portions of the project were observed to move forward despite Covid-related disruption. This is not an insignificant statement given the degree of disruption that occurred in both the K-12 and higher education environments. Programmatic elements that continued in both original and modified versions include:

1. Building awareness of the need for computer science literacy
   a. Wednesday December 9, 2020 - meeting with IT Fundamentals and one with Cybersecurity Fundamentals meeting - Quarterly review meeting in which they discussed the implementation of educational supplemental modules and student feedback.
   b. Cyber Camp for middle school students was delivered to 5th-9th graders on July 6-8, 2021 from 7:30 am - 2:00 pm.
   c. ODU School of Cybersecurity had 2 GenCyber camps in summer 2021 for high school students.
   d. Coordinated activities in Norfolk Public Schools Career & Technical Ed programs and pathways.
   e. Registered students for CyberOps Competition on April 16th & 17th, 2021.
   g.
2. Deliver professional training workshops on Computer Science to high school teachers
3. Deliver professional training workshops on Cybersecurity to high school teachers
a. The team is working on educational modules for “Cybersecurity Software”. The Google Drive folder is shared with all Cybersecurity Software teachers in NPS as they are being created. The team is trying to create modules on time when NPS CTE teachers need them during the school year. Dr. Jovanovic made blank templates for each one of the modules that included the task list and a slide for each task. ODU students are working with their faculty mentors on some initial drafts, most of the other modules are being created by ODU faculty. All modules, once the first draft is made, are revised by NPS CTE teacher Michael Crespo and NPS CTE Teacher Specialist Dr. Deborah Marshall.

b. Facilitated professional developments with Cybersecurity (12/09/21)

4. CTE educational programming in Computer Science
   a. The team has started to work on the Virtual Arduino Platform Autodesk TinkerCAD - https://www.tinkercad.com/dashboard - Simulator
   b. Distributed laptops to Sponsors of CyberPatriot Teams on 12/10/20, 1/20/21, 02/10/21.
   c. Developed and delivered a workshop on Internet of Things during the ODU BLAST summer camp (a summer program for 160 high school students from the Commonwealth of Virginia attended - 80 girls and 80 boys).
   d. CF Tasks 95-100 Programming and Technology Implications
   e. CF Tasks 77-83 Examining Data Security as it Relates to Cybersecurity
   f. Guest Speaker - NORSTAR Career & Technical Ed. STEM Program - Dr. Ozgur Guler - Artificial Intelligence Expert and Software Developer - Hello World! General Programming - November 12, 2020
   g. Guest Speaker - NORSTAR Career & Technical Ed. STEM Program - Levent Gurses - Fintech Innovation Leader and Software Developer - Careers In Programming - December 14 & 15, 2020
   h. Guest Speaker - NORSTAR Career & Technical Ed. STEM Program - Dave Einfeldt - Intellectual Property Manager - Patent, Copyright & Trademarks - February 23, 2021
   i. ITF Tasks 39 - 57 - Mastering Digital Technology Basics
   j. IT-Tasks 48-51 - Using Digital Applications
   k. IT-Tasks 92-95 - Exploring Web Page Design
   l. IT-Tasks 96-100 - Exploring Graphics and Interactive Media
   m. IT Tasks 101-104 - Preparing for Industry Certification
   n. IT Tasks 105-109 Developing Career Exploration and Employability Skills
   o. 5. CTE educational programming in Cybersecurity
      a. Finalized educational modules for Cybersecurity Fundamentals and IT Fundamentals were distributed to all CTE cybersecurity teachers in Norfolk Public Schools on 8/26/2021 and statewide through the project website, hosted at ODU.
      b. CS Tasks 100 - 105 - Maintaining Servers
      c. CS Tasks 106 - 112 - Implementing and Managing Web Servers
      d. Guest Speaker - Cyber Security Fundamentals- Dr. Hongyi (Michael) Wu - cybersecurity and Java programming introduction to Cryptography Past, Present, and Future - October 6, 2020
e. Guest Speaker - Cyber Security Fundamentals - Susan Zehra - Cybersecurity Expert and Software Developer, Lecturer of Computer Science, ODU, October 7, 2020
g. CF-Tasks 66-76 - Exploring Ethics as it Relates to Cybersecurity
h. CF-Tasks 59-65 - Understanding Cyber Threats and Vulnerabilities
i. CF-Tasks 101-105 - Research career opportunities for cybersecurity professionals & Cybersecurity and Future Military Career
j. CF-Tasks-106-109 - Preparing for Industry Certification
k. 6. Engage college students as mentors to NPS high school students
   a. Student Drew Brown is currently doing his senior design project focused on cybersecurity and Internet of Things in Busch Manufacturing, Virginia Beach, VA, one of our industry partners. Drew Brown (Mechanical Engineering Technology student) works as a mentor for the Maury High School CyberPatriots Team AY 2021-22.
   b. Jorge Ramirez (Electrical Engineering Technology student) works as a mentor for the Lake Taylor High School CyberPatriots Team AY 2021-22.
   c. Karrisa Crawford, a Civil Engineering Technology student is starting to work as an Undergraduate Student Researcher mentoring Girls in STEM after school club at Granby High School AY 2021-22.
   d. We hired an Electrical and Computer Engineering graduate student Omid Rajabi Rostami to work on a project.
   e. Norstar program - ODU student Neil St Clair mentored the rocketry team students in NPS CTE NORSTAR Program various engineering topics in AY 2021-22.

Covid-19 continued to impact data collection and programmatic implementation. However, the project team made extraordinary efforts to mitigate these impacts and provide at least some level of service (often exceptional levels) to participants. With exception of better articulating/signaling the realized inclusive nature of the program through altered branding as first identified by DOE, SCS recommends that the project team continue their efforts as executed in Year 2 of the project.

**Effectiveness**

**Data Collection and Analysis**

Following the substantial challenges to data collection by NPS partners in Year 1, efforts were made to collect as much as possible in Year 2. Those efforts were largely successful resulting in the receipt by SCS of 33 data files by Oct 19, 2021. These files will be analyzed over the coming months. Based on the level of data (i.e. school, class, student) we will modify study structure. Initial anticipated data levels were not always achieved, so evaluation design must now be altered to fit with the data available.
Consequently, the evaluation team has received data regarding:

1. Focus Group Interview Questions with CTE Teachers targeting pedagogy and including content analysis of instructional materials (1 data collection time point per year)
2. Student Career Development Focus Group Interview Questions (1 data collection time point per year)
3. Student Attitudes toward STEM Survey (2 data collection time points per year)
   a. MISO Test
4. Student Ideas and Beliefs about Technology and Science (2 data collection time points per year)
   a. CABATS Test
5. Students Computer Science Principles Test (2 data collection time points per year)
6. Students Cybersecurity Pathway for CTE Test (2 data collection time points per year)
7. Mentor Surveys (1 data collection time point per year)
8. Mentee Surveys (1 data collection time point per year)

We have the following data currently collected and a revised timeline for collection/analysis based on Covid-19 response.

Participant Overview:

1. Demographics
   iv. All demographic data is being collected and descriptive statistics applied (collection and analysis underway)
2. Focus Group Interview Questions with CTE Teachers targeting pedagogy and including content analysis of instructional materials (1 data collection time point per year)
   i. Oct/Nov 2020 collection planned (Covid-delayed; collection and analysis underway)
   ii. April 2021 collection planned (collection and analysis underway)
   iii. April 2022 collection planned
3. Student Career Development Focus Group Interview Questions (1 data collection time point per year)
   i. Oct/Nov 2020 collection planned (Covid-delayed; collection and analysis underway)
   ii. April 2021 collection planned (collection and analysis underway)
   iii. April 2022 collection planned
4. Student Attitudes toward STEM (2 data collection time points per year)
   b. MISO Test
      i. May 2020 (collected; analysis in progress)
      ii. Oct 2020 (collected, analysis in progress)
      iii. May 2021 collection planned
      iv. Oct 2021 collection planned
      v. May 2022 collection planned
5. Student Ideas and Beliefs about Technology and Science (2 data collection time points per year)
   a. CABATS Test
      i. May 2020 (collected; analysis in progress)
ii. Oct 2020 (collected, analysis in progress)
iii. May 2021 (collected, analysis in progress)
iv. Oct 2021 collection planned
v. May 2022 collection planned

6. Students Computer Science Principles Test (2 data collection time points per year)
i. May 2020 (collected; analysis in progress)
ii. Oct 2020 (collected, analysis in progress)
iii. May 2021 (collected, analysis in progress)
iv. Oct 2021 (collected, analysis in progress)
v. May 2022 collection planned

7. Students Cybersecurity Pathway for CTE Test (2 data collection time points per year)
i. May 2020 (collected; analysis in progress)
ii. Oct 2020 (collected, analysis in progress)
iii. May 2021 (collected, analysis in progress)
iv. Oct 2021 (collected, analysis in progress)
v. May 2022 collection planned

8. Mentor Surveys (1 data collection time point per year)
i. Oct/Nov 2020 collection planned (Covid delayed)
ii. April 2021 (collected, analysis in progress)
iii. April 2022 collection planned

9. Mentee Surveys (1 data collection time point per year)
i. Oct/Nov 2020 collection planned (Covid delayed)
ii. April 2021 (collected, analysis in progress)
iii. April 2022 collection planned

**Impact**

**Dissemination Efforts**

Publications:

1. “Digital Educational Modules Development for the Career and Technical Cybersecurity Pathways During Covid-19 Pandemic” has been conditionally accepted for publication in The Technology Interface International Journal. The research team is currently working on paper revisions submitted on October 1, 2021.


Presentations:


Websites:
1. https://sites.wp.odu.edu/odu-nps-cs-cybersecurity-pathway-for-cte/
2. https://github.com/muratkuzlu/ODU_CTE-RaspberryPi

Awards:
1. The research team has won a Creating Excellence Award from Virginia Department of Education (VDOE) in the Business Partnerships category in June 2021.

During the past year, the project team has managed to produce three presentations at a highly respected national conference, submitted and had accepted two manuscripts, maintained three web resources, and provided regular outreach via Newsletters and Lunch and Learn meetings. The research team was also recognized by the Virginia Department of Education (VDOE) for their work with this project. SCS has discussed with project leaders additional conference venues, including National Association for Research in Science Teaching (NARST) and the American Educational Research Association (AERA). Both conferences have SIGs/RIGs that are related to project foci and would expand dissemination. Given the timeline, the project team is exceptionally productive and impactful.

In summary, the project team appears to have built on a strong start despite challenging conditions and is making excellent progress towards programs goals and objectives. Data analysis will increase significantly over the next six months of the project from the evaluation team side, as a critical mass of data has now been collected. Strong observational evidence exists for the implementation and impact of project elements as described above.

**Year 3 Findings**

**Year 3 Evaluation**

**11.30.22**

(Reporting Period 10.01.21 – 9.30.22)
STEM Consulting Services

Year 3 data collection followed the primary goals/objectives established in Year 1 of the project. STEM Consulting Services (SCS) has provided information below to report on the implementation of the project: Computer Science Principles and Cybersecurity Pathway for Career and Technical Education. To date, evaluation efforts have included (a) evaluation plan modifications based on PI needs and U.S. Department of Education recommendations, (b) assistance in development and approval of IRB and data sharing agreements with Norfolk Public Schools, (c) continued data collection regarding pre/post test data for content and attitudinal instruments (d) continued data collection regarding mentors, (e) artifact analysis regarding programmatic implementation, (f) program leader interviews, and (f) data analysis regarding pre/post test data for content and attitudinal instruments, (g) data analysis regarding mentors, and (h) summative report.

Accountability

Overall Project Implementation

The project was observed to move forward despite Covid-related disruption and has accomplished its primary goals and objects. This is not an insignificant statement given the degree of disruption that occurred in both the K-12 and higher education environments. Programmatic elements that continued in both original and modified versions include:

- The team is working on educational modules for “Cybersecurity Software”. The Google Drive folder is shared with all Cybersecurity Software teachers in NPS as they are being created. The team is trying to create modules on time when NPS CTE teachers need them during the school year. Dr. Jovanovic made blank templates for each one of the modules that included the task list and a slide for each task. ODU students are working with their faculty mentors on some initial drafts, most of the other modules are being created by ODU faculty. All modules, once the first draft is made, are revised by NPS CTE teacher Michael Crespo and NPS CTE Teacher Specialist Dr. Deborah Marshall.
- Finalized educational modules for Cybersecurity Fundamentals and IT Fundamentals were distributed to all CTE cybersecurity teachers in Norfolk Public Schools on 8/26/2021 and statewide through the project website, hosted at ODU.
- Laptops that were distributed to all five Norfolk Public Schools CTE programs are now being used by high school students.
- Student Drew Brown is currently doing his senior design project focused on cybersecurity and Internet of Things in Busch Manufacturing, Virginia Beach, VA, one of our industry partners.
- All data have been collected about module evaluation through the Qualtrics survey from CTE teachers outside of NPS from other school districts, in Virginia and nationwide.
- Team collected pre-test data from all five NPS high schools.
- Team coordinated Visiting Speakers in multiple CTE classes in NPS high schools.
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• Modules for Cybersecurity Fundamentals and IT Fundamentals have been distributed to CTE cybersecurity teachers in the Commonwealth of Virginia through Judith Sams, Specialist, Business & Information Technology & Related Clusters, Virginia Department of Education.
• Modules for Cybersecurity Fundamentals and IT Fundamentals were modified by the Instructional Developer Ms. Mary Addison.
• Industrial Advisory Board Members provided their feedback for the Cybersecurity Fundamentals and IT Fundamentals modules in December IAB meeting that was held online and through the online survey on Qualtrics.
• Team presented the Showcase about the Code Nights at ITEEA 2021 Conference.
• Three conference papers were published in the American Society for Engineering Education (ASEE) virtual conference. One received an award as a Best Diversity Paper under Ocean and Marine Engineering Division.
• Undergraduate MET student Neil St. Clair advised the Northstar team on rocketry.
• Two Summer Gen Cyber Camp were held at Old Dominion University Campus.
• Cyber Camp for middle school students was hosted by NPS and organized by the team members in July 2021 at Booker T. High School in Norfolk, VA.
• Drew Brown (Mechanical Engineering Technology student) works as a mentor for the Maury High School CyberPatriots Team AY 2021-22.
• Jorge Ramirez (Electrical Engineering Technology student) works as a mentor for the Lake Taylor High School CyberPatriots Team AY 2021-22.
• Karrisa Crawford, a Civil Engineering Technology student is starting to work as an Undergraduate Student Researcher mentoring Girls in STEM after school club at Granby High School AY 2021-22.
• Norstar program - ODU student Neil St Clair mentored the rocketry team students in NPS CTE NORSTAR Program various engineering topics in AY 2021-22.
• Developed and delivered a workshop on Cryptography for the ODU BLAST summer camp (a summer program for 160 high school students from the Commonwealth of Virginia attended - 80 girls and 80 boys). June19-22, 2022
• Prepared workshop for Cyber Camp for middle school students to be delivered to 5th-9th graders (July 5-8, 2022, canceled due to transportation issues).
• Developed and delivered a workshop on the Internet of Things during the ODU BLAST summer camp (a summer program for 160 high school students from the Commonwealth of Virginia attended - 80 girls and 80 boys). June19-22, 2022
• Developed and delivered a workshop on CrowPi and Python at Cyber Camp for middle school students was delivered to 5th-9th graders (July 5-8, 2022, canceled).
• **Virtual Hands-on Activities with TinkerCAD using Arduino**: The team has completed the Virtual Arduino Platform Autodesk TinkerCAD (https://www.tinkercad.com/), and uploaded the presentation related to instructions to the public repository GitHub, https://github.com/muratkuzlu/VirtualArduino. Tinkercad Circuits combines Tinkercad with Arduino circuitry. Tinkercad Circuits allows anyone to virtually create and program Arduino projects without the need for physical hardware. These hands-on activities on TinkerCAD Software Activities using Arduino are (1) RGB LED with Arduino, (2) Digital output with Arduino, (3) Blinking LED, (4) Buzzer with Arduino, (5) Sensor reading with
Arduino. Students will learn a basic Arduino in Tinkercad, i.e., Arduino Simulation environment, with hardware components, such as microcontrollers, sensors, and wiring, and software programming languages, i.e., C++.

- **Development of Hands-on Activities with the CrowPi:** These hands-on activities include a set of sensing and measurement applications with and without IoT. on the CrowPi development kit. CrowPi is an educational tool based on Raspberry Pi, designed to help people learn electronics, programming, and basic computer science. These hands-on activities on CrowPi are (1) Vibration Device, (2) Servo Motor, (3) Blinking LED, (4) Christmas Song Using the Buzzer, (5) RFID Reader With IoT Integration, (6) Touch Sensor With IoT Integration and (7) Button Matrix Code With IoT Integration, (8) Distance Code With IoT Integration. In application developments, students use hardware (including microcontrollers and sensors) and software programming languages, i.e., Python, to monitor and control sensors locally and remotely. All source code and presentation will be delivered on the following GitHub repository, https://github.com/muratkuzlu/CrowPi_IoT_Projects.

Programmatic elements continued without disruption and appeared to be generally well-received at both the district and school levels.

**Effectiveness**

**Data Collection and Analysis**

Data collection was a challenge throughout the project due to Covid, teacher attrition, and district-level support. The team made substantial changes to the overall research design. Based on the level of data (i.e. school, class, student) provided, we modified the study structure. Ultimately, we were able to provide paired-sample t-tests for individual classes in Norfolk. We did not receive pre/post data from other schools or districts regarding the Cyber Security Operations, Cyber Security Fundamentals, and IT Fundamentals courses. Both school-level turnover in personnel and district-level support for data sharing impacted the timeliness and quantity of data that were available for analysis. However, the project team made extraordinary efforts to mitigate these impacts.

Quantitative Analysis
Based on the analysis, all courses analyzed (n=3) showed statistically significant increases in scores from pre to post.

Participants in the Cyber Security Operations course, test scores were compared before and after the course intervention. On averages, participants performed worse before (M=32.7, SD=6.973) the intervention than after (M=79.36, SD=13.444) the intervention. This improvement (Mean difference=46.6, 95% CI [50.5, 42.8], was statistically significant, t (24) = 25.185, p< 0.001.
Participants in the Cyber Security Fundamentals course, test scores were compared before and after the course intervention. On averages, participants performed worse before (M=43.99, SD=13.187) the intervention than after (M=90.31, SD=10.844) the intervention. This improvement (Mean difference=46.324% CI [48.545, 44.103], was statistically significant, t (70) = 41.604, p< 0.001.

Participants in the IT Fundamentals course, test scores were compared before and after the course intervention. On averages, participants performed worse before (M=33.54, SD=7.130) the intervention than after (M=78.09, SD=9.047) the intervention. This improvement (Mean difference=44.543% CI [46.218, 42.868], was statistically significant, t (34) = 54.033, p< 0.001.
Two schools did not provide post test scores in Cyber Security Operations and IT Fundamentals courses (Pretest score mean $M=37.00$, $SD=8.124$ and $M=25.03$, $SD=4.411$; respectively). However, their descriptives on the pretest that was administered are presented in the table below:

### Qualitative Analysis

Teachers of the Cybersecurity Fundamentals course were administered a survey that contained specific questions related to their interaction with all aspects of the course. A total of 15 teachers responded to the survey. A series of five open-ended questions were provided to the teacher participants, their responses were coded, and common themes were derived from the codebook using pattern matching. The Participants responses’ fell into more than one thematic category; therefore, outcomes will represent the majority of responses per theme. The following are the open-ended questions that were asked, and the themes derived from them:

**Question 1:** which materials do you currently use for the class? This question produced common list-style responses/themes which are presented in rank of popularity, and they are as follows: Virginia Cyber Range, Other materials, Self-made materials, Principals of Cyber Security textbook, Cyber.org, CodeHS, and TestOut.

**Question 2:** what do you like best about teaching a Cybersecurity Fundamentals course? Theme emerging from this question were Relevance to everyday like; Awareness of cyber threats; Learning about careers in Cyber Security. The majority of responses, (59%) were around Relevance to everyday life and other general related responses. For example, one teacher stated, “I like exposing students to the everyday uses of IT, cybersecurity, and computer science concepts.” Forty-one percent of the responses were in the themes of awareness of cyber threats and learning about careers in Cyber Security. A teacher stated that “Giving students an appreciation and understanding of existing cybersecurity threats and how to mitigate those threats.” Another teacher said “It affords my title 1 student an opportunity to prepare for a career in cybersecurity out of high school.”

**Question 3:** what do you see as the biggest challenges or barriers when teaching a Cybersecurity Fundamentals course? The three most common themes that emerged from this question are 1) Having appropriate curriculum materials, 2) Students lack the prerequisite background knowledge, 3) the scope and sequence of the topics does not scaffold. Fifty percent of the responses provided evidence of teachers needing more appropriate curriculum materials. For example, once teacher stated, “Finding good hands-on activities for students to
practice skills at this level of class.” Another teacher responded by saying “Finding and using exercises in a virtual simulated environment where students can really practice the command line interfaces and methods used in navigating, configuring, and securing network systems.” As it relates to student preparedness, which constitutes 33% of the responses, one teacher mentioned that “The subject requires a lot of critical thinking, and most freshmen want to be led through things rather than figuring them out for themselves.” In regard to course sequencing and scaffolding of topics theme (at 17% of responses), a teacher stated that “Course content, sequence, making the course something other than a list of vocabulary words each day...” are challenges in teaching the course.

Question 4; in your opinion, what do you see as the cause of problems teaching a Cybersecurity Fundamentals course? This question yielded four themes and their respective percent responses, 1) lack of access to appropriate materials (35%), 2) students not prepared for the rigors of the course (29%), 3) lack of professional development (24%), and 4) lack of funding (12%). Evidence for lack of access to appropriate materials is provided by a teacher that said “A lot of the cybersecurity resources are very text heavy and do not include any hands on activities,” or another teaching saying that “Our local computers are locked down so that students cannot access Windows configuration or networking features.” Also, the reoccurring theme of students not prepared for the rigors of the course, was illustrated by saying “Middle school not adequately preparing students with background computer knowledge and critical thinking skills.” Many teachers felt unprepared to teach a course this technical and would like additional professional development. For example, one teacher said, “I don't have a background in cybersecurity--it did not exist when I was in college (I am that old). There is too little time to get caught up so that I KNOW what I am doing instead of trying to survive.”

Question 5; in your opinion, what could be a solution that would help you with teaching a Cybersecurity Fundamentals course? This question yielded two primary themes and their respective percent responses, 1) provide appropriate professional development and time to prepare (69%), 2) identify appropriate teaching materials (31%). Several examples were provided that illustrate the need for professional development and preparation time, such as a teacher stating that “Being patient and devoting the time necessary to prepare and/or find suitable curriculum materials,” or saying” Really, I need to dive deeper into the cyber range to see what's available.” More evidence of this theme comes with teachers new to this topic says, “I am still learning (networking) so continuing my professional development is needed on my part.” Evidence for the theme identifying appropriate teaching materials is explained by the statement “need to find suitable curriculum materials and collaborate with other teachers to learn their ideas and work with them to develop better-quality curriculum.” This is further highlighted when a teacher says, “If the state could come up with a cloud-based virtual networking simulation environment that students could access, along with simulations and exercise sets that went along with these, which would be a huge help in teaching this course.”

In addition to the above 5 open-ended questions, seven Likert-style questions were administered and were asked to rate the following questions as Strongly Agree, Somewhat Agree, Neutral, Somewhat Disagree, Strongly Disagree. Fifteen teachers responded to this
portion of the survey, however 4 teachers did not enter ratings in this section. The questions are as follows: 1) Content was written at a level I could understand; 2) Content was informative; 3) Content was relevant; 4) Content was complete; 5) Visuals were engaging; 6) Visuals were relevant; 7) I learned something new. Below are frequency tables for responses for each question:

### Content was written at a level I could understand

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### Visuals were relevant

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### I learned something new

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**Impact**
Dissemination Efforts

Publications:
1. “Digital Educational Modules Development for the Career and Technical Cybersecurity Pathways During Covid-19 Pandemic” has been conditionally accepted for publication in The Technology Interface International Journal. The research team is currently working on paper revisions submitted on October 1, 2021.

Presentations:

Websites:
1. https://sites.wp.odu.edu/odu-nps-cs-cybersecurity-pathway-for-cte/
Awards:
1. The research team has won a Creating Excellence Award from Virginia Department of Education (VDOE) in the Business Partnerships category in June 2021.
2. Alvaro Rivera-Coreas recognized at the Virginia Cybersecurity Education Conference as part of the first Virginia Cyber Range Cyber Signing Day, Wednesday, July 21, 2022. As part of signing day, he received a letter from Senator Mark Warner. Alvaro Rivera-Coreas was one of five students selected to be recognized.
3. Nora Willkreson, Granby High School student has been selected to join Air Force Academy and to represent one of the Virginia candidates for Presidential CTE Scholars [https://www.youtube.com/watch?v=XmQ83oQTA4]. This video is created to feature NPS CTE programs and posted on the Norfolk Public Schools website.

Overall project implementation proved successful as the team completed activities and engagement as indicated in the proposal given modifications described in reporting in Years 1, 2, and 3 by the PI. Effectiveness was measured using t-tests and showed significant improvement at every measure from pre to post. Dissemination efforts were strong and successful, both in terms of academic and educational dissemination as evidenced by the PI and her team’s publishing, presenting, and curricular outreach.

Summary and Implications

Per the “Grant Performance Report Project Status Charts” from Years 1, 2, and 3, changes in performance measures are described across year.

<table>
<thead>
<tr>
<th>Performance Measure</th>
<th>Year 1, 2, and 3 Target Ratio and %</th>
<th>Year 1 Actual Ratio and %</th>
<th>Year 2 Actual Ratio and %</th>
<th>Year 3 Actual Ratio and %</th>
<th>Difference from Target to Year 2</th>
<th>Difference from Target to Year 3</th>
<th>Change from Actual Year 2 to Year 3</th>
<th>Difference from baseline (pref. meas. Descript.) to Year 3</th>
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<tr>
<td>1.1</td>
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<td>ND</td>
<td>18/60 30%</td>
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<td>-37%</td>
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<tr>
<td>1.2</td>
<td>62/126 49%</td>
<td>ND</td>
<td>33/126 26%</td>
<td>68/340 20%</td>
<td>-23%</td>
<td>-29%</td>
<td>-6%</td>
<td>+15%</td>
</tr>
<tr>
<td>1.3</td>
<td>54/109 50%</td>
<td>ND</td>
<td>28/109 26%</td>
<td>56/220 25%</td>
<td>-24%</td>
<td>-25%</td>
<td>+1%</td>
<td>+20%</td>
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<tr>
<td>2.1</td>
<td>5/6 83%</td>
<td>ND</td>
<td>5/6 83%</td>
<td>12/12 100%</td>
<td>0%</td>
<td>+17%</td>
<td>+17%</td>
<td>ND</td>
</tr>
<tr>
<td>2.2</td>
<td>6/12 50%</td>
<td>ND</td>
<td>4/12 33%</td>
<td>0/0 0%</td>
<td>-17%</td>
<td>-50%</td>
<td>-33%</td>
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## Performance Measure #

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<tr>
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<th>Performance Measure Description</th>
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<tbody>
<tr>
<td>1.1</td>
<td>Increase the current percentage (5%) of female students enrolled in course AP CS Principles to 50% by the end of the Year 3.</td>
</tr>
<tr>
<td>1.2</td>
<td>Increase the current percentage (5%) of female students enrolled in course IT Fundamentals to 50% by the end of the Year 3.</td>
</tr>
<tr>
<td>1.3</td>
<td>Increase the current percentage (5%) of female students enrolled in course Cybersecurity Fundamentals to 50% by the end of the Year 3.</td>
</tr>
<tr>
<td>2.1</td>
<td>Maintain the current percentage of minority female students enrolled in Girls in Engineering after school clubs to 100% by the end of the Year 3.</td>
</tr>
<tr>
<td>2.2</td>
<td>Increase the current percent (0%) of female students enrolled in STEM after school club CS Honor Society to 50% by the end of the Year 3.</td>
</tr>
<tr>
<td>2.3</td>
<td>Increase the current percent (20%) female students enrolled in STEM after school club Cyber Patriots Team.</td>
</tr>
<tr>
<td>2.4</td>
<td>Increase the current percent (14%) of female students enrolled in STEM after school club Great Computer Challenge to 50% by the end of the Year 3.</td>
</tr>
<tr>
<td>3.1</td>
<td>Provide one PD (online or in-person) workshop for HS CTE teachers each year of the grant cycle.</td>
</tr>
<tr>
<td>4.1</td>
<td>Develop educational modules that can be integrated within the IT Fundamentals course cybersecurity CTE pathway.</td>
</tr>
<tr>
<td>4.2</td>
<td>Develop educational modules that can be integrated within the Cybersecurity Fundamentals course cybersecurity CTE pathway.</td>
</tr>
<tr>
<td>4.3</td>
<td>Develop educational modules that can be integrated within the Cybersecurity Software course cybersecurity CTE pathway.</td>
</tr>
<tr>
<td>4.4</td>
<td>Distribute Computer Science (CS) educational modules to all CTE cybersecurity teachers in the Commonwealth of Virginia.</td>
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These data suggest that the program was particularly impactful with respect to Performance Measures 1.1-1.3 (i.e., increasing participation of students who identify as female in CTE computer science courses). That success was not realized in enrollment in after school learning experiences as defined by program activities. Development and distribution of educational modules was also highly successful in that all modules were developed as described in the proposal narrative (with approved edits as necessary) and distribution occurred at a considerable percentage. There is confusion however on whether the actual performance figure should be listed as 100% versus 70% (in the chart) due to the way in which the modules are available/can be accessed. It could be argued that due to the online nature of the content, the 70% figure should in fact be 100%.

In summary, the project team appears to have implemented a strong program despite challenging conditions and achieved their primary goals and objectives. During the life of the project, the team has managed to produce four manuscripts in various stages, five presentations, maintained three web resources, and provided regular outreach via Newsletters and Lunch and Learn meetings. The research team was also recognized by the Virginia Department of Education (VDOE) for their work with this project. SCS has discussed with project leaders additional conference venues, including National Association for Research in Science Teaching (NARST) and the American Educational Research Association (AERA). Both conferences have SIGs/RIGs that are related to project foci and would expand dissemination. Additionally, participants have received recognition regarding their efforts as described in the narrative of this report. Given the timeline and challenges, the project team was exceptionally
STEM Consulting Services

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