Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
Paper ID #46035

The State of the Practice Integrating Security in ABET Accredited Computer Science Programs

Dr. Walter W Schilling Jr., Milwaukee School of Engineering

Walter Schilling is a Professor and Cybersecurity Minor Coordinator in the Dwight and Dian Diercks School of Advanced Computing at the Milwaukee School of Engineering. He earned his B.S.E.E. from Ohio Northern University and his M.S. and Ph.D. from the University of Toledo. Before returning for doctoral studies, he worked as an Embedded Software Engineer for Ford Motor Company and Visteon for several years. Schilling has also spent time at NASA Glenn Research Center in Cleveland, Ohio, and has consulted for various embedded systems companies in the Midwest.

In addition to holding one U.S. patent, Schilling has numerous publications in refereed international conferences and journals. He was awarded the Ohio Space Grant Consortium Doctoral Fellowship and has received recognition from the IEEE Southeastern Michigan and IEEE Toledo Sections. He is a member of IEEE, IEEE Computer Society, and ASEE.

At MSOE, Schilling primarily teaches in the software engineering program, where he coordinates courses in software verification, real-time systems, DevSecOps, network security, and other cybersecurity topics.

The State of the Practice Integrating Security in ABET Accredited Computer Science Programs

Abstract:

Within the computing fields, concerns related to security continue to grow. Since the early 2000's, cyberattacks against deployed software systems have grown significantly. In 2017, recognizing this concern, a modification to the program accreditation criteria for computing programs was proposed and accepted which explicitly required topical coverage of security accredited programs. Since taking effect in 2019, all accredited computing programs have had to demonstrate proper coverage of the topic as part of the accreditation process. While the criteria require that the topic of security be covered, the implementation is left open to individual programs. This article will provide a snapshot of the state of the practice of how security is integrated into program curricula by analyzing a subset of the ABET accredited Computer Science programs. The article will identify at a high-level scope the topics that are covered in the programs, as well as provide an overview of other aspects of the institutions which impact the depth and breadth of security coverage available to undergraduate students.

Introduction

The term Computer Science first came about in 1961, coined by numerical analyst and computing pioneer George Forsythe [1]. The first computer science department was established at Purdue University in 1962, with other programs being created at Miami, Wisconsin, Illinois, and North Carolina shortly thereafter [2]. The first PhD in computer science was granted in December 1965 [3]. In 1965, the ACM published its first set of preliminary recommendations for computer science academic programs [4], followed by the first curriculum guide in 1968 [5]. The number of computer science programs grew rapidly, resulting in variations in quality. By 1967, there were more than 20000 undergraduate students in computer science across the United States and more than 5000 graduate students. [2]

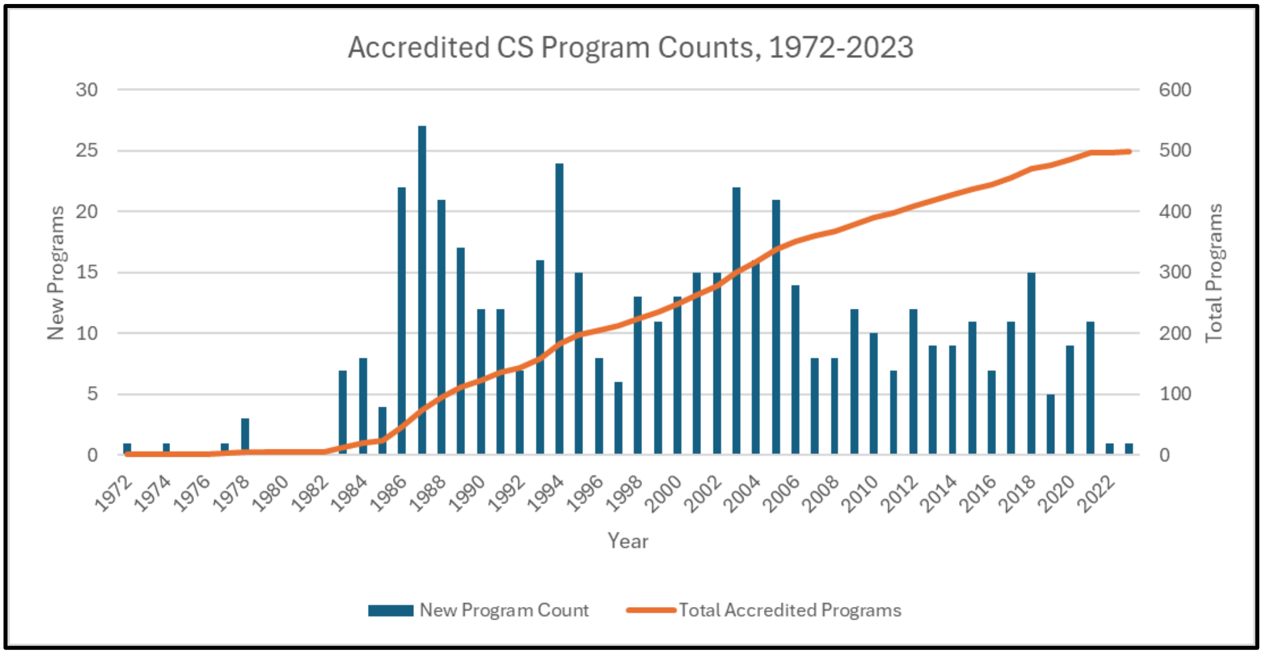

Figure 1 Growth in Accredited Computer Science Programs

In 1976, the IEEE Computer Society published a report on curricular needs for Computer Science and Engineering [6] [7] which provided a framework for accreditation as was commonly required of engineering programs. This led to ACM publishing a new curriculum guide in 1978 which helped to standardize curriculum [8]. The IEEE Computer Society and ACM formed a joint working committee to investigate accreditation of Computer Science programs, which resulted in the first accreditation visits by the Computer Science Accreditation Board (CSAB) in 1985, with certain programs being retroactively accredited as far back as 1972. By 1990, there were 124 accredited programs in Computer Science, and growth has been steady ever since, as is shown in Figure 1.

The accreditation criteria for Computer Science programs changed over the years, with the most significant changes occurring in the late 1990's and early 2000's. In 1998, CSAB and ABET signed a Memorandum of Understanding to integrate their activities, and legally, this transition was completed in 2001. The first Criteria under this joint organization was published in 2001 to be used for the 2002-2003 accreditation cycle. [9]

2002-2003 Criteria for Accrediting Computer Science Programs

IV. Curriculum

Intent

The curriculum is consistent with the program's documented objectives. It combines technical requirements with general education requirements and electives to prepare students for a professional career in the computer field, for further study in computer science, and for functioning in modern society. The technical requirements include up-to-date coverage of basic and advanced topics in computer science as well as an emphasis on science and mathematics.

Standards

Curriculum standards are specified in terms of semester hours of study. Thirty semester hours generally constitutes one year of full-time study and is equivalent to 45 quarter hours. A course or a specific part of a course can only be applied toward one standard.

General

IV-1. The curriculum must include at least 40 semester hours of up-to-date study in computer science topics.

IV-2. The curriculum must contain at least 30 semester hours of study in mathematics and science as specified below under Mathematics and Science.

IV-3. The curriculum must include at least 30 semester hours of study in humanities, social sciences, arts and other disciplines that serve to broaden the background of the student.

IV-4. The curriculum must be consistent with the documented objectives of the program.

Computer Science

IV-5. All students must take a broad-based core of fundamental computer science material consisting of at least 16 semester hours.

IV-6. The core materials must provide basic coverage of algorithms, data structures, software design, concepts of programming languages, and computer organization and architecture.

IV-7. Theoretical foundations, problem analysis, and solution design must be stressed within the program's core materials.

IV-8. Students must be exposed to a variety of programming languages and systems and must become proficient in at least one higher-level language.

IV-9. All students must take at least 16 semester hours of advanced course work in computer science that provides breadth and builds on the core to provide depth.

Mathematics and Science

IV-10. The curriculum must include at least 15 semester hours of mathematics.

IV-11. Course work in mathematics must include discrete mathematics, differential and integral calculus, and probability and statistics.

IV-12. The curriculum must include at least 12 semester hours of science.

IV-13. Course work in science must include the equivalent of a two-semester sequence in a laboratory science for science or engineering majors.

IV-14. Science course work additional to that specified in Standard IV-13 must be in science courses or courses that enhance the student's ability to apply the scientific method.

IV-15. The oral communications skills of the student must be developed and applied in the program.

IV-16. The written communications skills of the student must be developed and applied in the program.

IV-17. There must be sufficient coverage of social and ethical implications of computing to give students an understanding of a broad range of issues in this area.

Figure 2 2002-2003 ABET Curriculum Criteria for Computer Science [9]

These criteria werte then significantly modified in 2008-2009 with the definition of the "New Criteria" and further changed as the criterion was harmonized with the Engineering Accreditation committee (EAC).

2008-2009 Criteria for Accrediting Computing Programs - New Criteria

PROGRAM CRITERIA FOR
COMPUTER SCIENCE
AND SIMILARLY NAMED COMPUTING PROGRAMS
Lead Society: CSAB

These program criteria apply to computing programs using computer science or similar terms in their titles.

3. Program Outcomes

   The program enables students to achieve, by the time of graduation:

   (j) An ability to apply mathematical foundations, algorithmic principles, and computer science theory in the modeling and design of computer-based systems in a way that demonstrates comprehension of the tradeoffs involved in design choices. [CS]

   (k) An ability to apply design and development principles in the construction of software systems of varying complexity. [CS]

5. Curriculum

   Students have the following amounts of course work or equivalent educational experience:

   a. Computer science: One and one-third years that includes:
      1. coverage of the fundamentals of algorithms, data structures, software design, concepts of programming languages and computer organization and architecture. [CS]
      2. an exposure to a variety of programming languages and systems. [CS]
      3. proficiency in at least one higher-level language. [CS]
      4. advanced course work that builds on the fundamental course work to provide depth. [CS]

   b. One year of science and mathematics:
      1. Mathematics: At least one half year that must include discrete mathematics. The additional mathematics might consist of courses in areas such as calculus, linear algebra, numerical methods, probability, statistics, number theory, geometry, or symbolic logic. [CS]
      2. Science: A science component that develops an understanding of the scientific method and provides students with an opportunity to experience this mode of inquiry in courses for science or engineering majors that provide some exposure to laboratory work. [CS]

6. Faculty Qualifications

   Some full time faculty members have a Ph.D. in computer science.

Figure 3 ABET 2008-2009 Computer Science Criteria related to curriculum.

While ABET revised the accreditation criteria, ACM continued to update its curriculum guidance. One of the important curriculum changes was an increased emphasis on the need to understand security and secure computing. The 2008 Computer Science curriculum guide stated:

> *"The amount of malicious software in the form of viruses, worms, etc. is causing huge concerns to the extent that it is now seen as a major threat to the industry. The Review Task Force has received urgent requests from industrialists requesting that substantial attention to security matters be regarded as compulsory for all computing graduates."* [10]

In the 2013 revision, Information Assurance and Security was added to the Body of Knowledge as a Key Area [11]. This resulted in a change to the ABET accreditation criteria in 2018-2018 to require the principles and practices for secure computing to be taught in all computer programs, including computer science. [12]. These changes also mirrored the changes made to the ABET Software Engineering criteria. In 2015, a proposal [13] was made to modify the criteria for software engineering, removing specifics about students being prepared to work in one or more application domains and specifically requiring coverage of security within the curriculum. This change was subsequently adopted for the 2016-2017 criteria, resulting in the criteria shown in Figure 4 for Software Engineering and Figure 5 for Computer Science.

– Software and Similarly Named Engineering Programs

Lead Society: CSAB
Cooperating Society: Institute of Electrical and Electronics Engineers

These program criteria apply to engineering programs that include "software" or similar modifiers in their titles.

1. Curriculum

The curriculum must provide both breadth and depth across the range of engineering and computer science topics implied by the title and objectives of the program.

The curriculum must include computing fundamentals, software design and construction, requirements analysis, security, verification, and validation; software engineering processes and tools appropriate for the development of complex software systems; and discrete mathematics, probability, and statistics, with applications appropriate to software engineering.

2. Faculty

The program must demonstrate that faculty members teaching core software engineering topics have an understanding of professional practice in software engineering and maintain currency in their areas of professional or scholarly specialization.

Figure 4 2016-2017 ABET Criteria for software engineering [14]

Criterion 5. Curriculum

The program's requirements must be consistent with its program educational objectives and designed in such a way that each of the student outcomes can be attained. The curriculum must combine technical, professional, and general education components to prepare students for a career, further study, and lifelong professional development in the computing discipline associated with the program.

The curriculum requirements specify topics, but do not prescribe specific courses. The program must include mathematics appropriate to the discipline and at least 30 semester credit hours (or equivalent) of up-to-date coverage of fundamental and advanced computing topics that provide both breadth and depth. The computing topics must include:

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

PROGRAM CRITERIA FOR COMPUTER SCIENCE AND SIMILARLY NAMED COMPUTING PROGRAMS

Lead Society: CSAB

These program criteria apply to computing programs using computer science or similar terms in their titles.

3. Student Outcomes

In addition to outcomes 1 through 5, graduates of the program will also have an ability to:

6. Apply computer science theory and software development fundamentals to produce computing-based solutions. [CS]

5. Curriculum

The curriculum requirements specify topics, but do not prescribe specific courses.

These requirements are:

(a) Computer science: At least 40 semester credit hours (or equivalent) that must include:

1. Substantial coverage of algorithms and complexity, computer science theory, concepts of programming languages, and software development.
2. Substantial coverage of at least one general-purpose programming language.
3. Exposure to computer architecture and organization, information management, networking and communication, operating systems, and parallel and distributed computing.
4. The study of computing-based systems at varying levels of abstraction.
5. A major project that requires integration and application of knowledge and skills acquired in earlier course work.

(b) Mathematics: At least 15 semester credit hours (or equivalent) that must include discrete mathematics and must have mathematical rigor at least equivalent to introductory calculus. The additional mathematics might include course work in areas such as calculus, linear algebra, numerical methods, probability, statistics, or number theory.

(c) At least six semester credit hours (or equivalent) in natural science course work intended for science and engineering majors. This course work must develop an understanding of the scientific method and must include laboratory work.

Figure 5 ABET Criteria for Computer Science Programs incorporating the need for security. [12]

Methodology and Study

In 2023, a review of all 37 Domestic ABET Accredited software Engineering Programs was conducted [15]. Overall, it looked at how software engineering programs had integrated the topic of security into their programs, required a few years earlier in 2017, and how this coverage compared with other major topics within the curricula. Overall, while many other significant topics within the curriculum receive one or more specific course(s) targeting that topic, the coverage of security is considerably less targeted, as is shown in Figure 6.

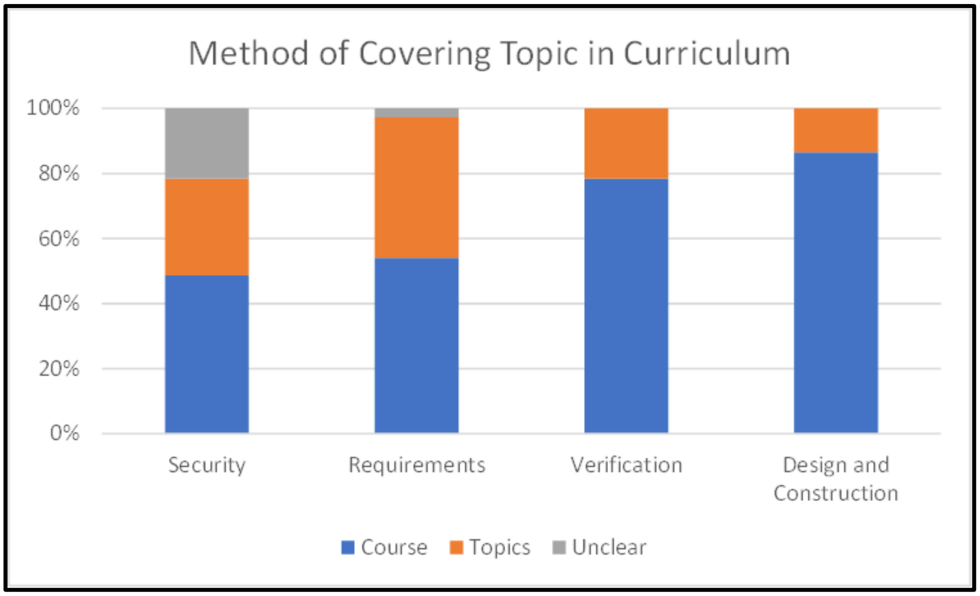

Figure 6 Method of covering assorted required topics in Software Engineering Curricula. [15]

The modification to the ABET Computer Science Program criteria [15] required all programs to revise their programs and document the inclusion of security. The structure of the change was not prescriptive in nature. Programs were free to add security into their program in the manner best deemed suitable to their environment. This could be done by modifying existing courses, course descriptions, or outcomes to address security. This could be done by requiring students to take an existing security course from another program, such as Cybersecurity, which had its own set of accreditation criteria adopted in 2019 [16]. This could be accomplished by requiring students to take a selective elective in security, allowing students to choose an area most applicable to their future career goals and plans.

To analyze how programs have incorporated security, a data set describing a random set of accredited programs was created. For each program reviewed, the Carnegie Classification and other institutional data were recorded. From the ABET annual enrollment summary data published on the program's website, information about the number of graduates and total number of enrolled undergraduate students was obtained. The program itself was then reviewed, capturing the number of credits in the program, and how each of the major portions of the program criteria was met. To determine this, the catalog was reviewed to identify where the topics of security were covered and what topics were covered. Lastly, it was determined if the institution also held an academic center of excellence distinction for cybersecurity.

Program Composition Findings

One of the first questions to ask is how the institutions with Computer Science Programs are defined. The most common way to define this is through Carnegie Classification. These results are shown in Figure 7 and Figure 8. Overall, the institutions hosting computer science programs are varied, though most accredited programs are at larger institutions.

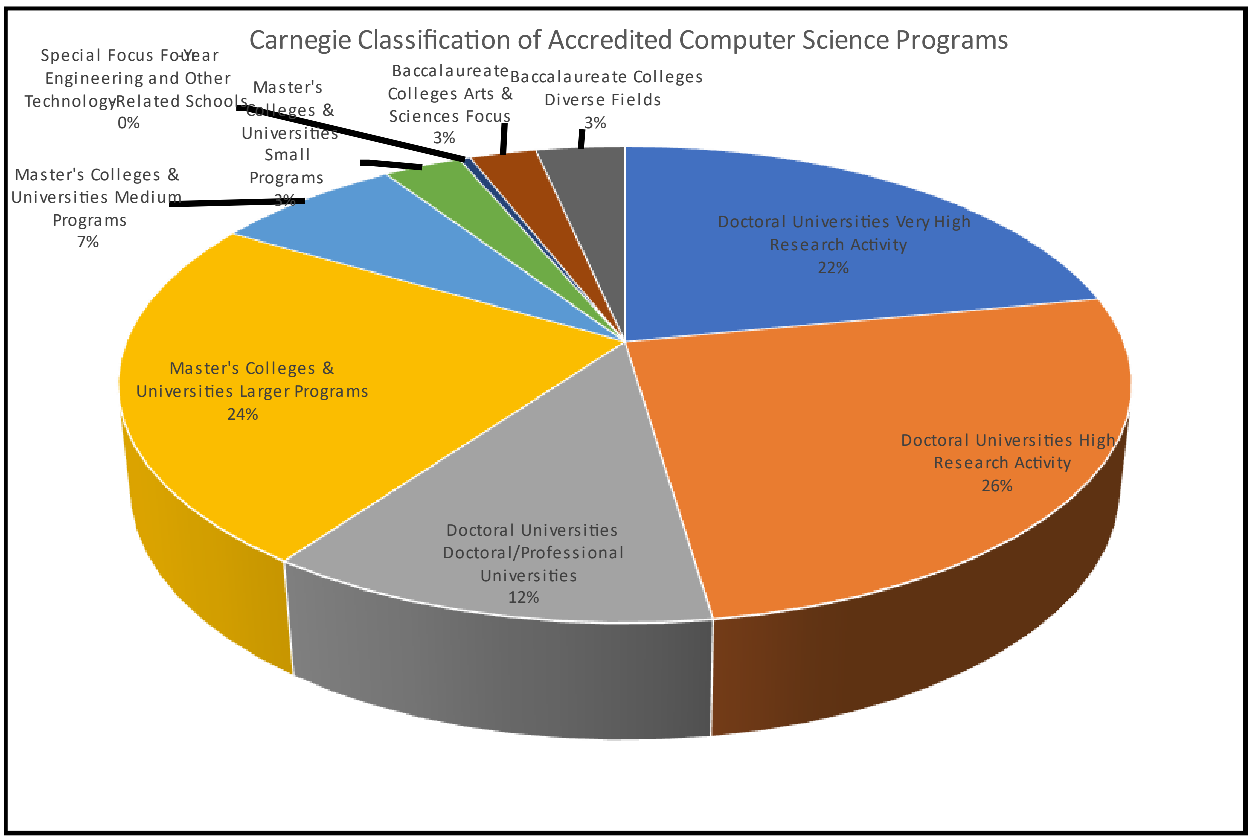

Figure 7 Carnegie Classification of Accredited Computer Science Programs

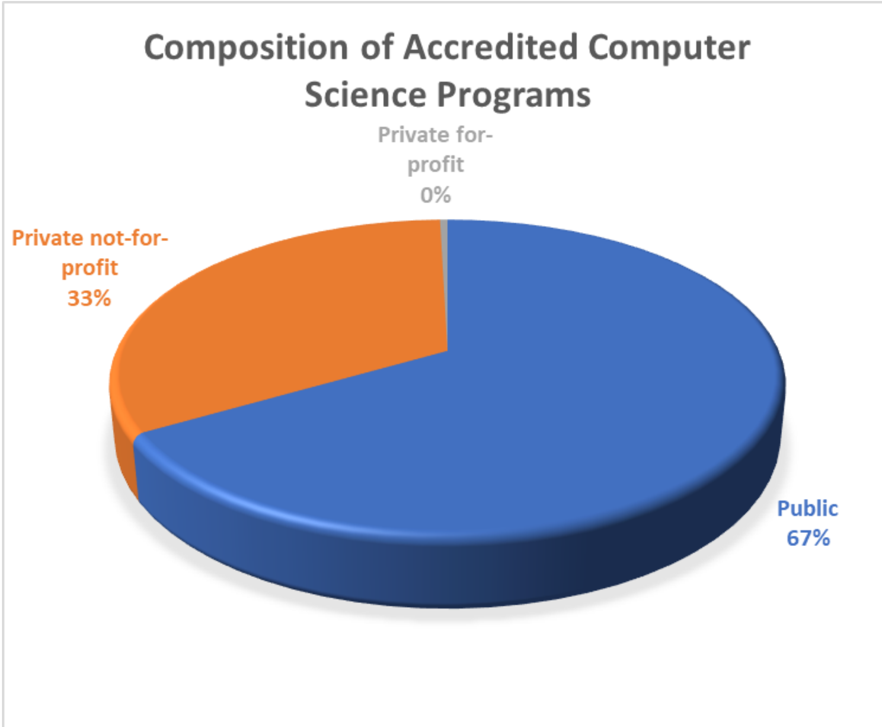

Figure 8 Type of university receiving accreditation.

Because of the considerable number of accredited computer science programs, a complete review of all programs is not feasible. Thus, a pseudo random sampling of instructions was reviewed, looking at 81 programs, or 22.5% of the 359 programs that existed in 2023 when the related Software Engineering work was published. Ideally, the population in the sampled set should mirror the overall population within the accredited set of programs, and overall, it is very similar, as is shown in Table 1.

Table 1 Differences in Populations by Carnegie Classification (Note: Sum is not equal to 100% due to rounding.)

Overall (n=81)	**Percent in Population**	**Percent in Sampled Set**	**Difference**
Doctoral Universities Very High Research Activity	*21.9%*	*19.1%*	*-2.8%*
Doctoral Universities High Research Activity	*25.7%*	*26.5%*	*0.7%*
Doctoral Universities Doctoral/Professional Universities	*12.2%*	*10.3%*	*-1.9%*
Master's Colleges & Universities Larger Programs	*23.6%*	*25.0%*	*1.4%*
Master's Colleges & Universities Medium Programs	*7.2%*	*7.4%*	*0.2%*
Master's Colleges & Universities Small Programs	*3.0%*	*4.4%*	*1.5%*
Special Focus Four-Year Engineering and Other Technology-Related Schools	*0.4%*	*1.5%*	*1.0%*
Baccalaureate Colleges Arts & Sciences Focus	*2.5%*	*1.5%*	*-1.1%*
Baccalaureate Colleges Diverse Fields	*3.4%*	*4.4%*	*1.0%*

When looking at programs in the sample set, all except for three universities were using the semester academic term. These schools then had their credit hours adjusted into semester hours. The required credit hours for the program ranged between 74 and 141, with a median value of 120 credit hours. When compared with the study of software engineering programs, Computer Science programs had a median of 4 less credit hours required than Software Engineering, representing a single less required course.

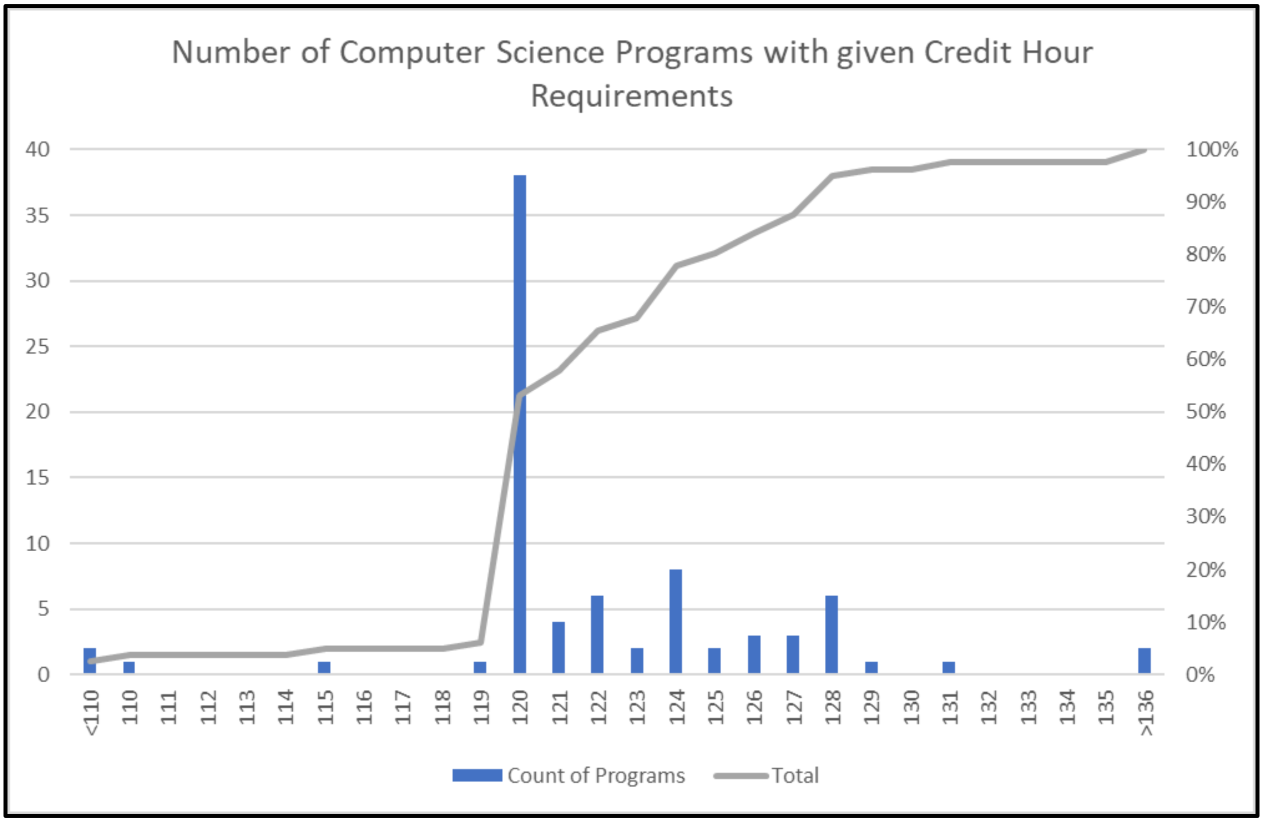

Figure 9 Credit Hours in Programs

An attempt was also made to determine the approximate number of graduates in each program from the ABET Accreditation material available on each program's website. This data represented the most up-to-date information published on the program's website, but did not necessarily represent the same year across programs. But, combining data from all programs from the most recent year reported, there were a total of 35019 students enrolled in the sampled computer science programs and 6012 graduates.

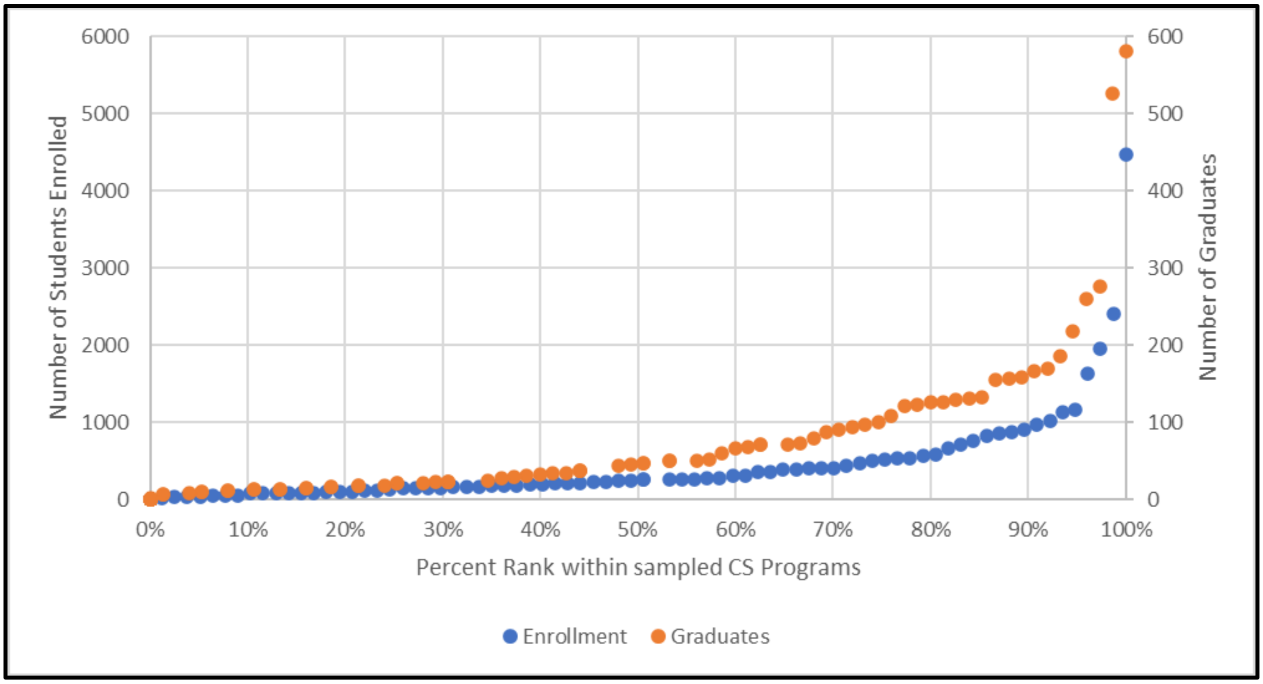

Figure 10 Enrollment and graduate sizes for sampled programs, collected from individual program's websites and ABET enrollment information.

Within the accredited programs sampled, there were vast differences in the number of students enrolled in computer science and the number of annual graduates. The smallest program enrolled just 7 students while the largest program had 4471 students, as is shown in Figure 10. The number of graduates varied similarly, from the smallest value of 3 to the largest value of 582. Overall, the median program enrollment was 254 and the median number of graduates was 47.

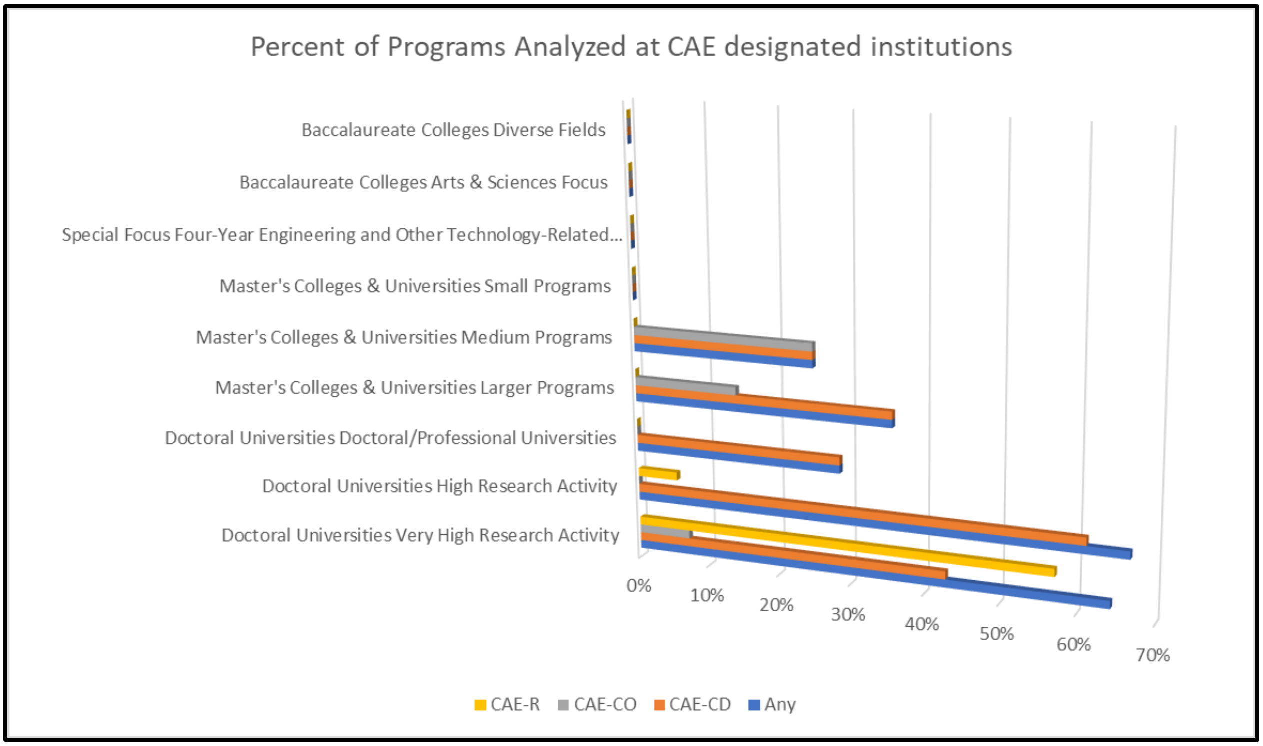

Figure 11 Accredited Computer Science Programs at CAE-CO and CAE-CD designated institutions within sample population.

Another interesting analysis was to look at the relationship between the sampled computer science programs and National Centers of Academic Excellence in Cybersecurity (NCAE-C) designees. A center of excellence designation could certainly be an advantage for a CS program, as there would be greater faculty expertise within the area as well as a richer set of courses that could potentially be used to teach cybersecurity material to students in the CS Program. Overall, it was quite common for the schools with R1 and R2 Carnegie Classifications to also be a designated cybersecurity center of excellence but was rarer for the other classifications.

Security Analysis

The key finding for this work was how do the computer science programs integrate security into their curricula, and how did this compare with Software Engineering. The ABET criteria does not specifically define how to integrate security or how much security is necessary within a program, as security is required in the general CAC Criteria and not the specific CS Criteria. In terms of the specific wording, computing topics must include "Principles and practices of security and privacy in computing". This differs from, for example, other aspects of the required curriculum, which require, for example, "Substantial coverage of algorithms and complexity, computer science theory, concepts of programming languages, and software development." [16] This difference makes it more challenging to ascertain what is required to have "sufficient" integration of security into the curriculum, which makes the computer science analysis slightly more difficult than the analysis of software engineering, as software engineering has a more substantial definition.

In reviewing the course catalogs, it was not possible to identify how security was integrated into a considerable number of programs. Of the programs studied, 43% required students to take a course which was focused on security. 19% covered security through random topics integrated into other required courses. A small number of programs required students to take a selective elective which is reported as requiring students to take a security course. However, a shocking 38% did not document within catalog entries how security was integrated into the curriculum. In all cases, the documentation of security coverage was less than that identified for software engineering conducted [16], as is shown in Figure 12.

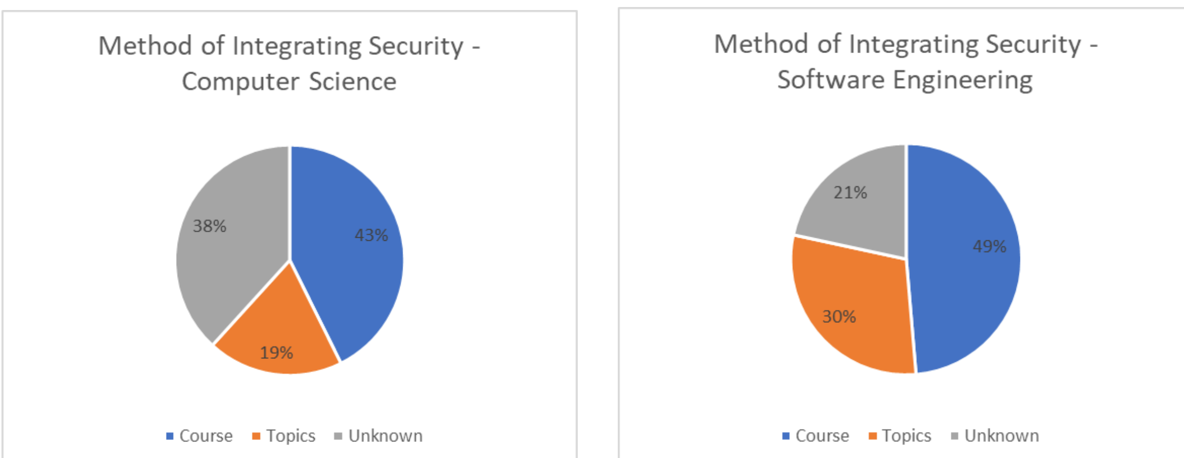

Figure 12 The techniques for covering security in the CS and SE curricula.

The analysis was then performed breaking programs down by Carnegie Classification, as is shown in Figure 13. Overall, there are slight differences across classifications, with more clarity in how security is integrated at higher levels of Carnegie classification.

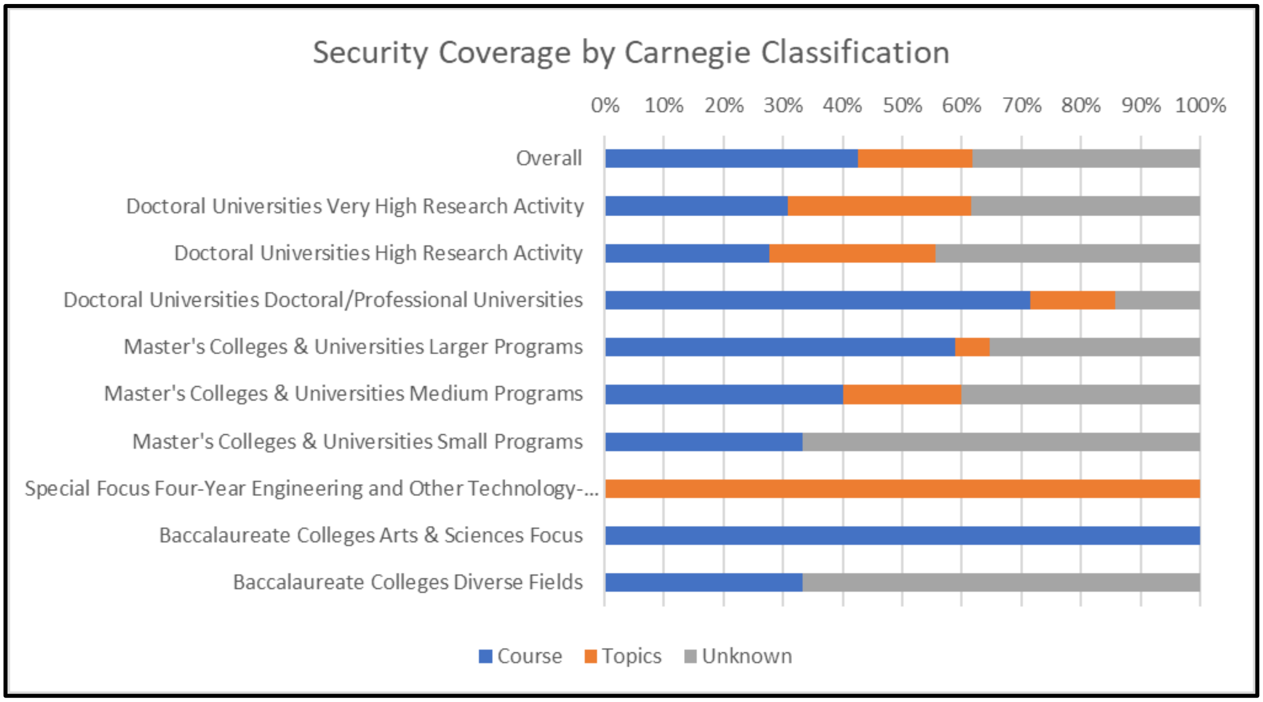

Figure 13 The techniques for covering topics in CS curricula broken out by Carnegie Classification.

The analysis was then broken down across CAE status for institutions. Overall, schools that had CAE designation tended to be slightly more formal in documenting coverage of security within the computer science program. This was especially evident at schools which had the CAE-CO designation, which is the program specifically targeting those in Computer Science areas. However, schools that held the CAE-R designation did not have any greater documentation than schools without the CAE designation, as is shown in Figure 14.

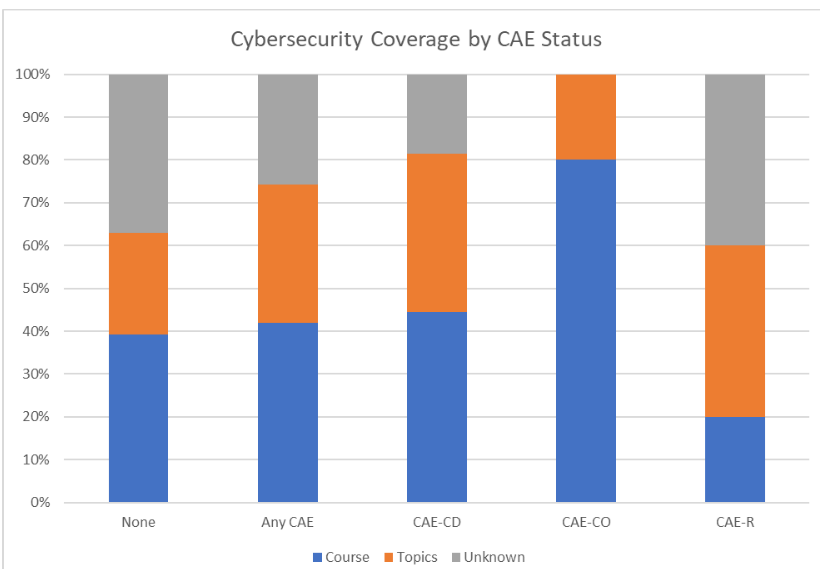

Figure 14 Security coverage by CAE status. Note a school may hold multiple designations.

Course titles were significantly varied, ranging from courses which focused on traditional Network Security, to courses which were clearly not as targeted to the discipline, such as Information Assurance. Example course titles that were consistent across multiple institutions included Introduction to Cybersecurity (5x), Computer Security (3x), Computer Networks and Security (3x), Secure Software Process (2x), and Cybersecurity Fundamentals. A word cloud with common title words is given in Figure 15.

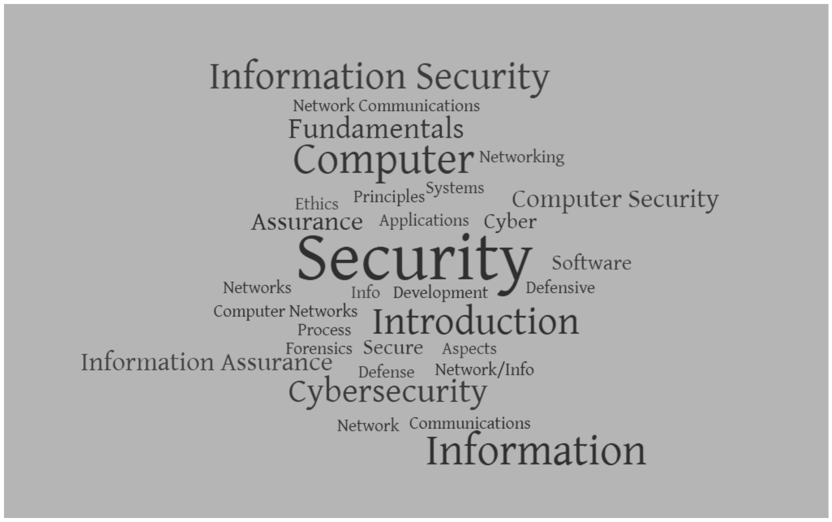

Figure 15 Word cloud of Cybersecurity title words.

With the course descriptions now being collected for each area, we also looked at what topics were included in these courses. To do this, the course descriptions were also converted into word clouds, with the most common topics appearing the largest. This resulted in a wide variety of topics, as is shown in Figure 16.

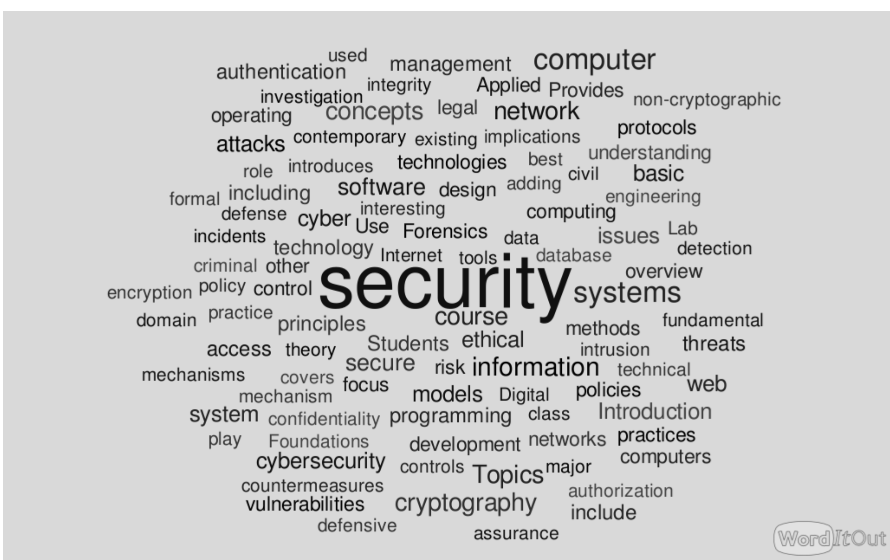

Figure 16 Security Word Cloud

Overall Analysis and Future Work

Overall, a review of existing accredited programs reveals that the security component is less formally documented than other areas of the computer science curriculum. In many programs, it is difficult to identify which security-related topics are covered based on course catalog entries alone. This is not entirely surprising, as security is the newest core area required by accreditation criteria, and its importance has grown significantly over the past decade. Additionally, the security field has evolved more rapidly than many other areas within the discipline.

Given the critical importance of security in both Computer Science and Software Engineering, it is essential that programs continue to enhance their coverage of these topics. The findings of this review of computer science programs closely mirror those observed in software engineering. While many programs are effectively integrating security through specific courses, others have not updated their curricula to adequately address this vital area. Both this review and the referenced review of software engineering are thorough in certain respects but limited in others, as they rely solely on catalog entries and curriculum descriptions. In practice, ABET evaluators also examine program self-studies, which may offer a more accurate reflection of how security is taught. It is hoped that this review presents a pessimistic view, since catalog entries may be outdated, and individual instructors often include content beyond what is officially documented.

As a study, this review is limited in scope. Although it analyzed 81 programs, this represents fewer than one-quarter of all accredited computer science programs. Moreover, while many computer science programs pursue accreditation, it is not as universal as it is in engineering disciplines. Although the programs were randomly selected, it remains difficult to determine whether the sample is truly representative of the broader set of accredited programs. Furthermore, data were collected over a period, which introduces the possibility that some programs added or removed security components between the earliest and latest data points, potentially skewing the results.

Beyond identifying what is currently covered in the security domain, additional work is needed to determine the most effective pedagogical approaches for teaching security and preparing students for the workforce. This will involve case studies of exemplary program integrations and further research into industry expectations for computer science graduates specializing in security.

Bibliography

[1] D. E. Knuth, "George Forsythe and the development of computer science," *Communications of the ACM,* vol. 15, no. 8, pp. 721-726, 1972.

[2] G. Gupta, "Computer Science Curriculum Developments in the 1960s," *IEEE Annals of the History of Computing,* pp. 40-54, April 2007.

[3] J. Shallit, "A Very Brief History of Computer Science," University of Waterloo, 1995. [Online]. Available: https://cs.uwaterloo.ca/~shallit/Courses/134/history.html. [Accessed December 2024].

[4] ACM Curriculum Committee on Computer Science, "An undergraduate program in computer science - preliminary recommendations," *Communications of the ACM,* vol. 8, no. 9, pp. 543-552, 1965.

[5] W. Atchison, S. Conte, J. Hamblen, T. Hull, T. Keenan, W. Kehl, E. McCluskey, S. Navarro, W. Rheinboldt, E. Schweppe, W. Viavant and D. Young, "Curriculum 68: Recommendations for academic programs in computer science: a report of the ACM curriculum committee on computer science," *Communications of the ACM,* vol. 11, no. 3, pp. 151-197, 1968.

[6] IEEE Computer Science Education Committee, "A Curriculum in Computer Science and Engineering," IEEE Computer Society, 1976.

[7] M. Mulder, "A Recommended Curriculum in Computer Science and Engineering," *Computer,* pp. 72-75, 12 1977.

[8] W. Atchison, "Curriculum 68: Recommendations for academic programs in computer science: a report of the ACM curriculum committee on computer science," *Communications of the ACM,* vol. 11, no. 3, pp. 151-197, 1968.

[9] ABET, *2002-2003 Criteria for Accrediting Computing Programs,* Baltimore: ABET, 2001.

[10] Association for Computing Machinery and IEEE Computer Society, *Computer Science Curriculum 2008: An Interim Revision of CS 2001,* ACM, 2008.

[11] The Joint Task Force on Computing Curricula, *Computer Science Curricula 2013: Curriculum Guidelines for Undergraduate Degree Programs in Computer Science,* ACM, 2013.

[12] ABET, *2018-2019 Criteria for Accrediting Computing Programs,* Baltimore: ABET, 2017.

[13] ABET, *2015-2016 Criteria for Accrediting Engineering Programs,* Baltimore: ABET, 2014.

[14] ABET, *Criteria for Accrediting Engineering Programs, 2016 – 2017,* Baltimore: ABET, 2015.

[15] W. W. Schilling, "The State of the Practice Integrating Security in ABET Accredited Software Engineering Programs," in *ASEE Annual Conference*, Baltimore, 2023.

[16] ABET, *Criteria for Accrediting Computing Programs, 2019 – 2020,* Baltimore: ABET, 2019.