Meeting Industry Needs for Secure Software Development

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***Abstract*—In this paper, we describe a partnership between the Central Illinois Center of Excellence for Secure Software (CICESS) and Illinois Central College (ICC) that resulted in the creation of a two-year degree program in Secure Software Development. That program incorporated an apprenticeship model and the Software Engineering Institute's software assurance curriculum recommendations at the community college level. We describe the industry needs, the software assurance curriculum recommendations, how ICC implemented those recommendations, and the return on investment model presented to industry.**

Keywords—Software Assurance Education, Industry/University Collaboration, Secure Software Development

I. Introduction

Modern society increasingly relies on software systems that put a premium on quality and dependability. The extensive use of the internet and distributed computing has made software security an increasingly prominent and serious problem. The growing number of cyber attacks represents a pervasive threat to critical infrastructure and other essential software-dependent systems. Defective software is insecure and a source of cybersecurity vulnerabilities that attackers exploit. It is no longer acceptable to leave the task of finding and fixing software defects until after the product has been delivered [1].

As a result, the interest in and demand for software security specialists have grown dramatically in recent years, and there is an urgent need for a workforce capable of developing software that is assured and secure from cyberattacks. The $(ISC)^2$ Global Information Security Workforce Study (GISWS) forecasts a shortfall of 1.5 million cybersecurity professionals by 2020 [2]. Government sources also project critical shortages of cybersecurity professionals.

The Software Engineering Institute (SEI) and government, commercial, and educational organizations have expressed interest in educating the software security workforce. However,

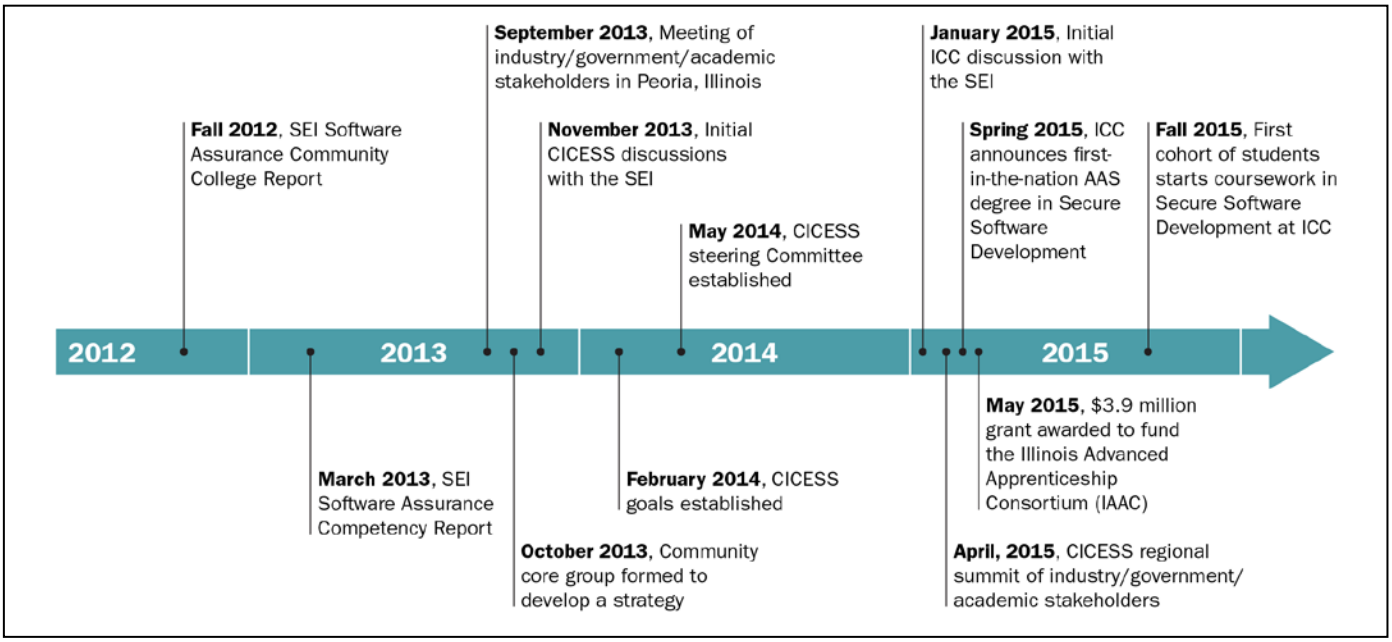

Fig. 1. Timeline for Establishing Secure Software Development Program

until recently, there was little guidance on how to prepare for a career in software security. Most specialists start with some sort of degree in computing, maybe with a programming course that included topics in secure coding; then, through on-the-job training and experience, they gain proficiency in certain aspects of building secure software. It can be a difficult and meandering road. Unfortunately, this approach does not provide the preparation needed for addressing current security risks, which are part of modern software and software-intensive systems [3, 4].

The SEI's Software Assurance Curriculum Project developed a series of software assurance curriculum recommendations, along with a software assurance competency model, and numerous additional educational resources and artifacts (listed at http://www.cert.org/curricula/). A number of universities and training organizations have adapted various aspects of the curriculum work. Courses and tracks based on the curriculum recommendations have been developed and offered by Carnegie Mellon University, Stevens Institute of Technology, The U.S. Air Force Academy, University of Detroit Mercy, University of Houston, and $(ISC)^2$. In addition, Polytechnic University of Madrid designed a Master of Software Assurance degree program. It is possible that there are additional offerings based on the software assurance curriculum work that have not been reported to us. There was a substantial outreach effort by the curriculum team resulting in numerous paper and conference talks, and there is a LinkedIn Software Assurance Education interest group with over 500 members.

In this paper, we describe a unique collaboration involving industry, government, and academia. Using the SEI's software assurance curriculum recommendations at the community college level, the Central Illinois Center of Excellence for Secure Software (CICESS) partnered with Illinois Central College (ICC) to develop a two-year degree program in Secure Software Development, incorporating an apprenticeship model. This is the first community college program based on the software assurance curriculum recommendations that we know of, although many community college programs in information security exist. We describe the industry needs, the software assurance curriculum recommendations, how ICC implemented those recommendations, and the return on investment (ROI) model presented to industry. We conclude this paper with our future plans. The timeline of activities in Figure 1 shows the major accomplishments at a glance.

II. Meeting Industry Needs

In September 2013, Girish Seshagiri (an author of this paper) met with industry, government, and academic stakeholders in Peoria, Illinois, and proposed an initiative to create software developer jobs and make the Peoria area a national center of excellence for producing software that is secure from cyber attacks. He proposed using the German apprenticeship model to create a skilled workforce that is trained, apprenticed, mentored, and certified in secure software production. The initiative would partner with the school districts to encourage graduating high school seniors to pursue software development careers in the Peoria area.

A. The Case for the German Dual Model Apprenticeship

In many countries, including the U.S., there appears to be a mismatch between the kinds of jobs offered and the qualification profiles that job seekers attain from college education. The skills gap, as it is known, is too high with significant adverse consequences to employers and job seekers alike.

Over the last several decades, the German dual model has successfully helped match jobs and skills. Dual apprenticeship programs are popular not only in Germany, but also in Switzerland, Austria, and several other European countries. *Dual* here means that, in addition to time spent in a vocational school, this theoretical training involves relevant practical training and experience at a partnering company, with the apprentices receiving a salary as they gain work-related skills. There is a growing awareness that the U.S. could reap substantial benefits from this model.

Apprenticeships allow businesses to meet the growing demand for skilled workers and lead workers to higher wages and better employment outcomes. Furthermore, apprenticeships are a smart public investment. A recent study in Washington State found that for every $1 in state investment in apprenticeships, taxpayers received $23 in net benefits—a return that far exceeds that of any other workforce-training program in the state [5, 6].

In October 2013, a community core group formed to develop a strategy for going forward with this project. The group received valuable input from major cybersecurity education initiatives [7, 8] and the SEI. It was clear to the group that a key cybersecurity focus area was secure software development. What was less clear was how many secure software development professionals were needed by employers in central Illinois and how quickly a workforce that meets their needs could be created. The group appointed subcommittees to research and quantify the supply of and demand for secure software developers in central Illinois.

Initially, we formed an ad hoc group to promote the apprenticeship model to create secure software middle class jobs because the timing was right considering the rise in cyberattacks and the need for secure software development. We analyzed the list of local employers in Central Illinois and discussed with some of them their difficulty in finding qualified local candidates to fill current software development job openings as well as their needs for secure software development. The group set an aggressive goal of cohort sizes of 20 to 40 apprentices per semester at ICC, a local community college with a track record of successful partnerships with local employers.

Table I lists the goals and achievement methods that the group established in February 2014.

TABLE I. GOALS OF THE COMMUNITY CORE GROUP

Goal	Method of Achievement
Direct connection between education and a job without accumulating debt	• Use the German apprenticeship model (described earlier) where the primary relationship is between the apprentice and the organization. • Apprentices will earn progressively increasing wages during the apprenticeship's on-the-job training.
Skilled workforce for secure software	• Create new capabilities and not just a hiring tool. • Implement on-the-job training and mentoring by journey workers. • Establish nationally recognized certifications to assess and validate competencies in skilled software development.
World-class education providers with core common standard curriculum offerings	• Follow an academic curriculum based on the SEI Software Assurance curriculum • Follow an apprenticeship curriculum that includes the SEI Personal Software Process (PSP) topics. • Coordinate the curriculum with alternate multi-week blocks of classroom instruction and on-the-job training. • Invest in faculty development and train the trainer.
A standard competency-based, registered, apprenticeship program with uniform guidelines	• Secure the defined software development competencies. • Access the Registered Apprenticeship Program.
Successful individuals	• Ensure that individuals receive more than just classroom training and internship. • Implement apprenticeship and on-the-job mentoring to guide an individual's progression through secure software competency levels and certification. • Reach out to women and minorities to increase participation in secure software careers.
Central Illinois is the destination choice for an exciting career.	• Increase high school students' awareness of secure software principles and exciting career opportunities. • Promote the dual model of company apprenticeship combined with vocational education at ICC as a pathway to middle-class jobs.
A skills formation and workforce development model scalable to other occupations and other communities across the nation	• Collaborate with local, statewide, and national workforce development intermediaries and community colleges. • Share lessons learned with others.

In May 2014, the group established a steering committee consisting of representatives from three local employers, ICC, local workforce development intermediaries, and the German American Chamber of Commerce Midwest (GACCM). The committee's goal was to design and implement the CICESS dual model program. The GACCM provided subject-matter expertise in the dual model implementation. ICC took the initiative to form a consortium of nine Central Illinois community colleges for scaling up CICESS implementation in other communities. First, the steering committee identified existing applicable efforts [9, 10]. Then, the committee leveraged those efforts by participating in relevant working groups and forums.

For ICC, demand was based on the employers who were part of the CICESS steering committee. As noted, we held a number of meetings and we also looked at local labor statistics that described a growing market in IT areas in the Peoria area. The timing seemed right as well given the local support from employers who were already involved and passionate about the program itself, the CMU curriculum and the development of an apprenticeship program. By the end of 2014, ICC had recognized the need to include concepts of computer security and software assurance in the current Computer Science Associate Degree program. As a result, the college modified its computer science courses and incorporated the SEI Software Assurance Curriculum and, with employer input, created an Associate of Applied Science (AAS) in Secure Software Development degree.

The steering committee designed other elements of the CICESS:

- Incorporated relevant topics from the SEI process models in a standard apprenticeship curriculum
- Incorporated $(ISC)^2$ training courses in the curriculum to prepare apprentices for acquiring standard industry certification for Associate of Certified Secure Software Lifecycle Professional (CSSLP) from $(ISC)^2$ to validate secure software development competencies
- Working with ICC faculty, developed the schedule for the alternating blocks of weeks of academic instruction and apprenticeship on-the-job training in the dual model
- Selected Berger Aptitude Test (B-Apt) for Computer Programming and established Pass/Fail criteria for entry to the apprenticeship program
- Specified recurring and one-time-only fees from participating employers for ongoing program administration, apprenticeship curriculum development, and train-the-trainer materials for the CICESS to be self-sufficient
- Set up guidelines for minimum hourly wages for the apprentices with flexibility to meet varied human resources practices of participating employers

In April 2015, the steering committee convened a regional summit of industry, government, and academic stakeholders and announced the planned launch of the first CICESS cohort in Fall 2015 with the anticipated time line shown in Table II.

The steering committee made a strategic decision to become an official project of the Greater Peoria Economic Development Council (GP EDC). The EDC's mission is to drive economic growth in Greater Peoria through targeted

TABLE II. CICESS TIME LINE

Semester	Tasks
Spring 2015	• ICC announces first-in-the-nation AAS degree in Secure Software Development. • Apprenticeship program is defined and launch date is finalized. • Program is announced to the general public.
Summer 2015	• Follow-on meetings take place with additional potential participating employers. • ICC receives applications for admission to AAS degree in Secure Software Development.
Fall 2015	• AAS degree Fall semester classes begin with first batch of students. • Students interested in the CICESS apprenticeship are tested for computer programming aptitude. • Additional employers sign letters of commitment with the Greater Peoria Economic Development Council (GP EDC) to hire apprentices. • Employers begin recruiting process and send offer letters to selected candidates. • Outreach occurs to community colleges to begin planning for secure software curriculum implementation and considering the dual model.
Spring 2016	• Apprentices begin alternate blocks of weeks of study and on-the-job learning at company site.
Summer 2018	• First cohort with AAS degree graduates with little or no debt. • Those graduates secure full-time job without need for additional training. • 10 to 20 new middle-class jobs are created for local citizens.

business and talent development and attraction. As an official economic development initiative, the CICESS gained access to the local employers to promote its apprenticeship as a talent pipeline and workforce development strategy. We needed an organization that could enter into agreements with employers and provide administrative support for marketing and finance. Since the GP EDC's board is made up of local employers, working with them was important.

The steering committee demonstrated to employers' decision makers the positive ROI of the CICESS apprenticeship in building a talent pipeline with an ROI calculator tool developed by the Manufacturing Institute. (The CICESS ROI is explained in detail in Section V.)

The steering committee is currently developing CICESS documentation to meet the Registered Apprenticeship Program standards [11].

In December 2014, an announcement was made of $100M in grants to transform apprenticeships for the 21st century by expanding training into new high-skilled, high-growth industries [12]. The CICESS met and in some cases exceeded the eligibility requirements of the grant proposal:

- American Apprenticeship (also referred to as Registered Apprenticeship) programs combine job-related technical instruction with structured on-the-job learning experiences.
- 21st century apprenticeship approaches are flexible and can be easily customized to meet the needs of the employer and apprentice.
- Apprentices are hired and earn a wage upon registration, and they receive progressive wages commensurate with their skill attainment throughout the training program.
- Upon successful completion of all phases of on-the-job learning and related instructional components, registered apprentices receive nationally recognized certificates of completion leading to long-term career opportunities.

The CICESS agreed to support the Illinois Manufacturing Association (IMA) in its role as the lead applicant for the American Apprenticeship Initiative (AAI) grant in Illinois.

In May 2015, the IMA was awarded a $3.9 million grant to fund the Illinois Advanced Apprenticeship Consortium (IAAC) [12]. The CICESS became a member of the IAAC, and is thus eligible to receive grant funds.

In July 2015, the DoL Office of Registered Apprenticeship reached out to the CICESS: "We believe that the CICESS industry-led apprenticeship approach and partnership with community colleges is an excellent model of a successful apprenticeship program and exactly what we're looking for in our Leaders of Excellence in Apprenticeship Development, Education and Research (LEADER) initiative. It is a new initiative that we kicked off following the State of the Union earlier this year to help meet the President's goal of doubling the number of apprenticeships in the U.S. We would like to invite the CICESS to be a LEADER in apprenticeship – and to highlight the efforts and commitments that the CICESS has put forth on apprenticeship development and expansion."[1]

From November 2 to November 6, ICC celebrated National Apprenticeship Week (NAW) with events throughout the week to:

1) Promote apprenticeships in manufacturing, healthcare, and IT sectors to support the President's goal of doubling the number of apprenticeships in America.

2) Demonstrate ICC's partnerships with employers to create middle-class jobs.

3) Share goals, progress to-date and lessons learned from projects that are recipients of the American Apprenticeship Initiative grant funds.

4) Recognize the chief executive officers (CEOs) of the companies that have signed letters of commitment with the GP EDC to hire CICESS apprentices.

The NAW events were officially inaugurated in Illinois on November 2, 2015 [13, 14].

[1] Email from DoL official to Girish Seshagiri, July 2015.

III. THE CURRICULUM AND COURSE MATERIALS

As noted earlier, the SEI recommendations for software assurance at the community college level were adopted for the Illinois Central College Program. These recommendations were part of the body of work of the SEI's Software Assurance Curriculum Project. The SEI Software Assurance Curriculum Project was established in 2009, and developed a set of four volumes described in Table III [15, 16, 17, 18]. In the curriculum, software assurance is defined as *the application of technologies and processes to achieve a required level of confidence that software systems and services function in the intended manner, are free from accidental or intentional vulnerabilities, provide security capabilities appropriate to the threat environment, and recover from intrusions and failures*. Since then, the definition has evolved, but it provides a useful context for discussion of the curriculum work and its transition.

Part of the reason we focus on community college education (in addition to four-year undergraduate degree programs and master's degree programs) is that, according to the American Association for Community Colleges, roughly half of U.S. undergraduate students have attended community college [19]. Community colleges provide access to post-secondary education that minority, low-income, and first-generation college students may not otherwise have. These colleges also prepare students for transfer to four-year institutions, help working adults prepare for new careers, and offer noncredit programs that offer a range of knowledge and skills.

In Volume IV [18], after studying related degree programs, we introduced a suite of six courses that could form part of a two-year degree program in software assurance. The first three courses modify existing courses from the Association for Computing Machinery Committee for Computing Education in Community Colleges (ACM CCECC) to add a security emphasis. The other three courses are more specialized. In the report, we include prerequisites, syllabi, sources, and Bloom's taxonomy levels for each course. Brief descriptions from Volume IV follow:

Computer Science I: This course is the first in a three-course sequence that provides students with a foundation in computer science. Students develop fundamental programming skills using a language that supports an object-oriented approach, secure coding awareness, human-computer interactions, and social responsibility.

Computer Science II: This course is the second in a three-course sequence that provides students with a foundation in computer science. Students develop intermediate programming skills using a language that supports an object-oriented approach, with an emphasis on algorithms, software development, secure coding techniques, and ethical conduct.

Computer Science III: This course is the third in a three-course sequence that provides students with a foundation in computer science. Students develop advanced programming skills using a language that supports an object-oriented approach, with an emphasis on data structures, algorithmic analysis, software engineering principles, software assurance checklists, and professionalism.

TABLE III. SEI SOFTWARE ASSURANCE CURRICULUM PROJECT DOCUMENTS

Name	Description
Volume I: Master of Software Assurance Reference Curriculum [15]	Provides material for establishing or revising a Master of Software Assurance (MSwA) program: curriculum development guidelines, graduate student outcomes, recommended student preparation, a SwA body of knowledge, a high-level MSwA curriculum architecture, and implementation guidelines.
Volume II: Undergraduate Course Outlines [16]	Provides the syllabi for seven undergraduate SwA courses: Computer Science I and II, Introduction to Computer Security, Software Security Engineering, Software Quality Assurance, Software Assurance Analytics, and Software Assurance Capstone Project. Each syllabus contains a course description, prerequisite knowledge, a list of learning objectives/topics, sources for the course, course delivery features, and course assessment features.
Volume III: Master of Software Assurance Course Syllabi [17]	Provides the syllabi for nine graduate SwA courses: Assurance Management, System Operational Assurance, Assured Software Analytics, Assured Software Development 1, Assured Software Development 2, Assured Software Development 3, Assurance Assessment, System Security Assurance, and Software Assurance Capstone Experience. The syllabi are organized similar to those in Volume II but also include a schedule of weekly in-class activities, suggested readings, and out-of-class assignments.
Volume IV: Community College Education [18]	Provides the syllabi for six SwA courses appropriate for community college students: Computer Science I, II, and III; Introduction to Computer Security; Secure Coding; and Introduction to Assured Software Engineering.

Introduction to Computer Security: This course provides an overview of the fundamentals of computer security. Topics include security standards, policies, and best practices; principles, mechanisms, and implementation of computer security and data protection; security policy, encryption, and authentication; access control and integrity models and mechanisms; network security; secure systems; programming and vulnerabilities analysis; principles of ethical and professional behavior; regulatory compliance and legal issues; information assurance; risk management and threat assessment; business continuity and disaster recovery planning; and security across the lifecycle.

Secure Coding: This course covers security vulnerabilities of programming in weakly typed languages like C and in more modern languages like Java. Common weaknesses exploited by attackers are discussed, as well as mitigation strategies to prevent those weaknesses. Students practice programming and analysis of software systems through testing and static analysis. Topics covered include methods for preventing unauthorized access or manipulation of data, input validation and user authentication, memory management issues related to overflow and corruption, misuse of strings and pointers, and inter-process communication vulnerabilities.

Introduction to Assured Software Engineering: This course covers the basic principles and concepts of assured

software engineering; system requirements; secure programming in the large; modeling and testing; object-oriented analysis and design using the unified modeling language (UML); design patterns; frameworks and application programming interfaces (APIs); client-server architecture; user interface technology; and the analysis, design, and programming of extensible software systems.

Subsequently, the project produced the Software Assurance (SwA) Competency Model [20]. Two of the objectives of the software assurance competency model are as follows:

- Enhance SwA curricula guidance by providing information about industry needs and expectations for competent SwA professionals.
- Provide direction and a progression for the development and career planning of SwA professionals.

From the viewpoint of the curriculum project, the four curriculum documents and the competency model set the stage for transitioning the work to educational institutions that wished to offer software assurance concentrations or full degree programs. This made for an ideal match with the objectives of Illinois Community College and CICESS. Next, we discuss the ways we have tried to meet the above two objectives in this unique community college program.

IV. THE COMMUNITY COLLEGE PROGRAM

ICC in East Peoria, IL is a comprehensive community college in the Illinois Community College system. Approximately 10,500 students are enrolled in 58 applied degrees, 72 certificates, and over 50 areas of study in associate of arts and associate of science degrees for transfer. ICC has a close working relationship with many local employers in central Illinois, particularly in the applied sciences with programs such as automotive technology; heating, ventilation, and air conditioning (HVAC); and welding and diesel.

In the Information Systems programs, these partnerships usually come in the form of student internships and work-study opportunities at the college. Apprenticeship programs with the employers involved in the CICESS had not been considered in prior years. The Information Systems programs at ICC consist of three areas of study: (1) science, (2) web, and (3) networking. Most of the students in the Computer Science programs are enrolled in one of the two Associate of Science (AS) transfer programs: (1) Computer Science with a Technical Emphasis or (2) Computer Science with a Business Emphasis. These were the programs first presented to the CICESS as an option for students to achieve their two-year degree prior to transferring to a four-year institution.

The employers involved with the CICESS were struggling to define the point at which a student would be prepared to work as an apprentice. In a traditional apprenticeship program, students would be employable from the beginning of their training and become more productive and able to work autonomously as time goes on. Because of the nature of the work of computer programming, these knowledge-management apprentices would be exposed to information of a much more sensitive nature and would need an established set of skills prior to starting. Unfortunately, this wouldn't lend itself to the typical Associate of Science transfer degree in which students take general education classes in English, communication, math, science, and the social sciences. Technical courses in their field of study are included but only to a limited degree. The typical computer science students would graduate in two years with only six to nine credit hours in computer science. The employers needed student apprentices who could program after the first semester of classes.

ICC faculty presented the option of the Applied Science degree in which students would take approximately 42 credit hours of technical computer science and database courses and only 18 credit hours in general education. ICC had an existing AAS degree in Computer Science and Database Development that seemed to more closely fit employer needs. The goal of the CICESS was to provide apprenticeships in Secure Software Development, however, so the current curriculum needed to include concepts of computer security and software assurance.

This is the point at which ICC faculty members began integrating the SEI Software Assurance curriculum with their own. The SwA curriculum recommendations for community colleges [18] consisted of the six courses described earlier. ICC faculty consulted with employers to determine which SwA courses were needed in addition to the SEI recommended courses. These are shown below:

- Essentials of Programming
- CSI: Programming in JAVA
- CSII: Advanced Programming in JAVA
- Introduction to Relational Database
- C# Programming
- Event Driven Programming in Visual Basic
- Advanced Programming in Visual Basic
- Mobile Application Programming
- Structured Query Language
- UNIX
- Database Administration
- Structured System Analysis
- Two electives from Computer Science, Web or Networking

Employers felt that students needed a good foundation in SQL, C#, and Mobile Applications in addition to the programming and security courses. With the addition of the third Java programming class and the three computer security courses identified while collaborating with the SEI, the new AAS degree in Secure Software Development consists of the following program requirements.

- CSI: Programming in Java
- CS II: Programming in Java

- CSIII: Advanced Programming in Java
- Structured Query Language
- Introduction to Relational Database
- C# Programming
- Mobile Application Programming
- Introduction to Computer Security
- Secure Coding
- Introduction to Assured Software Engineering
- Database Administration
- Structured System Analysis
- Two electives in computer programming, web, or networking, depending on employer needs

Students must also take 19 credit hours in general education courses.

When students enroll at ICC, they must provide high school transcripts, proof of other college credits, and scores from any standardized tests such as the ACT. An ACT composite score indicates whether a student will be successful doing college work. Students who don't have an ACT score or evidence of high school math and reading scores that show college preparedness must take the Compass Test. ICC administers this standardized test that assesses college readiness in the areas of math and reading. According to ICC, a score of 81 in reading is appropriate for the Secure Software program. Students also need to be ready for college algebra or take refresher courses to prepare them for that level of work.

Developed courses will be offered in a traditional 16-week semester, in 8-week courses, and in an online format. Students who wish to be eligible for the CICESS apprenticeship program will take the courses in accelerated 8-week sessions. In addition, employers wanted to be assured that the student apprentices had an aptitude for computer programming. Therefore, students who want to be considered for apprenticeship must also take a commercial computer programming aptitude test, the B-APT [21], and achieve a minimum score of 20. The B-APT assesses one's ability to do computer programming: "Organisations use the B-APT primarily to identify high aptitude candidates for programmer training. The examinee need have no prior experience in programming, and those with some experience gain no advantage over the inexperienced. The tutorial, which uses a hypothetical language, equates the potential of the inexperienced with the experienced."

ICC implemented and launched the first-in-the-nation AAS degree in Secure Software Development in the Fall 2015 semester with over 20 students in the program. We were off to a strong start with 18 students in all interested in taking the classes. Twelve of those students were eligible to work toward the apprenticeship. Like all students, we saw some drop out along the way or decide that secure software development was not what they wanted to pursue. We were down to twelve pretty quickly.

ICC provided the students with opportunities to work on resumes and interviewing skills prior to meeting the employers. Once the students met with the employers, 7 students clearly stood out as leaders. These seven were offered apprenticeship placement right away. One employer, the largest, was late in interviewing the apprentices and decided that none of the five final choices made a good fit. These students will be coached in the coming months to improve on their soft skills. The employer still wants to be involved but will wait until next year.

V. Return on Investment Model

One study estimates the cost to the U.S. economy caused by the skills gap at $160 billion a year [22]. The skills gap for tech workers is unacceptably high.

Analysis by the Georgetown University Center on Education and Workforce [23] found that U.S. employers spend nearly $600 billion annually on formal and informal post-secondary workforce education and training, in addition to the $400 billion spent on two-year and four-year college courses.

It takes an average of over five months for new employees to reach full productivity. The cost to replace an employee ranges from 6 to 24 months of the position's salary. These costs of the status quo are not sustainable in the global economy.

In the presentations to potential participating employers, we highlighted the following value proposition from the CICESS apprentice program:

- Augmentation of your current workforce development methods
- Ability to plan for and satisfy future needs for hard-to-fill secure software developers
- Ability to build a secure software talent pipeline that includes women and minorities who are trained, mentored, and certified
- A cost-effective solution to training and retaining new workers in secure software development
- High retention rates when apprentices become full-time employees

We emphasize these unique features of the design and implementation of the CICESS:

- Industry-defined competencies and certification in secure software development
- Employer-led governance model
- World-class training while paying apprentice wages
- Apprentices doing an increasing number of hours of productive work

We point out the capabilities of CICESS apprentices compared to other hires:

- Have an Associate degree in secure software development with nearly the same number of credit hours as a four-year Computer Science degree for technical courses
- Have over 3,000 hours of on-the-job training and work experience on real-life projects
- Are prepared for Associate CSSLP certification
- Are trained in quality methods
- Are trained to be self-managed
- Are experienced with your processes, standards, and procedures
- Understand your business fundamentals, corporate culture, and customer focus, leading to higher productivity and eventually leading to positions of increased responsibilities
- Are loyal to the company that trained and hired them, leading to a more stable workforce
- Are willing, content, and happy to work for a local employer, resulting in a motivated and satisfied workforce

One of the CICESS employers shows an anticipated return of $1.83 for every $1.00 invested in the CICESS apprentice using an ROI calculator developed by the Manufacturing Institute.

VI. Lessons Learned, Conclusions, and Future Plans

There are some areas where things could have gone better. Access to executives is needed to secure a commitment to a program of this type. In hindsight, we realize that improvement is needed in the following areas:

- We need to improve our access to decision makers at employers
- For workforce development, we need to reach out to Human Resources (HR) executives as well as CIOs and CISOs

In addition, to our surprise, large employers were not on board for the first cohort. We expected that it would be easier to get support from large employers than small or mid-size employers, but that turned out not to be the case.

We also learned that not all companies work under the same timing as the steering committee expected. The steering committee took for granted that the message that was being communicated to the employers was being heard and understood. We've learned that better communication, a strong message and timeline need to be conveyed to the employers and understood as they all go through the hiring process.

We also learned that while we have a need for this program in the area, not all companies and organizations are going to be interested in the same sequence of courses. One of the largest roadblocks we've run into in recruiting employers is that the program is taught with JAVA as the primary language. This didn't appeal to all of the employers and as a result many of them held back. We need to look at alternatives going forward. For example, we could offer more .NET courses and PHP.

On the other hand there were some unexpected bonuses:

- We were pleased with the caliber of the cohort in terms of positive attitude, motivation and work readiness.
- We received moral support and participation in our meetings from representatives of many organizations, including Department of Homeland Security, Department of Labor, National Institute for Standards & Technology, National Security Agency, and $(ISC)^2$.

It is apparent that a tremendous amount of work has gone into this effort, and each activity was essential for the success of the program so far. As noted here, the curriculum project started in 2009, and graduation of the first cohort of ICC students will take place in 2018. Collaboration among industry, government, and academia is a long and arduous process, but it is essential for successful implementation of apprenticeship programs for workforce development, and skills formation in high-wage, high-technology, secure software development positions.

Immediate plans for the CICESS include convening a meeting of the Community College Consortium to develop an action plan for a Fall 2016 launch in other Illinois locations to begin statewide scaling up of CICESS apprenticeships.

ICC has experienced quite a bit of interest in the academic program from many types of local employers. The apprenticeship program and the CICESS partnership is gaining membership and interest from businesses in the Peoria area. Some of those same organizations and others plan to send current employees to ICC to brush up their skills in Secure Software Development. ICC is developing a certificate program to answer this need.

ICC is also working with local high schools to develop pathways into the program through dual credit/dual enrollment. Students interested in this career path are encouraged to take computer science courses in high school, as well as logic, math, and other general education courses.

As stated earlier, 12 students of the initial cohort of 20 ICC Secure Software Development students are currently enrolled in the apprenticeship program. ICC will continue to promote the program throughout the year in order to start a second cohort in the Fall semester of 2016. Information sessions, high school visits, and promotions through workforce organizations are currently in the works to reach under-represented populations.

The SEI will continue its role in transitioning the SwA Curriculum and working with educators, industry, and government sectors that wish to improve the preparedness of secure software developers.

We look forward to continuing the current strategic partnership between the SEI, ICC, and the CICESS. We anticipate expansion of the secure software development programs at the community college level, broad recognition of

the CICESS apprenticeship program, and development of a certification in secure software development.

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