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Short Paper

Spawning Four-Year, ABET-Accreditable Programs in Cybersecurity from Existing Computer Science Programs in Thailand

Raymond Greenlaw
Department of Mathematics, Statistics, and CS, University of Namibia, Namibia
raymond.greenlaw@gmail.com

Nopadon Juneam
Department of Computer Science, Kasetsart University, Thailand
juneam.n@gmail.com
(corresponding author)

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Abstract

Purpose – Thailand faces many cybersecurity challenges. In the first few months of 2022 alone, there were over 300,000 cyber-attacks in the country, and annually the problem has gotten significantly worse. It is estimated that Thailand loses 286 billion US dollars per annum due to cybercrimes. These attacks include credit card fraud, phishing, ransomware, scamming, information, and identity theft, business email compromises, child pornography, intellectual property infringements, cyberstalking and harassment, denial of service, botnets, fake news, and stolen funds. To defend against cyber criminals, well-trained professionals in cybersecurity are needed. By 2025, there is an expected shortfall of over four million cybersecurity workers globally. We examine what it would take to spawn an accreditable four-year curriculum in cybersecurity from a typical Thai Bachelor of Science in Computer Science. At present, there are few university programs in Thailand dedicated to cybersecurity. We hope this work inspires educational institutions to develop quality four-year degrees in cybersecurity, with the goals of meeting workforce demands, reducing cybercrime, and promoting Thailand as a viable and healthy place to conduct e-business.

Method – The paper employs expert analysis to forge an accreditable program in cybersecurity from a computer science program.

Results – The authors describe an ABET-accreditable program in cybersecurity and show how to develop it in a step-by-step manner.

Conclusion – An ABET-accreditable program in cybersecurity can be spawned from a computer science program with relatively few additional courses and modifications while placing more emphasis on ABET's crosscutting concepts.

Recommendations – Institutions that are interested in developing four-year cybersecurity programs can begin crafting them in the manner described in this work.

Research Implications – Cybersecurity professionals can be developed.

Practical Implications – New quality cybersecurity programs can be developed promptly.

Social Implications – There will be more qualified professionals to help fight cybercriminals.

Keywords – cybersecurity, accreditation, cybersecurity-curriculum development, educational programs in cybersecurity

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INTRODUCTION

Like much of the world, Thailand has a growing and unsolved cybercrime problem. It is extremely detrimental to e-commerce there. This paper proposes a solution to this critical issue in the form of developing an educated workforce who can defend against cybercriminals and thwart cyber-attacks. The innovative way this paper aids in this goal is to demonstrate how to take a typical Bachelor of Science (BS) in Computer Science (CS) and convert it into an accreditable BS in Cybersecurity (CSec), meaning a high-quality program. Our methodology is to analyze critically a typical CS program in Thailand and a step-by-step manner show explicitly the changes that the program would need to undergo to achieve a CSec accreditation by the premier accrediting agency in the world. Our analysis and process effectively provide a fast track to the development of quality CSec programs. Graduates of such programs will form a cadre of workers who can help secure cyberspace in Thailand. This paper demonstrates a feasible and fast way forward to CSec workforce development.

LITERATURE REVIEW

ABET: World Leader in Accrediting Computing Programs

ABET, Inc. is the recognized world leader in accrediting programs in computing, engineering, applied and natural science, and technology. ABET is not an acronym. Over 35 professional

and technical member societies support ABET (ABET, 2022a). As of this writing, ABET accredits 4,350+ programs at 850+ institutions in 40+ countries (ABET, 2022a). On an annual basis, 175,000+ students graduate from ABET-accredited programs. This number is increasing. Graduates must meet the quality standards of their professions so that they are prepared to enter and succeed in the workforce. In the *2019-20 Criteria for Accrediting Computing Programs*, ABET published final Program Criteria for accrediting programs in CSec and other similarly named disciplines such as cyber operations, computer security, information assurance, information security, network security, and computer forensics (ABET, 2020). Leading members from ABET, industry, academia, government, and professional societies evolved the new Program Criteria to help establish high-quality programs in CSec to address workforce needs. The timing of this paper is appropriate, as there has been a great deal of interest in Thailand in ABET accreditation recently.

ABET Program Criteria are informed by the most knowledgeable people who have the latest and best curriculum information. Although guided by the most current curriculum models, ABET's Program Criteria themselves greatly influence how curriculums evolve at institutions. To become ABET accredited, a program must meet ABET's curriculum requirements. If one examines academic programs throughout the world, their curriculums often conform to the set of core topics specified in ABET's Program Criteria. Thus, the ABET curriculum model is the standard model, at least for those programs having or seeking ABET accreditation. For these reasons, we chose to adopt ABET's four-year model for CSec programs (ABET, 2022d), which is the best model available.

Need for a CSec Workforce and Thailand's CSec Problems

The USA's National Initiative for Cybersecurity Education (NICE) reported there was a *global* shortfall of 2,720,000 CSec professionals in 2021, with that number increasing rapidly by 13.5% per year (National Institute for Cybersecurity Education Factsheet on Workforce Demand, 2021). Thus, by 2025 there is expected to be a shortfall of approximately 4,500,000 CSec workers (National Institute for Cybersecurity Education Factsheet on Workforce Demand, 2021). Cloud services, data analysis, and programming are the areas facing the biggest demands (National Institute for Cybersecurity Education Factsheet on Workforce Demand, 2021). NICE reports that the most common job titles for such professionals are: CSec analyst, CSec manager, CSec consultant, software developer, systems engineer, network engineer, penetration and vulnerability tester, systems administrator, and CSec specialist (National Institute for Cybersecurity Education Factsheet on Workforce Demand, 2021). Graduates coming out of ABET-accredited CSec programs or programs with ABET-compliant CSec curriculums are ready to take on these roles.

In Thailand, cybercrimes such as credit card fraud, phishing, ransomware, scamming, information and identity theft, business-email compromises, child pornography, intellectual-property infringements, cyberstalking and harassment, denial of service, botnets, fake news, stolen funds, and online extortion are a growing daily occurrence: both in terms of frequency and significance of loss (Ngamkham, 2022; Bunnag, 2021; Kate, 2021; K. Johjit and T.

Thadaphrom, 2022; Leesa-Nguansuk, 2022). Due to the lack of educational programs in CSec, the country is unable to meet workforce demands. This paucity of workers contributes to cybercriminals being successful in Thailand. An educated workforce that is well-schooled in the fundamentals of CSec is necessary to remain one step ahead of cybercriminals. The CSec workforce needs to be able to think critically and adapt, as the field of CSec is rapidly evolving, as are the techniques and methods of attackers.

Thailand's Recent Interest in ABET Accreditation

In the 2021-22 ABET accreditation cycle, for the first time, several programs in Thailand received ABET accreditation. Due to how ABET allows programs to backdate their starting point for accreditation, assuming the program in place in earlier years was accreditable, these programs all are listed as being accredited from October 1, 2020, onward. Table 1 summarizes the state of ABET accreditation in Thailand (ABET, 2022b). All programs were evaluated by the Engineering Accreditation Commission (EAC) of ABET. None of the programs in Table 1 were evaluated by the Computing Accreditation Commission (CAC). The CAC is directly responsible for accrediting programs in CS, CSec, information technology, information systems, and data science (proposed). In this paper, our focus is on the CAC, CS, and CSec. Table 1 indicates there is a strong recent push for ABET accreditation within Thailand. It would be natural to develop and seek ABET accreditation for the much-needed programs in CSec.

Table 1. ABET-accredited programs in Thailand, as of this writing.

Institution	Engineering Program
Chiang Mai University	Mechanical
King Mongkut's University of Technology North Bangkok	Chemical
Mahidol University Phuttamonthon	Biomedical
Mahidol University Phuttamonthon	Chemical
Mahidol University Phuttamonthon	Civil
Mahidol University Phuttamonthon	Computer
Mahidol University Phuttamonthon	Electrical
Mahidol University Phuttamonthon	Mechanical
Suranaree University of Technology	Civil

METHODOLOGY

Representative Thai CS Programs and Spawning CSec from Them

There are many well-established, four-year programs in CS throughout Thailand. See (Kasetsart University, 2021; Chulalongkorn University, 2018; King Mongkut's Institute of Technology Ladkrabang, 2021; Chiang Mai University, 2021; Khon Kaen University, 2022) for representative examples. Of the 23 institutions in the USA that have achieved ABET accreditation for their four-year CSec programs (Greenlaw & Raj, ABET's Cybersecurity Accreditation: History, Accreditation Criteria, and Status, 2022), a majority evolved from departments of CS. It is natural to look to CS as a genesis for the rapid development of CSec programs. In

(Greenlaw & Mufeti, WEEF & GEEF, 2022), Greenlaw and Mufeti examined how difficult it would be to extract a two-year CSec program from an African four-year CS program. In this paper, to help Thais develop their needed CSec workforce promptly, we examine how a four-year program in CSec could be spawned from an existing four-year Thai CS program. In (Greenlaw & Mufeti, WEEF & GEEF, 2022), the authors looked at all aspects of ABET's General Criteria (ABET, 2022c). Here the focus is on curriculum. If a program is interested in seeking ABET accreditation rather than just becoming curriculum compliant, they can consult that paper.

We have analyzed and compared the CS curriculums listed earlier in this section with those at Kasetsart University (KU) (Kasetsart University, 2021). They are all relatively close in their course offerings and requirements. We chose KU as our representative CS curriculum from which to build a four-year CSec program, as this program captures the essence of many of the programs that we reviewed. Our analysis and methodology can be applied to other specific programs as desired. Although we examine how to construct an ABET-accreditable CSec curriculum from KU's CS program, institutions do not have to follow through and seek ABET accreditation for our work to be valuable to them. Offering a solid four-year CSec curriculum would help alleviate the tremendous shortage of CSec workers in Thailand. Over time, institutions can decide if they want to follow through and obtain a full ABET accreditation for their programs, as has been the recent trend for engineering programs in Thailand.

ABET's Accreditation Criteria for CSec

As mentioned in the introduction, ABET's Program Criteria for CSec applies to CSec and similarly named programs (ABET, 2020). Programs become ABET accredited by satisfying ABET's General Criteria and specific Program Criteria. In this work, we focus on curriculum. The computing General Criteria must be satisfied by all programs seeking accreditation from the CAC. We first describe the curriculum requirements contained therein. The bulk of the curriculum requirements are specified in Criterion 5 of the General Criteria. However, those requirements rely heavily on the CAC's Student Outcomes (SOs) that are prescribed in Criterion 3 of the General Criteria. We repeat those items here from (ABET, 2020) of ABET's Computing General Criteria, with the focus entirely on CSec. We have added annotations so that we can refer to these items more easily later. Graduates of the CSec program will have the ability to:

1. (SO 3-1) Analyze a complex computing problem and apply principles of computing and other relevant disciplines to identify solutions.
2. (SO 3-2) Design, implement, and evaluate a computing-based solution to meet a given set of computing requirements in the context of CSec
3. (SO 3-3) Communicate effectively in a variety of professional contexts.
4. (SO 3-4) Recognize professional responsibilities and make informed judgments in computing practice based on legal and ethical principles.
5. (SO 3-5) Function effectively as a member or leader of a team engaged in activities appropriate to CSec.

We next examine the elements from the General Criteria, Curriculum: Criterion 5 (ABET, 2020). Again, we have added annotations and restricted ourselves to CSec. (C 5-SOs) The curriculum must be designed so that the SOs can be attained. (C 5-broad) The curriculum must combine technical, professional, and general education components to prepare students for a career, further study, and lifelong professional development in CSec. (C 5-math) The program must include mathematics appropriate to CSec and (C 5-30 hours) at least 30 semester credit hours of up-to-date coverage of fundamental and advanced computing topics that provide both breadth and depth. Topics must include:

1. (C 5-topics 1) Techniques, skills, and tools necessary for computing practice.
2. (C 5-topics 2) Principles and practices for secure computing.
3. (C 5-topics 3) Local and global impacts of computing solutions on individuals, organizations, and society.

The curriculum requirements taken directly from the CSec Program Criteria (ABET, 2020) with our annotations are as follows: (SO Program Criteria-6) Graduates of the program will have the ability to apply security principles and practices to maintain operations in the presence of risks and threats. (C-5 Program Criteria a) Students must complete at least 45 semester credit hours of computing and CSec course work, including (C-5 Program Criteria 1) application of the crosscutting concepts of confidentiality, integrity, availability, risk, adversarial thinking, and systems thinking; and fundamental topics from following:

(C-5 Program Criteria 2a) Data Security: protection of data at rest, during processing, and in transit.
(C-5 Program Criteria 2b) Software Security: development and use of software that reliably preserves the security properties of the protected information and systems.
(C-5 Program Criteria 2c) Component Security: the security aspects of the design, procurement, testing, analysis, and maintenance of components integrated into larger systems.
(C-5 Program Criteria 2d) Connection Security: security of the connections between components, both physical and logical.
(C-5 Program Criteria 2e) System Security: security aspects of systems that use software and are composed of components and connections.
(C-5 Program Criteria 2f) Human Security: the study of human behavior in the context of data protection, privacy, and threat mitigation.
(C-5 Program Criteria 2g) Organizational Security: protecting organizations from CSec threats and managing risk to support the successful accomplishment of the organizations' missions.
(C-5 Program Criteria 2h) Societal Security: aspects of CSec that broadly impact society as a whole.

(C-5 Program Criteria 3) Advanced CSec topics that build on crosscutting concepts and fundamental topics to provide depth. (C-5 Program Criteria b) At least six semester credit hours of mathematics that must include discrete mathematics and statistics.

Kasetsart University's CS Program

KU's CS program is a representative one in Thailand. Here we describe the program's relevant curriculum elements. In the next section, we describe how to spawn a CSec program directly from KU's CS program. All the information presented in this section comes from the KU's Bachelor of Science in Computer Program (Kasetsart University, 2021).

To graduate from the program, students are required to complete at least 124 credits, breaking down into a minimum of 88 credits of elective courses (approximately 29 classes), 6 credits of free elective courses (approximately two classes), and 30 credits of general-education courses (approximately 13 classes). The credit system of KU is like that of many universities in the USA. At KU, one credit hour is equivalent to one contact hour of lecture per week. Semesters have approximately 15 weeks of instruction. Depending on instructional formats, full-semester courses are one, two, or three credits. Most lecture courses are two or three credits and may include a laboratory or a practical session as well. Typically, a two-credit course has one 120-minute session per week, resulting in a minimum of 30 contact hours in each semester. A three-credit course has two 75-minute sessions per week, resulting in a minimum of 45 contact hours. A lecture with laboratory course is usually three credits, made up of two credits of lecture and one credit of laboratory, having two 75-minute lecture sessions and one 120-minute practical session per week, resulting in a minimum total of 75 contact hours. All general education courses are managed by the School of Integrated Science and are organized under the following themes: Wellness, Entrepreneurship, Language and Communication, Thai Citizen and Global Citizen, and Aesthetics. Since 2021, there have been over 200 general education courses being offered (Kasetsart University, 2021). In what follows, we focus on technical courses rather than general education courses.

In the first year, students are required to take the following ABET-relevant, computing-CSec-related courses: Introduction to CS, Calculus I, Fundamental Programming Concepts, Intellectual Properties and Professional Ethics, Computer Programming, Basic Linear Algebra, Statistical Programming, and Fundamentals of Computing. First-year students are also required to choose six general education courses. Second-year students take the following ABET-relevant courses: Software Construction, Data Structures and Algorithms, Computer Architecture, Fundamentals of Database Systems, Algorithm Design and Analysis, Operating System, and Fundamentals of Artificial Intelligence. In their second year, students choose two of the following selective-elective courses: Practicum Software Development, Enterprise Information System, Data Science and Application Program, Programming Internet of Things, Unix Operating System and Shell Programming, Financial and Banking Information Technology, Principles of Computer Animation, and Image and Video Processing. Also in their second year, students choose four general education classes. Third-year students take the following ABET-relevant courses: System Analysis and Design, Theory of Computation, Computer Networks and Cloud Computing Principles, Information System Security, Project Management and Digital Startup, Co-operative Education Preparation, and Seminar. In their third year, students choose three of the following selective-elective courses: Challenging Computational Programming, Introduction to Data Science, Data Quality Management, Decision Support and

Business Intelligent Systems, Data Visualization, Compiler Techniques, Parallel Computing with CUDA, Mobile Application Design and Development, Enterprise Resource Planning System Design and Development, Business Data Dimension and Report Management, Data Communications and Networks, Cloud Computing Concepts and Services, Introduction to Computer Vision, Introduction to Machine Learning, Natural Language Processing, Introduction to Interactive Computer Graphics, Visual Effects, and Extended Reality. Also in their third year, students choose one free elective course and three of the general-education courses. Fourth-year students take the following ABET-relevant courses: Co-operative Education and CS Project. In the fourth year, students choose three of the following selective-elective courses: User Experience and User Interface Design, Web Technology and Web Services, Network Design and Administration, Software Design and Development, Integrated Agile Process and DevOps, Computer Control and Audit, Software Testing and Verification, and Selected Topic in CS. Also in their fourth year, students choose two free elective courses. Note that students take approximately 13 classes of general education courses to complete the program. We next determine which courses in this program are useful for a program seeking ABET accreditation in CSec.

Reusing Parts of KU's CS Program to Develop a CSec Curriculum

We methodically studied KU's courses and analyzed them concerning ABET's requirements for the Program Criteria in CSec and the CAC's General Criteria. Table 2 shows the courses that we selected from KU's CS program to satisfy the bulk of these curriculum requirements. Note that all the courses in the table are required in KU's CS program (Kasetsart University, 2021). Thus, all these courses exist and are being taught. Although KU's CS program requires other CS courses, they are not directly useful or needed for CSec. We have not included them in Table 2.

In the second column of Table 2, we indicate which ABET-related CSec curriculum items are covered by a particular course. In some cases, the terminology used in a KU course may not correspond exactly with ABET's jargon. In addition, in some cases, the courses might need to present the topics in Table 2 at a slightly more advanced level than they currently do, emphasize them more, or approach them from a CSec perspective rather than a CS perspective. For the moment, our goal is not to attempt to be precise in the categorizations of these issues, but rather to simply point out that there are some issues. Later in this section, we will make the shortcomings precise.

Table 2. KU's CS program's required courses that can be used in a CSec program. The table illustrates which ABET requirements are satisfied by a given course.

KU CS's Program's Required Course	Satisfies the Following ABET General Criteria and CSec Program Criteria Curriculum Requirement(s)	Credits
Introduction to CS	C 5-topics 1. Techniques, skills, and tools for the computing practice. Overview of CS basics.	2
Fundamental Programming Concepts	C 5-topics 1. Techniques, skills, and tools for the computing practice.	3
Intellectual Properties and Professional Ethics	C 5-topics 3. Local and global impacts of computing solutions on individuals, organizations, and society. C-5 Program Criteria 2h. Societal Security. SOs 3-3 and 3-4.	3
Computer Programming	C 5-topics 1. Techniques, skills, and tools for the computing practice.	3
Statistical Programming	C-5 math. C-5 Program Criteria b. Statistics.	3
Fundamentals of Computing	C-5 math. C-5 Program Criteria b. Discrete mathematics.	3
Software Construction	C 5-topics 1. Techniques, skills, and tools for the computing practice.	3
Data Structures and Algorithms	C 5-topics 1. Techniques, skills, and tools for the computing practice. SOs 3-1 and 3-2.	3
Computer Architecture	C 5-topics 2. Principles and practices for secure computing. C-5 Program Criteria 1. Availability and systems thinking. C-5 Program Criteria 2cd. Component and Connection Securities.	3
Fundamentals of Database System	C-5 Program Criteria 1. Confidentiality, integrity, and availability. C-5 Program Criteria 2a. Data Security.	3
Algorithm Design and Analysis	C 5-topics 1. Techniques, skills, and tools for the computing practice. SOs 3-1 and 3-2.	3
Operating Systems	C 5-topics 2. Principles and practices for secure computing. C-5 Program Criteria 1. Confidentiality and availability. C-5 Program Criteria 2abe. Data, Software, and System securities. C-5 Program Criteria 3. Advanced topics. SOs 3-1 and 3-2.	3
Fundamentals of Artificial Intelligence	C 5-topics 1. Techniques, skills, and tools for the computing practice. SOs 3-1 and 3-2.	3

Table 2. KU's CS program's required courses that can be used in a CSec program. The table illustrates which ABET requirements are satisfied by a given course (cont.)

KU CS's Program's Required Course	Satisfies the Following ABET General Criteria and CSec Program Criteria Curriculum Requirement(s)	Credits
System Analysis and Design	C 5-topics 2. Principles and practices for secure computing. C 5-topics 3. Local and global impacts of computing solutions on individuals, organizations, and society. C-5 Program Criteria 2abce. Data, Software, Component, and System securities. SOs 3-1 and 3-2.	3
Theory of Computation	C-5 Program Criteria a. Computing coursework. SO 3-1.	3
Computer Networks and Cloud Computing Principles	C 5-topics 2. Principles and practices for secure computing. C 5-topics 3. Local and global impacts of computing solutions on individuals, organizations, and society. C-5 Program Criteria 1. Confidentiality, integrity, availability, risk, and systems thinking. C-5 Program Criteria 2bcde. Software, Connection, Component, and System securities. SOs 3-1, 3-2, and 3-3.	3
Information System Security	C 5-topics 2. Principles and practices for secure computing. C-5 topics 3. Local and global impacts of computing solutions on individuals, organizations, and society. C-5 Program Criteria 1. Confidentiality, integrity, availability, risk, and systems thinking. C-5 Program Criteria 2aceg. Data, Component, System, and Organizational securities. C-5 Program Criteria 3. Advanced topics. SOs 3-1, 3-2, and 3-3.	3
Project Management and Digital Startup	C 5-topics 3. Local and global impacts of computing solutions on individuals, organizations, and society. C-5 Program Criteria 1. Confidentiality, availability, risk, and system. C-5 Program Criteria 2bg. Software and Organizational securities. SOs 3-1 and 3-2.	3
Seminar	C 5-topics 1. Techniques, skills, and tools for the computing practice. SOs 3-3 and 3-4.	1
Co-operative Education	SOs 3-3 and 3-4.	6
CS Project	SOs 3-1, 3-2, and 3-3.	3
Practicum Software Development	C 5-topics 2. Principles and practices for secure computing. C-5 topics 3. Local impact of computing solutions on individuals. SOs 3-1, 3-2, and 3-5.	1

Table 2. KU's CS program's required courses that can be used in a CSec program. The table illustrates which ABET requirements are satisfied by a given course (cont.)

KU CS's Program's Required Course	Satisfies the Following ABET General Criteria and CSec Program Criteria Curriculum Requirement(s)	Credits
Enterprise Information System	C 5-topics 3. Local and global impacts of computing solutions on individuals, organizations, and society. C-5 Program Criteria 1. Confidentiality, availability, and risk. C-5 Program Criteria 2abceg. Data, Software, Components, System, and Organizational securities. SOs 3-1 and 3-2.	3
Unix Operating System and Shell Programming	C 5-topics 1. Techniques, skills, and tools for the computing practice. C 5-topics 2. Principles and practices for secure computing. C-5 Program Criteria 1. Confidentiality and availability. C-5 Program Criteria 2abe. Data, Software, and System Securities. SOs 3-1 and 3-2.	3
Challenging Computational Programming	C 5-topics 1. Techniques, skills, and tools for the computing practice. SOs 3-1 and 3-2.	3
Introduction to Data Science	C 5-topics 1. Techniques, skills, and tools for the computing practice. C 5-topics 3. Local and global impacts of computing solutions on individuals, organizations, and society. C-5 Program Criteria 2afh. Data, Human, and Societal Securities. SOs 3-1, 3-2, and 3-4.	3
Compiler Techniques	Program Criteria a. Computing coursework. SO 3-1.	3
Data Communications and Networks	C 5-topics 2. Principles and practices for secure computing. C 5-topics 3. Local and global impacts of computing solutions on individuals, organizations, and society. C-5 Program Criteria 1. Confidentiality, integrity, availability, risk, and systems thinking. C-5 Program Criteria 2abcd. Data, Software, Connection, Component, and System Securities. C-5 Program Criteria 3. Advanced topics. SOs 3-1, 3-2, and 3-4.	3

Table 2. KU's CS program's required courses that can be used in a CSec program. The table illustrates which ABET requirements are satisfied by a given course (cont.)

KU CS's Program's Required Course	Satisfies the Following ABET General Criteria and CSec Program Criteria Curriculum Requirement(s)	Credits
Cloud Computing Concepts and Services	C 5-topics 2. Principles and practices for secure computing. C 5-topics 3. Local and global impacts of computing solutions on individuals, organizations, and society. C-5 Program Criteria 1. Confidentiality, integrity, availability, risk, and systems thinking. C-5 Program Criteria 2abcde. Data, Software, Connection, Component, and System Securities. C-5 Program Criteria 3. Advanced topics. SOs 3-1, 3-2, and 3-4.	3
Introduction to Machine Learning	C-5 Program Criteria a. Computing coursework. SO 3-1.	3
User Experience and User Interface Design	C 5-topics 1. Techniques, skills, and tools for the computing practice. C 5-topics 2. Principles and practices for secure computing. C-5 topics 3. Local and global impacts of computing solutions on individuals, organizations, and society. C-5 Program Criteria 1. Confidentiality, integrity, and availability. C-5 Program Criteria 2afh. Data, Human, and Societal Securities. SO 3-2.	3
Web Technology and Web Services	C 5-topics 2. Principles and practices for secure computing. C-5 topics 3. Local and global impacts of computing solutions on individuals, organizations, and society. C-5 Program Criteria 1. Confidentiality, integrity, and availability. C-5 Program Criteria 2abce. Data, Software, Component, and System Securities. C-5 Program Criteria 3. Advanced topics. SOs 3-1 and 3-2.	3
Network Design and Administration	C 5-topics 2. Principles and practices for secure computing. C 5-topics 3. Local and global impacts of computing solutions on individuals, organizations, and society. C-5 Program Criteria 1. Confidentiality, integrity, availability, risk, and systems. C-5 Program Criteria 2bcde. Software, Connection, Component, and System Securities. C-5 Program Criteria 3. Advanced topics. SOs 3-1, 3-2, and 3-4.	3
Software Design and Development	C 5-topics 2. Principles and practices for secure computing. C 5-topics 3. Local and global impacts of computing solutions on individuals, organizations, and society. C-5 Program Criteria 1. Confidentiality, integrity, availability, risk, and systems. C-5 Program Criteria 2bce. Software, Component, and System Securities. SOs 3-1, 3-2, and 3-4.	3

Table 2. KU's CS program's required courses that can be used in a CSec program. The table illustrates which ABET requirements are satisfied by a given course (cont.)

KU CS's Program's Required Course	Satisfies the Following ABET General Criteria and CSec Program Criteria Curriculum Requirement(s)	Credits
Integrated Agile Process and DevOps	C 5-topics 2. Principles and practices for secure computing. C 5-topics 3. Local and global impacts of computing solutions on individuals, organizations, and society. C-5 Program Criteria 1. Confidentiality, integrity, availability, risk, and systems. C-5 Program Criteria 2bce. Software, Component, and System Securities. C-5 Program Criteria 3. SOs 3-1, 3-2, and 3-4.	3
Software Testing and Verification	C 5-topics 2. Principles and practices for secure computing. C 5-topics 3. Local and global impacts of computing solutions on individuals, organizations, and society. C-5 Program Criteria 1. Confidentiality, integrity, availability, risk, and systems. C-5 Program Criteria 2bce. Software, Component, and System Securities. C-5 Program Criteria 3. Advanced topics. SOs 3-1, 3-2, and 3-4.	3
Total		106

We needed to be judicious in our choices of what to include in the CSec program that we are building. We selected courses that give us the greatest coverage of the curriculum requirements in the Program Criteria for CSec, as well as in the General Criteria. Table 2 shows a total of 34 computing/CSec courses (100 credits) and two math courses (6 credits), for an overall total of 106 credits. KU's CS program has a minimum of 124, but typically 136 credits, and we are targeting this value for the spawned program. The credits not yet specified give us some wiggle room to add curriculum elements not yet covered.

Analysis and Evaluation of the Partial CSec Curriculum

Using Table 2 as our guide, one by one we methodically analyzed and evaluated ABET's curriculum requirements specified in section 2 to determine if they were met. Table 3 summarizes our findings. When there is an ABET shortcoming for our partial curriculum, meaning a part of ABET's Criteria is not yet met, we indicate that by a ShCo-i in Table 3, where 'i' is a number representing the shortcoming's number in consecutive order.

Table 3. An evaluation of the partial curriculum is shown in Table 2 against ABET's General Criteria curriculum requirements and ABET's Program Criteria for CSec.

ABET Requirement	Satisfied or Covered Where?	Shortcomings (Yes or No)
SO 3-1	Addressed in Data Structures and Algorithms, Algorithm Design and Analysis, Operating System, System Analysis and Design, Theory of Computation, Computer Networks and Cloud Computing Principles, and several other courses.	No. There are many courses where the required elements of SO 3-1 are addressed.
SO 3-2	Addressed in Data Structures and Algorithms, Algorithm Design and Analysis, Operating System, System Analysis and Design, Computer Networks and Cloud Computing Principles, Information System Security, Project Management and Digital Startup, and several other courses.	No. There are many courses where the required elements of SO 3-2 are addressed.
SO 3-3	Addressed in Intellectual Properties and Professional Ethics, Computer Networks and Cloud Computing Principles, Information System Security, Seminars, Co-operative Education, and CS Projects.	No. As part of these courses, students are asked to develop written reports and give oral presentations.
SO 3-4	Addressed in Intellectual Properties and Professional Ethics, Seminars, Co-operative Education, Data Communications and Networks, Cloud Computing Concepts and Services, Network Design and Administration, Software Design and Development, Integrated Agile Process and DevOps, and Software Testing and Verification.	No. Professional responsibilities, legal issues, and ethical principles are covered in these courses.
SO 3-5	Addressed in Practicum in Software Development.	No. Teamwork is taught, and a team project is required in the course.
C 5-SOs	As rows two through six of this table indicate, everything is enabled.	No. All the SOs are enabled.

Table 3. An evaluation of the partial curriculum shown in Table 2 against ABET's General Criteria curriculum requirements and ABET's Program Criteria for CSec (cont.)

ABET Requirement	Satisfied or Covered Where?	Shortcomings (Yes or No)
C 5-broad	The curriculum must combine technical, professional, and general education components to prepare students for a career, further study, and lifelong professional development in CSec.	No. The curriculum includes a minimum of 30 credits of general education (approximately 25% of credits).
C 5-math	In the CS program, students take Introduction to Statistical Programming and Fundamentals of Computing, where discrete mathematics is taught. This statistics offering is not a rigorous course for statistics majors, so statistics is not covered appropriately. The discrete mathematics material needs to focus more on CSec's needs and applications.	Yes. ShCo-1.
C 5-30 hrs.	The program must have 30 semester credit hours of up-to-date coverage of fundamental and advanced computing topics that provide both breadth and depth.	No. As Table 2 shows, the program far exceeds 30 hours of the type of coverage required.
C 5-topics 1	The program must cover techniques, skills, and tools necessary for computing practice.	No. A review of column 2 of Table 2 shows this requirement is met.
C 5-topics 2	The program must cover principles and practices for secure computing.	No. A review of column 2 of Table 2 shows this requirement is met.
C 5-topics 3	The program must cover the local and global impacts of computing solutions on individuals, organizations, and society.	No. A review of column 2 of Table 2 shows this requirement is met.
SO Program Criteria-6	Graduates of the program will have the ability to apply security principles and practices to maintain operations in the presence of risks and threats.	No. Students obtain this ability in Computer Networks and Cloud Computing Principles, Information System Security, and Network Design and Administration.

Table 3. An evaluation of the partial curriculum shown in Table 2 against ABET's General Criteria curriculum requirements and ABET's Program Criteria for CSec (cont.)

ABET Requirement	Satisfied or Covered Where?	Shortcomings (Yes or No)
C-5 Program Criteria a	Students must complete at least 45 semester credit hours of computing and CSec coursework.	No. As Table 2 shows, the program far exceeds 45 hours of the type of coverage required.
C-5 Program Criteria 1	The program must cover the application of the crosscutting concepts of confidentiality, integrity, availability, risk, adversarial thinking, and systems thinking.	Yes. The application of the crosscutting concept of adversarial thinking is missing. ShCo-2.
C-5 Program Criteria 2a	Coverage of Data Security: protection of data at rest, during processing, and in transit.	No. This topic is well covered in six different courses including Information System Security, Enterprise Information System Security, Introduction to Data Science, Data Communications and Network, Cloud Computing Concepts and Services, and Web Technology and Web Services.
C-5 Program Criteria 2b	Coverage of Software Security: development and use of software that reliably preserves the security properties of the protected information and systems.	No. This topic is well covered in nine different courses including Fundamentals of Database Systems, Operating Systems, System Analysis and Design, Enterprise Information System, Cloud Computing Concepts and Services, Web Technology and Web Services, Software Design and Development, Integrated Agile Process and DevOps, and Software Testing and Verification.

Table 3. An evaluation of the partial curriculum shown in Table 2 against ABET's General Criteria curriculum requirements and ABET's Program Criteria for CSec (cont.)

ABET Requirement	Satisfied or Covered Where?	Shortcomings (Yes or No)
C-5 Program Criteria 2c	Coverage of Component Security: the security aspects of the design, procurement, testing, analysis, and maintenance of components integrated into larger systems.	No. This topic is well covered in eight different courses including Computer Architecture, System Analysis and Design, Computer Networks and Cloud Computing Principles, Information System Security, Enterprise Information System, Data Communications and Networks, Cloud Computing Concepts and Services, and Network Design and Administration.
C-5 Program Criteria 2d	Coverage of Connection Security: security of the connections between components, both physical and logical.	No. This topic is well covered in six different courses including Computer Architecture, Computer Networks and Cloud Computing Principles, Data Communications and Networks, Cloud Computing Concepts and Services, and Network Design and Administration.
C-5 Program Criteria 2e	Coverage of System Security: security aspects of systems that use software and are composed of components and connections.	No. This topic is well covered in nine different courses including Operating Systems, System Analysis and Design, Computer Networks and Cloud Computing Principles, Information System Security, Enterprise Information System, Cloud Computing Concepts and Services, Web Technology and Web Services, Network Design and Administration, and Software Design and Development.
C-5 Program Criteria 2f	Coverage of Human Security: the study of human behavior in the context of data protection, privacy, and threat mitigation.	No. This topic is covered in Introduction to Data Science, and User Experience and User Interface Design.

Table 3. An evaluation of the partial curriculum shown in Table 2 against ABET's General Criteria curriculum requirements and ABET's Program Criteria for CSec (cont.)

ABET Requirement	Satisfied or Covered Where?	Shortcomings (Yes or No)
C-5 Program Criteria 2g	Coverage of Organizational Security: protecting organizations from CSec threats and managing risk to support the successful accomplishment of the organizations' missions.	No. This topic is covered in Project Management Digital Startup, and Enterprise Information System.
C-5 Program Criteria 2h	Coverage of Societal Security: aspects of CSec that broadly impact society as a whole.	No. This topic is covered in User Experience and User Interface Design.
C-5 Program Criteria 3	Coverage of advanced CSec topics that build on crosscutting concepts and fundamental topics to provide depth.	No. A review of column 2 in Table 2 shows this topic is touched on in seven different courses including Operating Systems, Information System Security, Data Communications and Networks, Web Technology and Web Services, Network Design and Administration, Integrated Agile Process and DevOps, and Software Testing and Verification.
C-5 Program Criteria b	At least six semester credit hours of mathematics that must include discrete mathematics and statistics.	Yes. ShCo-3. ShCo-1 also addressed this issue previously.

RESULTS

For the partial curriculum that we pulled out of KU's CS program and summarized in Table 2, we then in Table 3 identified the shortcomings of this curriculum concerning ABET's General Criteria curriculum components and the Program Criteria for CSec. In this section in Table 4, we explicitly show how to eliminate these shortcomings and provide a difficulty rating for each fix. Although not too precise, we classify a fix as easy if it in our estimation requires a few minor curriculum adjustments and perhaps 10-15 hours of work. A medium fix requires a substantial amount more effort and perhaps up to 40 hours of work; a hard fix will require a substantial amount of work and expertise; and will require 40+ hours to accomplish. For example, the development and implementation of an entirely new course will require a great deal of expertise, time, and effort. Such an undertaking is rated as hard, whereas adding a couple of new lectures or a new assignment to a course is deemed easy (at least in comparison).

Table 4. Fixes for the shortcomings identified in Table 3. The difficulty column provides a relative sense of how difficult a suggested modification is. In the fourth column, D = Difficulty, M = Medium, and H = Hard.

Shortcoming Number	Shortcoming	Proposed Fix	D
ShCo-1	C 5-math. Students need discrete math that is focused on CSec applications, and they require a rigorous statistics course.	Make enhancements to Fundamentals of Computing by adding more material relevant to CSec. Require a rigorous statistics course that the Department of Mathematics already offers. Note this makes six credits.	H
ShCo-2	C-5 Program Criteria 1. Missing application of the crosscutting concept of adversarial thinking. The other crosscutting concepts are covered, as shown in column 2 of Table 2.	Include modules and discussions that involve adversarial thinking in Computer Architecture, Information System Security, Computer Networks and Cloud Computing Principles, Operating Systems, and Network Design and Administration.	M
ShCo-3	C-5 Program Criteria b. At least six semester credit hours of mathematics that must include discrete mathematics and statistics.	This issue was addressed in the C 5-math item earlier.	H

Table 4 provides fixes for the shortcomings discussed in the previous section. In the next section, we summarize the entire proposed curriculum and provide some discussion.

DISCUSSION

KU's BS in CS requires at least 44 classes or 124 credits (not all are three-credit courses), according to how we have done our accounting (see section 3). Table 2 shows a total of 34 computing/CSec courses (100 credits, again not all are three credits) and two math courses (6 credits), for an overall total of 106 credits for our partial curriculum for the BS in CSec. In Table 4, we discussed including modules and material involving adversarial thinking in the relevant existing courses and adding a solid course in statistics. By adding 13 classes of general-education courses as electives, we have a total of 34 computing/CSec courses (100 credits), two math courses (6 credits), and 13 general-education courses (30 credits). This overall total matches the total credits in the CS program (136 credits), and relative to the CS program, the proposed CSec program contains more than double the number of general education courses, ensuring students receive a well-rounded education.

Table 5 summarizes the modifications required to spawn the CSec program. The light gray shading indicates making use of an existing KU course, and the darker shading indicates modifying an existing course. The remarkably small number of changes, coupled with some other minor changes depicted in Table 5, strongly suggests that developing such a program is feasible and would not require a great deal of effort or resources.

Table 5. Modifications to courses in the new CSec program.

Course Name/Type	Notes/Purpose
Statistical Programming	Addition of a rigorous course in statistics.
Fundamentals of Computing	Enhance this course and shift its focus more towards CSec.
Computer Architecture	Add material on adversarial thinking.
Information System Security	Add material on adversarial thinking.
Computer Networks and Cloud Computing Principles	Add material on adversarial thinking.
Operating System	Add material on adversarial thinking.
Network Design and Administration	Add material on adversarial thinking.

With a shift in focus toward CSec, we have constructed an ABET-compliant CSec program. We have mentioned more subtle changes to several courses. Such changes leaning towards CSec would need to be institutionalized and become part of the course descriptions, for example, applications of the crosscutting concepts throughout the program, rather than just casually entered in passing.

CONCLUSIONS AND RECOMMENDATIONS

To address the rapidly increasing number and severity of cybercrimes in Thailand, there is a critical need to expand the workforce in the CSec domain. From a typical four-year Thai CS program, we spawned a four-year CSec program that meets ABET's Program Criteria for CSec and its General Criteria curriculum requirements. The required curriculum modifications were relatively minor:

1. Increase the coverage of the ABET's crosscutting concepts in CSec. In particular, incorporate adversarial thinking into several required courses (see Table 5).
2. Add a rigorous (existing) course in statistics.
3. Shift the focus in a few courses to CSec rather than CS.

With these relatively minor changes and no new courses, CS programs in Thailand can quickly evolve into four-year CSec programs. Once such programs are implemented, students already in the pipeline could transfer and perhaps enter the workforce in just one or two years. The costs of developing such programs are minimal. The rewards and benefits are great. We hope many new four-year programs in CSec will emerge. If such programs decide to pursue

ABET accreditation, they will also need to ensure that there is an appropriate level of institutional support for the CSec program and that there is sufficient budget to cover ABET's annual dues and visit fees.

We have shown a way forward for a typical Thailand CS program to develop a solid ABET-accreditable four-year CSec program. Although we have focused our discussion on Thailand, programs throughout the world can make use of our analysis and evaluation as well. They too can spawn from their CS programs viable CSec curriculums. Perhaps with a few dedicated faculty members, a supportive administration, and a knowledgeable consultant, the dream of expanding the CSec workforce in Thailand can be realized in a relatively short time. We hope this paper moves things farther down that path, as a more secure Internet anywhere is beneficial to everyone everywhere. Our recommendation is for institutions that want to develop a CSec program using a CS program as a starting point to consider evolving the program in the manner described here.

PRACTICAL IMPLICATIONS

CS departments in Thailand can quickly evolve four-year CSec programs from CS programs. Once such programs are implemented, students already in the pipeline can transfer and perhaps enter the workforce in just one or two years. Additional workers can be added quickly to the employment ranks to combat a growing cybercrime problem. This methodology can be used in other countries as well.

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DECLARATIONS

Conflict of Interest

The researcher declares no conflict of interest in this study.

Informed Consent

Not applicable.

Ethics Approval

Not applicable.

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Author's Biography

Raymond Greenlaw received an MS in Computer Science in 1986 and a Ph.D. in Computer Science in 1988 from the University of Washington. While in graduate school, he worked for Paul Allen (cofounder of Microsoft, RIP) at Asymetrix Corporation. Raymond retired as the Office of Naval Research Distinguished Chair in Cyber Security from the United States Naval Academy in Annapolis, Maryland in 2016 to focus on his consulting and publishing businesses. In his career he won four Senior Fulbright Fellowships (Iceland, Namibia, Spain, and Thailand), a Humboldt Fellowship (Germany), a Sasakawa Fellowship (Japanese), and additional fellowships from Italy, Japan, and Spain; he published 20 books in the areas of complexity theory, graph theory, the Internet, parallel computation, networking, operating systems, theoretical Computer Science, the Web, and wireless networking. Raymond has 375+ invited talks and publications, and his research was supported by the governments of Germany, Hong Kong, Iceland, Italy, Japan, Malaysia, Namibia, Spain, Taiwan, Thailand, and the USA.

Nopadon Juneam received a PhD degree in Computer Science from Chiang Mai University, Thailand in 2017. He is an Assistant Professor and the Assistant Dean of the Department of Computer Science, Faculty of Science, Kasetsart University, Thailand. Nopadon served as the Chair of the Undergraduate Program Executive Committee during 2021-22. His work focuses mainly on solving complex problems in complexity theory, networking, and algorithms.