Employer Degree Apprenticeship in Secure Software Development - A Collaborative Approach

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Abstract

Cybersecurity education, knowledge, and skills are extremely important to safeguard data, systems, and networks and protect the critical infrastructure against malicious attacks and intrusions, and a number of academic institutions offer cybersecurity programs classified as minors, concentrations, certificates, and degrees programs with varying amount of course credits. Despite our best efforts, the cyberattacks on our infrastructure are on the rise, and course work alone is not going to solve this severe shortage of cybersecurity skilled workers, and the theoretical knowledge gained from the course work must be enhanced with real-world experience through hands-on skills using a flexible training schedule. This model is otherwise called the "Apprenticeship Model", and there are a number of existing apprenticeship models. But the majority of these models are primarily focused on the associate degree programs and are limited to few Cybersecurity/Information Technology (IT) job categories. Also, there is a lack of awareness in the Cybersecurity/IT community, especially in the Historical Black Colleges and Universities (HBCU) community about the cost/benefits of apprenticeships and the government/industry/academic collaboration needed to design and launch degree apprenticeships. We are currently working to develop an Employer Degree Apprenticeship program for Cybersecurity/IT degrees at HBCUs and our core group leadership has also met with representatives from the Department of Labor (DoL), International Business Machines (IBM), and others to discuss registered apprenticeship and mapping of cybersecurity curriculum to National Initiatives on Cybersecurity Education (NICE) framework competencies. This effort is ongoing (published in CIEC 2022 by the authors), and the objective of this paper is to share our experiences with IT/cybersecurity community.

Introduction

The abundance of data and resources in cyberspace makes it a lucrative battlefield for hackers to carry out malicious acts such as phishing, identity thefts, denial-of-service, and ransomware. More importantly, complex and sophisticated cyber-attacks such as advanced persistent threats pose serious risks to critical infrastructures such as energy, transportation, financial services, agriculture, healthcare, and public health. In 2019, many ransomware attacks were impacting at least 948 government agencies, educational institutions, and healthcare providers in the U.S. resulting in a cost of more than $7.5 billion [1].

A 2018 report shows that more than half of all data breaches globally are expected to occur in the United States by 2023 [2]. As a result, cybersecurity education, knowledge, and skills (KSA) are extremely important to safeguard data, systems, and networks and protect the critical infrastructure against malicious attacks and intrusions, and many academic institutions offer cybersecurity programs classified as minors, concentrations, certificates, and degree programs with varying amount of course credits. Offering these cybersecurity programs has improved the situation but the field still suffers from ashortage of skilled workforce.

According to Cyberseek.org [3], there are currently 507,924 cybersecurity job openings but the skilled Cybersecurity workforce supply/demand ratio is very low. It is clear that course work alone is not going to solve this severe shortage of cybersecurity skilled workers, and the theoretical knowledge gained from the course work must be enhanced with real-world experience through hands-on skills using a flexible training schedule. This model is otherwise called the "Apprenticeship Model", and there are many organizations such as DoL, Apprenticeship.gov, National Institute of Standards and Technology (NIST), NICE, and ISHPI Information Technologies who have developed Apprenticeship models for IT and Cybersecurity for addressing the shortage of skilled IT/Cybersecurity workers. But the majority of these models are primarily focused on the associate degree programs and are limited to few Cybersecurity/IT job categories. Also, there is a lack of awareness in the Cybersecurity/IT community, especially in HBCUs about the cost/benefits of apprenticeships and the government/industry/academic collaboration needed to design and launch degree apprenticeships.

We are currently working on such an initiative that is based on the model shown below:

Employers + HBCU +NICE Framework Work Roles + Competency + Aligned Degree Curriculum + On-The-Job Training + Registered Degree Apprenticeships at Scale = Industry/Government/Academic Collaboration +Solving IT and Cybersecurity Skills Shortage + Increasing Workforce Diversity.

Our model is based on the following eight steps:

- IT and Cybersecurity Workforce Summit
- Core Group Inaugural Meeting to Establish Mission
- Career Pathways through Degree Apprenticeships
- Employer Survey to Establish Hard-to-fill IT and Cybersecurity Work Roles
- Mapping Degree Curricula to NICE Framework Competencies, and Knowledge, Skills, and Abilities for Hard-to-fill Work Roles
- Degree Apprenticeships Return on Investment and Funding Model
- Registered Apprenticeship Work Process Standard for Hard-to-fill Work Roles
- Employer Partners' Meeting to Establish Roles and Responsibilities to Design and Launch Degree Apprenticeship Cohorts

On-Going Work

Here is a brief description of the On-Going work [4]:

IT and Cybersecurity Workforce Summit

South Carolina State University, a public HBCU and a fast-growing Information Technology defense contractor ISHPI, Inc, jointly hosted an HBCU Cybersecurity Workforce summit in February 2020. More than sixty (60) participants including senior executives from academia, industry, and government such as Charleston Regional Development Alliance (CRDA), Apprenticeship Carolina, DoL, IBM, NICE, and others participated in this event and shared their experiences and ongoing apprenticeship activities.

Core Group Inaugural Meetings

One of the important outcomes of this summit is the formulation of an apprentice working group with a mission to plan, design, and launch employer-led Cybersecurity/IT degree apprenticeship cohorts at SC HBCUs by fall/winter 2020. This working group has met a number of times with active participation from HBCU faculty, representatives from Apprenticeship Carolina, and CRDA. The group leadership has also met with representatives from DoL and IBM to discuss registered apprenticeship and mapping of cybersecurity curriculum to NICE framework competencies.

Employer Survey to Establish Hard-to-fill IT and Cybersecurity Work Roles

The group leaders decided to survey employers in SC to better understand the hard-to-fill positions in cybersecurity/IT in their organizations and received a number of positive responses. The employer response identified four (4) hard-to-fill work roles in IT and Cybersecurity, and one of these hard-to-fill work roles was the Secure Software Developer work role. This was because of the availability of properly skilled graduates to meet this demand. The group leaders met with the representatives from participating South Carolina HBCUs, and it was decided that HBCUs will review their existing Computer Science/Cybersecurity/IT curriculum and map it to the NICE framework competency and KSA's. Once fully developed with employer partnership, this Degree Apprenticeship Program will be one of its kind in SC and the nation. Benefits to both employers and apprentices include:

- availability of a skilled and productive Cybersecurity and IT workforce with knowledge, skills, and competency
- diverse workforce
- reduced on the job training costs
- enhanced retention
- better wages and career advancement
- better addressing the national Cybersecurity and IT challenges

Career Pathways through Degree Apprenticeships

The Degree Apprenticeship Program has the potential of providing students with various career opportunities/pathways. It provides students with the opportunities to earn a salary by working with an employer while enrolled in a curriculum of study. They learn the practical skills necessary to succeed in high-demand careers in the industry.

Mapping Degree Curricula to NICE Framework Competencies, and Knowledge, Skills and Abilities for hard-to-fill Work Roles

The NICE Framework is a blueprint to categorize various cybersecurity and IT-related occupations and it provides a wide group of stakeholders with competencies and KSA requirements for a wide range (entry-level to advanced level) of cybersecurity and IT jobs. The intent of this framework is to provide a uniform template/guidance for cybersecurity education and workforce development. This framework was developed collaboratively by NICE, the Office of the Secretary of Defense, and Department of Homeland Security (DHS). Although the NICE framework is used by many employers, the use of NICE framework in academia is rather limited until now because of its complexity [5].

Registered Apprenticeship Work Process Standard for Hard-to-fill Work Roles

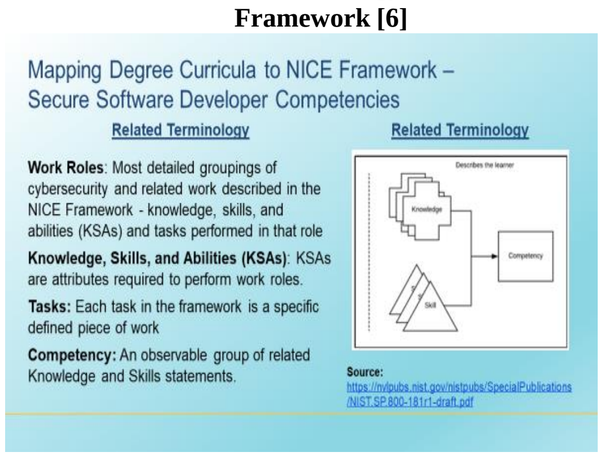
The Work Process Standard is a DoL form consisting of two parts – Work Process Schedule and Related Instruction Outline. We have completed this form Our Degree Apprenticeship program consists of 6 Work Process Schedules and includes 11 Computer Science/Cybersecurity courses with 495 hours of instruction.

We filed this form along with other required documents to DoL in November, and we are glad to say that our Degree Apprenticeship Program is registered with DoL in the state of South Carolina in November [11].

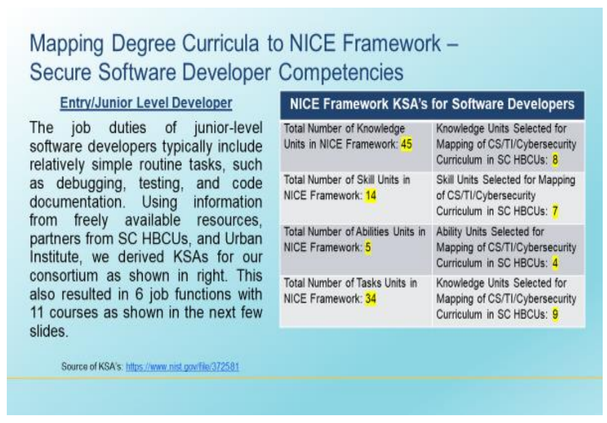
Employer Partners' Meeting to Establish Roles and Responsibilities to Design and Launch Degree Apprenticeship Cohorts

We have drafted a document highlighting the apprenticeship cohort selection process and the roles and responsibilities of various stakeholders. We have scheduled a meeting with the stakeholders on December 15, 2021, to discuss and finalize the draft.

Some Relevant Terminology used in NICE Framework [6]



NICE Framework Mapping for Specialty Area Software Developer



Job Functions and Competencies [8, 9]

Here are modified examples of mapping of two job functions and their mapping to the NICE framework. The original job function competencies are developed by Urban Institute and are available in the public domain. Here is a summary of the job functions and corresponding job descriptions.

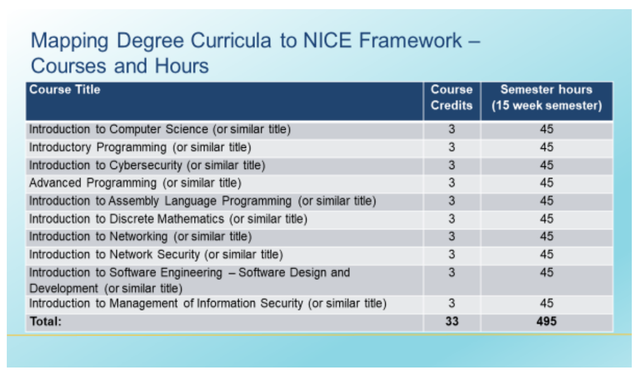
Job Functions	Job Descriptions
JOB FUNCTION 1: Participation in the Development of a new platform – collecting and analyzing user needs	Participates in and supports the collection and analysis of user needs for the development of a new secure software platform by assisting the Principal Developer and the team.
JOB FUNCTION 2: Supporting the development of a new platform	Participates in and support designing a of new software platform by assisting the Principal Developer and the team.
JOB FUNCTION 3: Modifying an existing platform	Participates in and supports the analysis of performance issues and limitations of an existing platform and identifies needs for modification of an existing platform by assisting the Principal Developer and the team.
JOB FUNCTION 4: Testing, Debugging, and Deployment	Supports the team or Principal Developer in the testing, debugging and deployment of the new or modified secure software platform
JOB FUNCTION 5: Monitoring and Maintenance	Supports the team or Principal Developer in the monitoring and maintenance of the new or modified secure software platform.
JOB FUNCTION 6: Customer Support and Documentation	Supports the team or Principal Developer in providing technical support to customers who need assistance utilizing client-level hardware and software in accordance with established or approved organizational process components

Table 2 – Competencies with Knowledge, Skills, and Abilities (Job Function 1 is shown as an example)

JOB FUNCTION 1 Participates in and supports designing newsecure software or platform with the appropriate team			
Competencies	Core or Optional	OJT	RTI
A. Supports team or team members in various phases ofsecure software development under supervision	Core	X	X
B. Participates in the selection of prototype suited for the project, if any; supports the team in the identificationof appropriate languages, operating systems, security, and monitoring methods applicable for the final program	Optional	X	
Knowledge, Skills and Abilities			
KNOWLEDGE	**SKILLS**	**Abilities**	
• Knowledge of computer networking protocols, and security methodologies. • Knowledge of computer programming principles • Knowledge of complexdata structures. • Knowledge of programming languagestructures and logic. • Knowledge of securecoding techniques. • Knowledge of software debugging principles. • Knowledge of software engineering. • Knowledge of operatingsystems.	• Skill in conducting software debugging. • Skill in creating programs that validate and process multiple inputs including command line arguments, environmental variables, and input streams. • Skill in developing and applying security system access controls. • Skill in writing code in a currently supported programming language (e.g., Java, C++). • Skill in developing applications that can log and handle errors, exceptions, and application faults and logging. • Skills in communicating (both written and oral) with stakeholders	• Ability to develop securesoftware according to secure software deployment methodologies, tools, andpractices. • Ability to clearly document and recordactivities. • Ability to clearly communicate withteam members and external partners	

OJT – On the Job Training (customarily learned in a practical way through a structured, systematic program of on-the-job supervised training supplemented by related technical instruction.

RTI – Related Technical Instruction (Related instruction is commonly provided in the classroom, but other types of instruction, such as online learning and individualized instruction are also permitted)



Course Title	Course Credits	Semester hours (15 week semester)
Introduction to Computer Science (or similar title)	3	45
Introductory Programming (or similar title)	3	45
Introduction to Cybersecurity (or similar title)	3	45
Advanced Programming (or similar title)	3	45
Introduction to Assembly Language Programming (or similar title)	3	45
Introduction to Discrete Mathematics (or similar title)	3	45
Introduction to Networking (or similar title)	3	45
Introduction to Network Security (or similar title)	3	45
Introduction to Software Engineering – Software Design and Development (or similar title)	3	45
Introduction to Management of Information Security (or similar title)	3	45
Total:	**33**	**495**

We expect the classroom instruction (RTI) part to cover the above courses related to the NICE framework KSA for Software Developer usually present in a Cybersecurity/IT curriculum.

Results

- Registered with the Department of Labor (DoL) with SC State as the sponsor and lead
- SC HBCU Member Institutions – Benedict College, SC State University, and Voorhees College
- Program Offered – Degree programs/Minors in Computer Science/Cybersecurity
- Enrollment (2019-20 numbers): Benedict 50; SC State – 85; Benedict – Data NA
- Other SC HBCU Institutions Expected to be Members – Claflin University, Morris College, and Allen University
- Industry Partners: Integer Technologies and Robert Half
- Recruitment of first apprenticeship cohort: Summer 2022 - Ongoing; 4 applicants from Benedict College, SC State University, and Voorhees College

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