Information Assurance Education in Two- and Four-Year Institutions

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ABSTRACT

The 2011 ITiCSE working group on information assurance (IA) education examined undergraduate curricula at the two- and four-year levels, both within and outside the United States (US). A broad set of two-year IA degree programs were examined in order to get a sense of similarities and differences between them. A broad set of four-year IA degree programs were also examined to explore their similarities and differences. A comparison between the two-year and fourfour-year degree programs revealed that the common challenge of articulation between two- and four-year programs exists in IA as well. The challenge of articulation was explored in some depth in order to understand what remedies might be available. Finally, a number of IA programs at international institutions were examined in order to gain insight into differences between US and non-US IA programs.

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1 INTRODUCTION
A lack of consensus of what constitutes information assurance (IA) education has led to IA degree programs with widely varying curricula. The US National Security Agency (NSA) and the US Department of Homeland Security (DHS) jointly sponsor the National Centers of Academic Excellence (CAE) in IA program [1]. An academic institution's resulting designation provides some evidence of the coverage of that institution's IA program. There are three different CAE program designations:

1. CAE-Research (CAE-R) [2] for research institutions, primarily a measure of the college's research output in IA.
2. CAE/Information Assurance Education (CAE/IAE) [3] which measures four-year US institutions according to the following criteria: Outreach/Collaboration, the extent to which IA is treated as a multidisciplinary science, the extent to which the institution encourages the practice of IA, the extent that the academic program encourages student research in IA, the extent of faculty activity in current IA practice and research, IA Resources, robustness of the IA academic program, existence of a declared center for IA education, and the number of IA faculty and their course load.
3. CAE two-year (CAE2Y), which measures two-year institutions with similar criteria to four-year institutions without a research expectation, and with the expectation that faculty members will have appropriate industry certifications.

The NSA/DHS CAE program is only open to US institutions. A key component of the application process is the mapping of an existing curriculum to a series of training standards (the CNSS 401X standards [4]). It should be noted that the CAE standards are currently in the process of being updated.

This working group has examined the programs of several two- and four-year institutions with respect to IA education. This paper defines and describes the distinct and complementary missions of two and four-year institutions with respect to IA education, describes the differences and similarities of the educational programs at two- and four-year institutions and at US and non-US institutions, and documents some of the challenges and opportunities for articulation between two- and four-year IA degree programs. This working group's mission is motivated by the increasing role community colleges have been playing in IA education, and builds on the work of the 2009 and 2010 ITiCSE IA working groups.

Previous working groups in IA education: During the 2009 Conference on Innovation and Technology in Computer Science Education (ITiCSE), the "Addressing Information Assurance Education Standards" working group undertook a retrospective study of the state of IA education. The working group consisted of 15 faculty, researchers, and government officials from Australia, Sweden, the UK and the US with a broad range of experience in IA in the educational, industrial and government sectors. The working group's paper [11] presented a brief history of IA education followed by a comprehensive review of extant academic, government, and industry standards and guidelines in the field. The paper also considered the issues of maintenance and updating of standards and the assessment of IA training and educational programs. Through its exploration of existing IA standards and guidelines, as well as in its discovery of what guidance is being provided from other areas of computing, the paper established a foundation on which future efforts to develop IA curricular guidelines could build. A key conclusion of the 2009 working group was that it was necessary to have a concerted global effort to develop models for IA education appropriate for two-year, four-year and graduate degrees housed in a variety of academic units and that these models should rely less on training standards and more on modern pedagogical and educational practices. The full report is available as [11].

In 2010, the "Towards Information Assurance Curricular Guidelines" working group endeavored to build on this foundation and to move forward with the first steps toward defining IA educational models. To this end, the working group attacked two specific problems. First, the working group sought to identify the set of topic areas that comprehensively define the field of IA, independent of the type of degree program and the specific discipline of the academic unit in which it resides. Second, the working group sought to develop a set of topics and associated student-learning outcomes for one particular subject in IA, namely, secure coding. This set of topics and corresponding student learning outcomes can serve as a model for future efforts to similarly define the other subjects. The full report is available as [12].

There are currently a wide variety of degree programs being offered by two-year and four-year institutions in and outside the US. These programs differ in the length, structure and emphasis of the curriculum and the purpose of the program with respect to both the professional and academic trajectories of their graduates. In conducting its work, the working group examined several examples of degree programs offered by two-year and four-year institutions. In doing so, no judgment was made on the quality of the program nor was any particular example endorsed as an exemplar for others to follow.

We emphasize the technical courses in each degree program as we are interested in understanding the information assurance content of the degree programs, but also examine, at a higher level, similarities and differences between the general education and supporting courses.

In the remainder of this document, we will refer to graduates of two-year degree programs as IA Technicians/Practitioners and graduates of four-year degree programs as IA Professionals. This is not a judgment on their quality or importance to the profession, but rather a reflection of the terminology used in human resources departments to distinguish between exempt and non-exempt employees.

2. ASSOCIATE DEGREE PROGRAMS IN INFORMATION ASSURANCE
Community colleges are playing an increasingly significant role as providers of IA education. The potential role of community colleges in IA education was first explored in 2002 [5, 6]. This American Association of Community Colleges (AACC) report identified several key areas in need of being addressed:

- Certification and skill standards (including collaborative initiatives with four-year schools, integrating courses and certifications into courses and programs, ensuring

the qualification of cybersecurity graduates, and providing resources and support),

- Establishment and maintenance of cybersecurity programs at community colleges (including strong partnerships between two- and four-year institutions, local, state, and federal government support for IA programs at community colleges, and local industry support),
- Specification of topics, courses, curricula and programs (including preparation of students for immediate employment post graduation as well as for continued education/career advancement, alignment of content, and student support and advising),
- Preparation for cybersecurity positions (including developing collaborative activities across institutions to promote careers in cybersecurity, encouraging students to participate in activities that are attractive to their future employers and graduate schools, and work with government agencies to create descriptions of cybersecurity positions appropriate for community college graduates), and
- Advancing the role of community colleges in cybersecurity education.

The AACC report laid important groundwork for providing direction to community colleges, and to the IA community in general, about the potential role community colleges should play in IA education. In the ensuing years, many subsequent grants in IA education were issued by the US National Science Foundation's Advanced Technological Education (ATE) program to community colleges to create IA programs. There are now three ATE Centers (CSSIA [7], CSEC [8], and CyberWatch [9]). The increasing role of community colleges in IA education led the NSA/DHS to create a specific designation in their CAE program for community colleges, referred to as CAE2Y. This designation was influenced by a report from CyberWatch [10].

Today, associate degree programs in information assurance, typically offered by community and technical colleges, play a major role in the education of IA technicians, practitioners and professionals in the US. These programs vary in their particular emphases, their curricular structure, and whether they are meant to place graduates into the workforce or to matriculate students into more advanced degree programs.

There are two common two-year degrees in IA, the Associate of Science (AS) degree and the Associate of Applied Science (AAS) degree. AS degree programs are typically designed to articulate seamlessly into four-year undergraduate curricula and students delay their workforce entry until after completing the baccalaureate degree. AAS degree programs, on the other hand, traditionally prepare students to enter the workforce immediately upon graduation.

2.1 Examination of Associate Degree Programs

In this section, we examined the content, context and purpose of 16 associate degree IA programs (see Table 1) in an attempt to uncover significant commonalities and differences. Although not a randomly selected sample, a broad range of degree programs was examined. Of the approximate 1200 community colleges nationwide, only 13 have received the CAE2Y designation as of the writing of this paper. Of the 13 CAE2Y institutions, seven were examined along with nine other non-CAE2Y programs. Of all 16 associate degree programs examined, 14 were workforce-oriented (e.g. AAS) and two were transfer-oriented (e.g. AS) degrees. It is interesting to note that all the CAE2Ys are workforce-oriented and are not focused on transferring into baccalaureate-degree programs.

In the examination of courses offered in IA associate degree programs, the working group considered three broad categories of courses: general education, supporting, and technical. General education courses include English composition, communications, social and natural sciences. Associate-level supporting courses include mathematics and logic, and form the non-technical, required component of an IA degree program. The primary component of an IA degree program is the required technical courses that cover specific information assurance and related topics.

2.2 General Education and Supporting Courses

The American Association of Community Colleges strongly recommends that one-third of the work for an associate of applied science degree and one-half of the work for an associate of science degree be in general education [13]. Overall, the general education courses help to satisfy college and state education department core requirements, expectations of employers relative to soft skills and general knowledge, and students' personal interests in areas such as health, music, and art. In the AS degree programs, the general education courses also provided the students with greater flexibility in completing two full years of coursework that transfer to a baccalaureate degree.

Table 1: Institution, location, degree type and program name of the 16 associate degree programs examined by the working group.

Institution	Location	Degree Type	Program Name
Owens Community College (CAE2Y)	OH	AAB	System Security and Information Assurance
Anne Arundel Community College (CAE2Y)	MD	AAS	Information Assurance and Cybersecurity
The Community College of Baltimore County (CAE2Y)	MD	AAS	Information Systems Security
Asheville-Buncombe Technical Community College	NC	AAS	Information Systems Security
Craven Community College	NC	AAS	Information Systems Security
Gwinnett Technical College	GA	AAS	Information Security Specialist
Bossier Parish Community College	LA	AAS	Information Network Security Specialist
Northern Virginia Community College	VA	AAS	Information Systems Technology with a Network Security concentration
Whatcom Community College (CAE2Y)	WA	AS Technical	Computer Information Systems with a Network Security concentration (not intended to transfer)
Highline Community College	WA	AAS	Networking Specialist
Highline Community College	WA	AAS	Data Recovery/Forensics Specialist
Hagerstown Community College (CAE2Y)	MD	AAS	Information Systems Technology with a Computer Forensics concentration
Broome Community College	NY	AAS	Computer Security and Forensics
Oklahoma City Community College (CAE2Y)	OK	AAS	Computer Science - Cyber/Information Security concentration
Oklahoma City Community College (CAE2Y)	OK	AS	Computer Science - Cyber/Information Security University Parallel (transfer)
Harrisburg Area Community College	PA	AS	Computer Information Security (transfer)

Table 2 shows the results of the working group's examination of the general education requirements of the 16 IA associate degree programs. For all career (workforce) and transfer degrees, English Composition I was required. Using a weighted average, English Composition II was required 50% of the time, while Technical Writing was required only 10% of the time for both career and transfer degrees. It is interesting to note that Technical Writing was present only in the career-oriented programs. Also noteworthy is that social or behavioral science was required in 90% of the AAS degrees and 100% in the AS degrees for a combined weighted average of 91%.

Supporting courses help to satisfy expectations of employers relative to mathematical skills and knowledge, prerequisites for technical courses, vendor-specific, industry and government certification requirements, and to develop analytical and problem-solving skills. Associate-level supporting courses also serve to satisfy prerequisite requirements for advanced science, mathematics and technical courses.

Table 3 shows the results of the working group's examination of the supporting course requirements of the sixteen IA associate degree programs. College algebra was the most common required mathematics course for both career (workforce) and transfer degrees with a 63% weighted average. Courses in Calculus and Discrete Mathematics were only required in the transfer programs.

Table 2: Composition of the general education requirements of IA associate degree programs.

General Education College Requirements Associate Degrees			
	Career Degrees (sample size = 14)	**Transfer Degrees** (sample size = 2)	**Career and Transfer Degrees** (sample size = 16)
English Comp. I	100%	100%	100%
English Comp. II	43%	100%	50%
Technical Writing	11%	0%	10%
Speech or Communications	75%	100%	79%
Humanities or Fine Arts	54%	100%	60%
Social or Behavioral Science	90%	100%	91%
History or Political Science	8%	100%	19%
Biological or Physical Science	36%	100%	44%
Health or Wellness	15%	50%	19%

Table 3: Composition of the supporting course requirements of IA associate degree programs.

Supporting Program Requirements Associate Degrees			
	Career Degrees (sample size = 14)	**Transfer Degrees** (sample size = 2)	**Career and Transfer Degrees** (sample size = 16)
Finite Math	18%	0%	16%
College Algebra	65%	50%	63%
Logic	18%	0%	16%
Trigonometry	8%	50%	13%
Pre-calculus	15 %	100%	25%
Calculus I or Discrete Mathematics	0%	100%	13%
Calculus II	0%	50%	7%

2.3 Technical Courses

In examining the required technical courses, there was considerable variation across the 16 associate degree programs (14 AAS and two AS). However, the working group was able to identify certain commonalities across the surveyed curricula:

- The majority of all associate degree programs include a
  - general computer survey course,
  - security fundamentals course,
  - networking course.
- Approximately half of all the programs include a
  - digital forensics course,
  - general operating systems course,
  - database course.
- Half of the AAS programs included either a capstone course or internship.
- As expected the AS programs required an introductory programming course, whereas only half of the AAS programs required it.

Technical degree programs at community colleges typically have advisory boards comprised of representatives from local business, industry, government and/or transfer institutions that help shape IA associate degree programs. AAS programs are populated with a variety of specialized technical IA courses, such as ethical hacking, wireless security, secure e-commerce, and security policies to fulfill regional needs. The three NSF ATE Regional Centers for IA education (as cited previously) have also influenced some IA degree programs, in particular the model curriculum developed by CyberWatch.

2.4 Role of Industry Certifications

There was significant discussion at the working group sessions about the role that industry-based certifications could and should play as part of AAS degree programs. There are several advantages of embedding content from industry certifications within an AAS degree. The first advantage is differentiation. Students with an associate degree along with an industry certification may receive special consideration when applying for employment. Graduates of these programs often have additional knowledge and an increased skill level with a particular product (e.g. Cisco Networks). Consequently, they often receive increased compensatory benefits, such as raises and promotions, for possessing specific industry-based certifications.

Attracting students from technical high schools is a second advantage. The completion of a certification during high school may afford students an opportunity to receive college credit and/or advanced placement when entering a community college. In the US, there has been a reshaping of the old vocational education programs in high schools in many states. The new programs, rebranded as Career and Technical Education (CTE), are meant to attract students who are interested in attending college whereas the older vocational education programs tended to be focused on those students who wished to enter the workforce immediately after completing high school. Several 2 + 2 articulation programs have arisen, where the first 2 refers to classes taken during high school and the last 2 refers to classes taken at a community college. A student's passing a certification exam is one way to "validate" the quality of the course the student took at high school.

Enhanced perception is a third advantage. Both high school students with certifications and their parents often look favorably on college degrees offering industry certifications as they afford enhanced opportunities for gaining employment upon graduation.

A fourth advantage is a standardized assessment of prior learning. Students, in particular returning adults, can be given credit and/or advanced placement for industry certifications.

A fifth advantage is meeting employer requirements. For example, positions in some federal sectors require industry certifications. Many federal entry-level positions are required to obtain certification such as A+, Network+, Security+, and SCSP, while senior level positions may require the CISSP certification. This is especially true of the Department of Defense (DoD) civil service or contractor roles that involve managing or securing DoD systems. The necessity for community colleges to incorporate certification content into degree programs is likely regionally based and dependent on the prevalence of employment requirements in the region.

On the other hand, there are also challenges associated with embedding content from industry certifications into AAS degree programs. Community colleges are challenged by courses that are heavily-based upon certification content; they often do not transfer since equivalent courses are not typically offered as part of a baccalaureate degree in IA. The goal of passing certification exams tends to focus the curriculum more on specific skills and less on underlying educational concepts in IA that are emphasized in four-year degree programs. Historically, this has not been a problem as the AAS was designed as a terminal degree and relatively few graduates matriculated to baccalaureate degree programs. However, there is evidence that this is changing [25].

Another challenge with certifications is the pressure on community college faculty and the curriculum to remain current with the changing requirements in industry. Community colleges may not provide the funds to assist faculty with the cost associated with recertification requirements. This may be particularly important for faculty, since some may be evaluated on the number of students who pass these exams.

Cisco (vendor-specific) and CompTIA (vendor-independent) were common certifications that appeared to map well to security courses in 11 of the 14 AAS degree programs examined. Conversely, the two AS degree programs did not include industry certifications.

2.5 Examples of AAS Programs in IA

The AAS degree typically includes a specialization or concentration in a particular subtopic of information assurance.

There were two such concentration areas discovered in this examination, network security and computer forensics. The working group further examined the AAS degree programs for these two specializations.

Figure 1 shows an AAS IA degree in network security. The large technical component of this program includes the first four courses in Cisco networking certification (I, II, III, and IV).

Figure 1: Course content of a typical AAS IA degree program in network security.

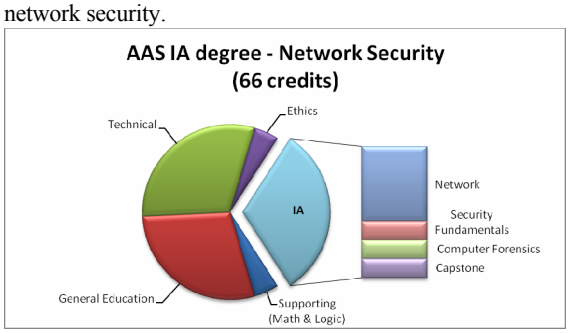
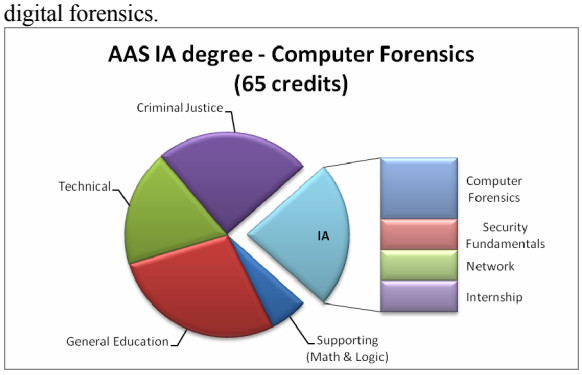


Figure 2 demonstrates an AAS IA degree in Computer Forensics This program resembles the AAS Network Security degree with criminal justice courses taking the place of some technical courses.

Figure 2: Course content of a typical AAS IA degree program in digital forensics.



See Figure 4 (in section 4) for a representation of a typical AS degree program that is designed to transfer into a baccalaureate IA degree program with foundations in computer science.

3. FOUR-YEAR DEGREE PROGRAMS IN INFORMATION ASSURANCE

At the moment, the majority of information assurance programs in the US exist at the graduate level; however, four-year programs are becoming increasingly widespread. It is not clear exactly what constitutes an undergraduate program in IA. For example, a single security course taken as part of a CS or CIS (computer information systems) degree seems not to be an IA program. As reported below, the vast majority of undergraduate CAE/IAE IA programs are housed within CS or CIS departments. But what about a sequence of two security courses? Or three security courses? And what about IA content covered as part of several CS courses (operating systems, networking, programming languages, etc.)? Despite the challenges involved in determining how much IA coverage is enough, an examination of the courses that make up baccalaureate CS and CIS degrees shows both an increase in the number of security courses as well as an increase in the number of security topics covered as part of required and elective courses. The reported need for a large cadre of cybersecurity professionals [28] may be stimulating the creation of many new four-year IA degree programs.

The working group could identify 73 CAE institutions that offered baccalaureate degrees with IA concentrations or minors [1]. Of these, 42 are housed in computer science departments, 16 are housed within computer information systems departments, six are in security departments, five are housed within information technology departments, four are housed within schools/departments of informatics, three are housed within electrical and computer engineering departments, one is located within a software engineering department, and one is located within a criminal justice department. Five of the 73 schools housed baccalaureate programs in two departments, and both departments were included in the above totals. While well more than 50% of all baccalaureate programs are housed in departments of computer science, the working group intentionally selected to examine programs that represented the breadth of IA rather than a proportional sample of the CAE IA baccalaureate programs. Thus, the 16 programs examined, represented a much wider range of IA programs than had programs been randomly selected from the 73 CAE baccalaureate institutions. Note that the working group also chose to examine a few IA baccalaureate programs that did not have a CAE designation as it felt these programs might represent some of the less mature, but more original IA programs.

3.1 Examination of Baccalaureate-Degree Programs

The working group chose to study nine four-year IA degree programs (see Table 4) and examined an additional seven programs in lesser detail. In choosing the programs to examine, the working group chose programs that had clearly documented curricula and which represented the broadest spectrum of degree types. Another factor in selecting programs was the familiarity of working group members with certain degree programs.

Table 4: Institution, degree type and program name of the nine four-year degree programs examined by the working group.

Institution	Degree Type	Program Name
Kennesaw State University (CAE/IAE)	BS	Information Security and Assurance
Mercy College (CAE/IAE)	BS	Cybersecurity
Oklahoma State University Institute of Technology	BT	Information Assurance and Forensics
Pennsylvania College of Technology	BS	Information Technology
Rochester Institute of Technology (CAE/IAE)	BS	Information Security and Forensics
Stevens Institute of Technology (CAE/IAE)	BS	Cybersecurity
University of Texas, San Antonio (CAE/IAE, CAE-R)	BBA	Infrastructure Assurance
Towson University (CAE/IAE)	BS	Computer Science with a Security Track
University of Wilmington (CAE/IAE)	BS	Computer and Network Security

3.2 General Education and Supporting Courses

The working group found that for the nine four-year programs examined in great detail, the general education and supporting course requirements differ widely from program to program – there even is great variation of programs offered within the same state. Many of the programs examined require specific courses that at the same time also fulfill some of the general education and/or supporting course requirements. Some of the schools specifically require courses such as English Composition/Writing or Communications. The science requirements typically include a laboratory component. Furthermore, seven of the nine programs examined require an ethics course (typically on the upper level). The working group observed that the more technical a program is the greater a challenge it is to combine the in-depth coverage of technical material with a well-rounded, broad-based education – typically represented by general education and supporting courses. The more technical programs included requirements such as (two semesters of) calculus, discrete mathematics, and statistics.

3.3 Technical Courses

A detailed examination of the specific course requirements for the nine degree programs in Table 4 indicated that the curricula span a spectrum from highly concentrated in CS to highly concentrated in IT. Unique program offerings include: Oklahoma State University of Technology which offers a Bachelors of Technology in Information Assurance and Forensics; the University of San Antonio, which offers a Bachelor of Business Administration (BBA) in Infrastructure Assurance with a heavy emphasis on IS; and the interdisciplinary BS in Security and Risk Analysis in the College of Information Science and Technology at Penn State which offers three tracks (Intelligence Analysis and Modeling, Information and Cyber Security, and Social Factors and Risks).

All programs studied include a course in the greater context of network security. Most programs include some introductory course on security as well as a course on ethics. Aside from that, no other commonalities across the nine programs could be identified with respect to the technical courses. This observation is likely an artifact of the intentional choice of the working group to examine a diverse set of four-year degree programs, including some that are housed at non-CAE institutions.

A few of the examined four-year IA degree programs (typically the non-computing ones) exhibit an "applied" focus and as such appear to be more of a terminal degree. These programs lack advanced math courses and foundational theoretical courses and thus may preclude their graduates from pursuing advanced studies. This seems particularly true for programs that do not require both Calculus I and Calculus II that are typically required for entrance into advanced degrees in technical fields.

The working group identified some practices that could potentially serve as a model for future implementation of IA degree programs. Specific examples include: a capstone security project (involving real customers) at Stevens Institute of Technology (SIT) and Mercy College; and a strong emphasis on practical experience through required co-ops and internships at Rochester Institute of Technology and Penn State.

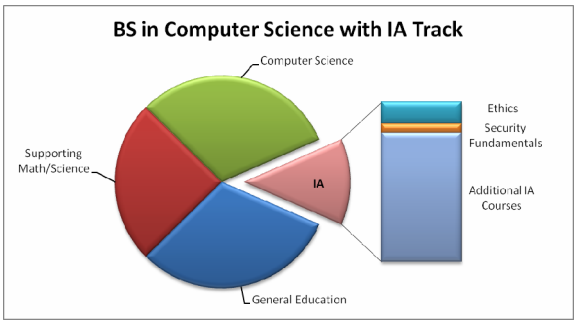
3.4 Baccalaureate Programs in Computer Science with IA Track

Given that 58 of the 73 baccalaureate degrees offered by CAE institutions are in computing-related departments and 42 of these 58 are housed in computer science departments. the working group examined seven baccalaureate degree programs in computer science (CS) with a track in IA (in addition to the nine programs in Table 4) in order to investigate whether there are commonalities among such programs. The programs examined are the BS in CS programs at Towson University, SIT UMass Amherst, NJIT, NYU Poly, Ohio State University, and UMBC. Note that SIT has both a BS in CS with a track in cybersecurity as well as a dedicated BS in Cybersecurity program.

As expected, the working group found that all seven of the programs examined include the typical requirements for a BS in CS. In comparing the programs to a traditional CS degree, the BS in CS programs with a IA track typically replace electives with security-specific courses such as network security, secure coding, cryptography, and privacy. Tracks in the programs examined typically include two to six courses. Most programs examined include a course on ethics and some of the programs include a course on security fundamentals.

Figure 3 provides an average across the seven institutions examined. The core in CS is clearly prevalent. In addition, there is a strong general education and supporting course component across all programs.

Figure 3: Course content of a typical BS in Computer Science with an IA track.



Given the large number of degree programs housed in computing departments, the working group conjectures that offering a security track within a computing degree is a practical way to construct a first response to the cybersecurity education challenge.

4. ARTICULATION OF TWO-YEAR AND FOUR-YEAR INFORMATION ASSURANCE PROGRAMS

Both two-year and four-year schools face the challenge of producing qualified graduates to meet the nation's demand for information assurance technicians/practitioners and professionals. Given the prolonged downturn in the economy and limited capacity at public four-year state institutions, students of all ages have chosen to attend community colleges to earn either an associate career degree, begin a pathway to a baccalaureate degree, or retrain to change careers [29]. As institutions attempt to respond to the national need for professionals with IA skills,

degree programs are being built with little guidance from the field. This has further complicated the already difficult articulation process between two-year and four-your degree programs. In the remainder of this section, the relationship between two-year and four-year IA curricula is examined, and suggestions are provided that may facilitate articulation between IA programs.

4.1 Articulation in IA Degree Programs

Of the programs examined, there are a few examples where there is a clear path for course articulation between two- and four-year information assurance degree programs. Pennsylvania College of Technology articulates with Harrisburg Community College, Wilmington University College of Technology has established a transfer agreement with the Community Colleges of Baltimore County, and Oklahoma State University of Technology articulates with Oklahoma City University. The program at Penn State University includes three tracks and is offered across four Penn State Campuses, namely, Penn State Altoona, Penn State Berks, Penn State Harrisburg, and University Park. Additionally, there are some examples of AAS IA degree programs articulating with baccalaureate degrees, such as the Community College of Baltimore County (Maryland) and the University of Wilmington (Delaware) as well as Oklahoma City Community College and Oklahoma State University, Institute of Technology [27].

It is possible that such agreements will be more common, but at the moment they are the exception and several challenges remain across the curriculum with respect to articulation. We now present some observations about these challenges and some suggestions for addressing them.

4.2 General Education and Supporting Courses

When examining the general education and supporting courses in the curricula of two-year and four-year information assurance degree programs, it is clear that there exists key differences in both areas.

First, four-year degree programs typically have general education requirements that exceed those in AAS degree programs. For example, an essential tool in the information assurance workforce is effective oral and written communication skills. Currently many four-year institutions will not accept a technical writing course as a substitute for the second composition course. Close cooperation between institutions might allow for a technical writing course to substitute for a composition course. Alternatively, four-year institutions could include a technical writing course as part of their curricula.

Second, few two-year programs include an ethics course where as most four-year programs typically require an upper level ethics course. This situation may present another opportunity for facilitating articulation between two- and four-year programs by having four-year schools examine opportunities for lower level ethics courses. For example, the University of Texas at San Antonio currently offers Social and Ethical Issues in Business as a sophomore-level course in their BBA in Infrastructure Assurance curriculum.

Finally, most four-year programs require a science course with a laboratory component, whereas two-year AAS degrees have no science requirement. In addition, the more technically rigorous four-year programs require calculus and other advanced mathematics courses such as statistics or discrete math. It should be pointed out that this is a challenge that impacts many technical degree programs and not just IA programs.

4.3 Technical Courses

With respect to technical courses, two common situations were identified that can lead to articulation difficulties. The first occurs when a course is required in the two-year program, but is simply not part of the four-year program. Examples of this include certification-based courses (see section 2.4), computer concepts courses, platform-specific operating systems courses, and specialized security courses such as ethical hacking. The second occurs when the two-year program and the four-year program each have a course about a specific topic, such as forensics, but the course in the two-year program is not considered equivalent to the course in the four-year program. This situation often occurs because of additional pre-requisites and differences in the depth of content coverage between the courses. Both scenarios result in the loss of college credit for students. Again, increased cooperation between institutions is necessary for these situations to be minimized.

4.4 Certification

As noted in section 2, certifications have significant influence on the curricula of AAS degrees programs that produce a very large number of the information assurance technicians. Many two-year IA degree programs are using curricula developed by consortia such as CyberWatch [9] and CSEC [8]. These curricula are heavily weighted in favor of industry certification and/or meeting local workforce needs and this frequently inhibits articulation with four-year degree programs. This challenge is magnified by the fact that certifications may also be obtained through high school curricula and professional training institutes such as CompTIA, Cisco, and SANS.

In the future it may be that these critical members of the information assurance workforce will need to earn higher-level degrees to advance their careers. This might require four-year programs that accept some certification-based courses. For example, it might be possible to allow the following based on detailed analyses of the specific course outcomes:

- CompTIA Security+ could articulate as a Security Fundamentals course (four-year)
- CompTIA Network+ could articulate to a lower level technical elective (four-year)
- Cisco course sequences could articulate to a lower level technical elective (four-year)

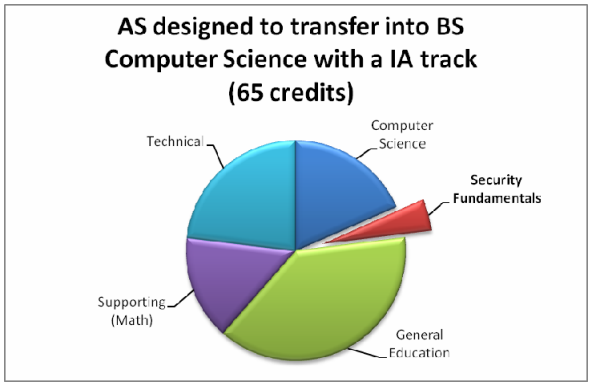
As another example, CyberWatch provides an AS model degree program that provides an additional six credits of general education courses that, while retaining many certification-oriented and security specialization courses that make the degree valuable to employers, enhances transferability. Two-year institutions must carefully consider the goals of the degree in terms of the trade-off between transferability and certification.

4.5 Comparing Traditional AS in Computer Science with BS in Computer Science with IA Track

The working group explored whether it is possible to tailor a typical AS degree program in Computer Science that generally transfers to a BS in Computer Science in such a way that the

modified AS degree may service as a basis for a transfer in the IA context – specifically to a typical BS in Computer Science program with a track in IA. Figure 4 represents a typical AS degree program in Computer Science that was modified by including a course on Security Fundamentals. Comparing Figures 3 and 4 shows that such a modified AS degree will provide the typical connection points enabling the transfer between a traditional AS in CS and a traditional BS in CS. In addition, the inclusion of a course on Security Fundamentals will possibly provide for the transfer of some credits in IA.

Figure 4: Course content of an AS degree program designed to transfer into a baccalaureate degree in computer science with a track in IA.



4.6 Suggestions for Improving Articulation

Clearly better working relationships and closer cooperation between institutions are necessary to improve course articulation between two- and four-year IA degree programs. However, the problem is exacerbated by the fact that these curricula have been developed without accepted curricular guidelines or a standard body of knowledge and this has complicated the articulation issue. In the following, we present some approaches that are being used to address articulation challenges.

In order to facilitate articulation between two-year and four-year degree programs, four-year programs could include "placeholder" courses at the freshmen and sophomore levels that could be filled in with courses from associate degrees. Similarly, certification-based courses in two-year programs could be redesigned to achieve a better balance between skills training and fundamental IA educational outcomes. The latter would be much easier if the IA community adopted a student learning outcomes approach to course and curriculum design.

Though not unique to IA, IA seems to attract a large number of non-traditional students, such as veterans and returning adults, who would benefit from innovative approaches such as elective credit for service learning, internships, and independent project/undergraduate research. This needs to be taken into account in both two-year and four-year degree programs in a consistent manner.

Other approaches to improving articulation and transfer include bridge programs and improved academic advising. Bridge programs, whether offered at the two-year or the four-year institution, typically include a sequence of short courses designed to fill in the curricular gaps between two- and four-year programs. In order to provide better advising to transfer students, updated and complete program descriptions should be readily available. Again, this would be easier if the community agreed on student learning outcomes based approach.

For BS in CS security track programs, CS1 and CS2 are common courses [30]. The working group notes that secure coding and secure software development could be integral elements throughout CS1, CS2, and all subsequent programming courses. Additionally, curricular bodies of knowledge produced by professional societies such as ACM and IEEE-CS should include security in their guidelines for Computer Science (CS2013), Information Systems, Software Engineering, Computer Engineering and Information Technology.

An interesting recent development in information assurance education is that some two-year colleges are dropping the "community college" designation and have developed Bachelor of Applied Technology degrees (examples include Brazosport College and South Texas College in Texas) to better accommodate technical and occupationally oriented programs. These degrees will almost certainly limit a student's ability to eventually pursue graduate work, but may meet an existing need in some locations for technical degrees that accommodate a large number of hands-on, skills-based courses and workforce needs.

5. NON-US INFORMATION ASSURANCE DEGREE PROGRAMS

The working group considered the applicability of information assurance at institutions outside the US. As expected, the term "information assurance" is not used internationally as terms such as ICT[1] security, computer network and security, information security systems, corporate and ICT security, and cyber security are preferred. For the purposes of this section, the term "computing security" is used to identify the intended degree areas sponsored by the various institutions.

The working group searched for security programs at the baccalaureate and at the diploma (two-year college, community college) levels. Alas, the working group could not find reasonable diploma programs, except for one diploma program in Canada (that did not include a program description). While it believed that some diploma programs could exist, many descriptions appeared in foreign languages, such as Japanese, that were not decipherable within the working time of the group. Hence, the group focused only on baccalaureate computing security programs.

5.1 External Validation of Programs

The working group investigated the role of independent, non-governmental validation of computing security programs. While it found some informal synergistic groups, it found no agency that validated baccalaureate security programs in any country beyond the US. However, it did find that some programs, for their own interest, made an attempt to model their curricula according to previously published ACM/IEEE such as IS2003, CE2004, SE2004, CS2008, and IT2008 [31]. Unfortunately, the ACM and the IEEE Computer Society have not yet addressed the need of a curriculum model for computing security.

As a future endeavor, this working group recommends strongly that professional societies within and beyond the US undertake the task of developing a computing security curriculum. It also

[1] Note that information and communication technology (ICT) as an international term is generally considered equivalent to the term information technology (IT) in the United States.

recommends that this effort consider the use of the "areas" and "subjects" developed at ITiCSE 2010 [12], which informed this working group effort. Having a uniform foundation or basis for a security curriculum would facilitate a measure of quality of a program and provide a vehicle of comparison among programs. It would also be helpful if external agencies consider the accreditation of computing security programs. Such agencies include the British Computer Society in the UK, the Akkreditierungsagentur für Studiengänge der Ingenieurwissenschaften, der Informatik, der Naturwissenschaften und der Mathematik (ASIIM) e.V. in Germany, the Swedish National Agency for Higher Education (Högskoleverket – HSV) in Sweden, and ABET in the US that does international accreditation of computing programs.

5.2 Graduate Profiles

Graduates from non-US institutions in computing security have ample opportunities to enter the job market or to continue their studies at the post-graduate (masters and doctoral) levels. Graduating from a computing security program does not preclude entrance to the job market or post-graduate studies in non-security areas as the security curriculum is robust enough to enable students to migrate to other areas of work or study.

Regarding professional employment, opportunities exist in the areas such as IT/ICT security specialists or systems communications developers. Opportunities exist in a graduate's native country or beyond and the greater the specificity, the better opportunity for employment. A simple search of applicable employment opportunities include IT security architect, IT security analyst, senior security developer, security manager, cyber security engineer, cyber R&D engineer, security advisor, senior specialist within government security, platform security manager, security officer, assistant security manager, radio and communications security repairer, cyber security engineer, analyst in education information security, senior information security engineer, senior network security engineer, information security tool developer, systems security engineer, and many others.

Many universities outside the US prepare students for post-graduate education. It is at the postgraduate level where computer security programs most frequently reside. Some examples of institutions that offer master-level studies include Masters in Information Security, University of London (UK); MSc in Computer Security, University of Birmingham (UK); Masters in Information and Communication Systems Security; Stockholm University (Sweden); Information Security Graduate Degree program for Adult Professionals, University of Fairfax, Austria; Master of Information Systems Security, Charles Sturt University, Australia; Cryptology, Security and Information Coding, Université Joseph Fourier, Grenoble (France); and Master in Internet Security, University of Applied Sciences Gelsenkirchen (Germany).

At the doctoral level, some institutions offering doctoral-level studies include PhD in Information Security, University of London; PhD in Information Security, Gjøvik University College, Norway; PhD student in Computer Science with specialization in Privacy and Security, Royal Institute of Technology, Sweden; and Information Security Collaborative PhD program with specialization in information security, Indraprastha Institute of Information Technology, Delhi, India. In countries such as Russia and Ukraine and other eastern countries, when they study within a baccalaureate program at a university or at an institute (as opposed to colleges) one can choose a masters degree or a doctoral program from the fourth year of study. At some places such as Sweden, the baccalaureate is not a good way to prepare for MSc or PhD studies since the applied/professional work during the third year cannot be counted in a longer educational program.

5.3 Analysis of non-US Four-Year Degree Programs

The working group performed a comparison of baccalaureate computing security programs offered at seven non-US institutions. The program titles, institutions, and countries appear in Table 5. In performing their analysis, the working group began with the list of twelve IA subjects suggested by the 2010 ITiCSE working group [12] and augmented it with four additional subjects (the last four entries in Table 6) to reflect the reality of the non-US programs. The complete list of subjects is given in Table 6. Table 7 shows a summary of the computing security curricula offered at seven institutions around the world.

Table 5: Listing of non-US baccalaureate degree programs examined by the working group.

Country	Institution	Bachelor Program Title
Canada	Seneca	Informatics and Security
Germany	Bochum	IT Security
Germany	Offenburg	IT Security
Malaysia	University of Technology Malaysia	Computer Network and Security
Russia	Moscow Institute of Physics and Technology (MFTI) - PhysTech	Informatics and Security
Sweden	Blekinge	Security Engineering
United Kingdom	East London	Information Security Systems

Table 6: List of subjects of computing security/information assurance degree programs.

Subject	Code Designation	Year Initiated
Fundamental Aspects	FA	2010
Cryptography	CR	2010
Ethics	ET	2010
Policy	PO	2010
Digital Forensics	DF	2010
Access Control	AC	2010
Security Architecture	SA	2010
Network Security	NS	2010
Risk Management	RM	2010
Attacks / Defenses	AD	2010
Operational Issues	OI	2010
Secure Software Design and Engineering	SD	2010
Computer Science	CS	2011
Soft Skills	SS	2011
Practice, Project, Thesis	PP	2011
Other	OT	2011

Table 7: Composition by subject area of non-US information assurance degree programs.

Country	Institution	AREA															
		Information Assurance												Other Areas			
		Fundamental Aspects	Cryptography	Ethics	Policy	Digital Forensics	Access Control	Security Architecture	Network Security	Risk Management	Attacks /Defenses	Operational Issues	Secure Software Design and Engineering	Computer Science	Soft Skills	Practice / Project / Thesis	Other Areas
Canada	Seneca	0.64	0.00	3.85	3.21	2.56	0.00	0.00	2.56	15.38	5.13	0.00	2.56	23.72	12.82	14.74	12.82
		35.90															
Germany	Bochum	0.00	15.38	0.00	0.00	0.00	0.00	3.85	5.13	0.00	0.00	0.00	0.00	38.46	0.00	21.79	15.38
		24.36															
Germany	Offenburg	3.59	5.13	3.08	2.56	9.23	2.56	1.54	4.62	6.15	0.00	0.00	2.56	26.67	0.00	27.18	5.13
		41.03															
Malaysia	University of Technology	1.61	4.84	2.42	1.61	0.40	0.00	0.40	5.24	0.00	0.40	0.00	0.00	50.40	10.89	12.10	9.68
		16.94															
Sweden	Blekinge	7.50	14.50	7.50	0.00	7.50	0.00	0.00	7.50	0.00	7.50	0.00	7.50	35.33	0.00	25.00	0.00
		39.67															
Russia	PhysTech	2.72	7.48	0.34	0.68	0.34	0.34	1.02	1.02	1.70	0.68	0.00	0.00	12.24	15.65	6.80	48.98
		16.33															
United Kingdom	East London	11.11	5.56	0.00	0.00	5.56	0.00	0.00	16.67	5.56	5.56	11.11	0.00	27.78	5.56	5.56	0.00
		61.11															

Some programs have many other topics within their curricula. For example, PhysTech in Russia is among the top universities in Russia and contains many robust courses in mathematics, engineering, and technology as core courses, with many laboratories embedded within courses. It also has four extra security/encryption courses and five research projects. Other programs such as those at Blekinge, Offenburg and Bochum have a heavy emphasis on projects and practice. Others (e.g. East London, Blekinge, Offenburg) have a greater emphasis in ICT security. About half the programs have ample opportunities to engage in soft skills and general computer science courses.

The amount of ordinary computer science exposure varies between the programs with University of Technology Malaysia being the heaviest. This could be an indicator as to whether the baccalaureate program is really a computer science program with a security add-on rather than a pure security program. Additionally, programs with more of a computing and science orientation might be beneficial for subsequent post-graduate studies, whereas a more security heavy program might be more suitable for a professional career.

The working group found many similarities among the security programs. All programs contained a substantial number of computer science topics such as software development, networks, and operating systems. The database and operating systems courses contain security topics, while only some programming and architecture courses do. Furthermore, network security topics prevail among all programs including elements of cryptography, forensics, risk management, and some form of practical experience.

The programs also demonstrated some significant differences. For example, the quantity and depth of security-related topics were not consistent within all curricula. This indicates that the programs differ regarding their foundations within computer science or security topics. Furthermore, this discrepancy relates to programs focused either on a professional career within the security field or on advanced studies. Other areas that exhibited a difference are ethics (not included in the programs at Bochum or East London) and usability such as human-computer interaction security (HCISec).

Some programs have a significant component in soft skills such as foreign languages while others had little. Some programs focused on computing security (e.g. East London) while others were extensions of existing programs such as engineering (Bochum and PhysTech), business (Offenburg and Seneca), or computer science. Some were project oriented and one lacked depth in mathematics or cryptography.

Common Core Topics

Based on the examined programs, the working group tried to find a common core of subjects or topics within the supporting

courses, but also across the whole range of general education, supporting, and technical courses. As it turns out, very little cohesion seems to exist. For example, although true for many programs, not all programs require a foundation in mathematics. The only core that could be identified can be defined as computer science, which should be interpreted broadly to include, for example, computer networking. Hence, it follows that the common core is fairly small related to computing security areas, which could indicate that the programs differ regarding their individual focus areas such as in cryptography, digital forensics, network security, and risk management.

Given the small "core" identifiable by looking at the investigated programs, one must address the question concerning the identification of the minimum core that must be in a curriculum to designate it as computing security. This is important since a program should not deserve the designation of a "computing security" program if it does not contain essential topics such as ethics, access control, and secure software design.

Topic Integration

In non-US countries, it is common that students achieve a degree in an established academic subject such as computer engineering as opposed to studying a subject that might be more suitable for a computing security area. The introduction of a new academic subject usually includes establishing a new professor chair that typically takes several decades to accomplish. Instead, students seek a degree in an established academic subject with a specialization in an area of computing security. For example, students studying at the Blekinge Institute of Technology obtain a "Bachelor of Science in Computer Science with specialization in Security Engineering"; the courses taken are still fairly security oriented. On the contrary, students studying at PhysTech must learn many "non-security" subjects related to diverse areas such as electrical engineering, advanced science, and computing to obtain their degree. Hence, the level and the method of integrating computing security topics into the overall curriculum differ between various programs to a fairly significant extent depending on the possibilities to adjust the content relative to the traditional academic subject. However, some subjects such as network security still appear among all programs.

Curricula Structures

As indicated in Table 4, the roles of general education, supporting courses, and technical courses differ from country to country. Specifically, general education is only applicable to Seneca in Canada where it integrates within the entirety of the program. In other countries, the general education topics appear within the gymnasium or college curricula, which are the cases in Sweden, Russia, Germany, and Malaysia.

Supporting courses such as mathematics, chemistry, and physics have a greater difference depending on the school or the individual educational program. These courses sometimes appear as independent or elective courses and sometimes occur in security courses within the program.

Finally, the need for technical courses varies depending on the program's focus on "soft skills" and "other topics" versus technical depth. Again, see Table 4 for a comparison. Seemingly, however, there are many differences. Seneca, for example, favors soft skills and does not provide much technical depth whereas PhysTech has a significant amount of technical depth although still favoring the soft skills.

5.4 Articulation

The working group could find no comprehensive articulation agreements for information assurance programs outside of the US and Canada. In the rest of the world, the common practice seems to be that universities evaluate courses and entire programs based on content to see which parts of the curriculum are transferrable and which is the extent of the transferability. Sometimes a course at one university is worth fewer or more credits than at the original university institution, which could be acceptable to allow a transfer. Within Europe, the issue of articulation has been significantly impacted by the Bologna Process.

The Bologna Process

The purpose of the Bologna Process was to create a European Higher Education area with the goal to `make degrees comparable and transferable. In practice, the Bologna framework includes three degrees

- 3 year Bachelor
- 2 year Masters
- 3 + years Doctorate

that are defined in terms of qualifications, i.e., student learning outcomes.

Over the last few years, the Bologna Process has led to greater uniformity in higher education among the member countries of the European Higher Education area. However, challenges are still encountered when transferring to/from places outside of the European Higher Education area. Specifically, the bachelor degree programs in the US and UK are typically four-year programs. There is no general solution yet to this challenge. Rather, the transfer of credits and the compatibility of programs is assessed on a case by case basis. Students transferring from the European Higher Education area to the US and UK are faced with the perception that they are missing credits. Yet, the argument from within the European Higher Education often is that the general education components prevalent in US or UK bachelor degrees are part of the respective high school curricula in the European Higher Education area. In turn, students transferring into the European Higher Education area may face the problem that courses taken as part of their bachelor degree may be considered more hands on and less theoretical, thus necessitating them taking ramp courses before they can pursue their Masters studies at an institution within the European Higher Education area. For example, students transferring from university XYZ in Canada to university ABC in Paris must take additional math classes in order to pursue a Masters degree at the institution in Paris.

During the last several years, the Bologna Process has facilitated the process of making education transferrable within the European Union due to the coherent way of specifying so-called "learning goals". That is, European universities are now supposed to specify explicit goals focusing on what the student is supposed to be able to accomplish after taking a certain course or program. As many European teachers can attest, this has not been an easy task but has come to affect education in a very positive way since the course goals are becoming clear. Learning goals can be stated at both course level and program level but should be explicit and concrete when it comes to what the student should be able to accomplish after taking a certain course or program. Here, certain "verbs" such as "reproduce" or "program" are integral when stating to what extent students should understand topics. As indicated, the working group looks upon the Bologna learning goals as a

possible substitute for the US articulation process. The group recognizes that such learning goals are in the process of adoption within the US.

5.4 Comparing US and non-US Programs

Examining bachelor programs within and outside the US has revealed a number of commonalities and differences. Both within and outside the US there are degree programs in fields such as computer science or computer engineering that allow students to pursue a concentration in security. Similarly, both within and outside of the US there are specific degree programs in security at the bachelor level with a varying degree of focus on CS, IT, IS, etc. Both within and outside the US, some of the degrees are terminal degrees while others lend themselves to continued education at the graduate level. Although not studied in detail, anecdotal evidence suggests that both within and outside of the US there is a great wealth of security-oriented programs at the masters level. Based on the scope of the respective programs, students without prior background in security may be able to pursue these programs. The students may be required to take bridge courses in order to obtain the necessary background for pursuing the studies in the respective degree program.

As discussed previously, the degree programs tend to differ in length (three years versus four years) and whether or not general education components (e.g., humanities, general science/math requirements) are included in the curricula. The curricula of US and non-US institutions have in common that they all include some basic or introductory course in security as well as some coverage of network security. The coverage of ethics is more prevalent in programs within the US (oftentimes covered as part of the general education requirements). The programs within and outside of the US share some major shortcomings. The programs lack coverage of some major areas such as secure coding, identity management, and privacy. In addition, programs tend to have insufficient coverage of security topics within the context of courses such as networking, operating systems, database systems, software engineering, hardware design, etc. Very few of the curricula studied include current topics and trends. Specifically, of the curricula studied, only one explicitly included a course on malware.

Another observation that comes from this comparison, is that the majority of software developers are unlikely to pursue a bachelor degree in security. As such, it is suggested that security topics in general and secure coding in particular are included in curricula outside of security in order to obtain a large-scale base training across the computing disciplines. Traditional course material may need to be altered or taken out in order to make room for the covering of security-related materials. The ACM curriculum 2013 is expected to include security and that may help with this issue.

Also, security curricula need to discuss and establish access control and identity management in great depth. In particular, security programs will need to include an international perspective as security is a global issue. This does not only pertain to establishing an identity on a global level but extends across the field, particularly also in the context of cyberwar, cybercrime, etc.

Programs outside of the US may consider introducing some general education (such as ethics) or math components prevalent in US degree programs. In turn, US institutions may consider reducing the general education requirements to allow for greater coverage of program-specific material. US institutions should consider moving to a Bologna style learning outcome based curriculum in order to enable the transfer of credits and degrees from and to institutions outside of the US.

6. CONCLUSIONS, OBSERVATIONS AND RECOMMENDATIONS

The 2011 ITiCSE working group on information assurance (IA) education examined undergraduate curricula at the two- and four-year levels, both within and outside the US. Based on the examination of a small subset of two-year, four-year and international degree programs, we conclude the following. First, there is a large variety of two-year and four-year IA educational programs and the variety seems to be increasing. Second, IA degree programs face many of the same articulation problems that other disciplines face. This is to a large extent due to the difference purposes of the two-year AAS degree and the four-year BS or BA degree. Third, in the US and abroad, the majority of IA related degrees seem to be at the graduate level, and particularly at the masters level.

The working group speculates that the large variation in the type of degree programs at both two-year and four-year institutions is due primarily to two factors. The first is the absence of a set of curricular guidelines around which institutions can build their programs and the second is a lack of a clear understanding of the needs of the employers of the graduates of these programs.

In order to make progress on the articulation challenges, it is necessary for two-year and four-year institutions to develop closer and more functional relationships. We believe course articulation between AAS and BS/BA degrees will remain a significant challenge due to the very distinct purposes of these degrees. Adopting a student learning outcome approach to curricular guidelines is likely to be the most fruitful approach to a broad solution to this challenge.

The fact that most IA programs exist at the graduate level is at least in part due to several historical factors including the nature of the CAEIAE designation and the closely aligned NSF SFS program. It is not clear to the working group whether or not the preponderance of future IA programs will be at the graduate level. This will likely be heavily influenced by a better understanding of workforce needs.

Finally, the working group believes that the time has come for an appropriate organization to engage the broad IA educational community in an effort to create meaningful curricular guidelines using a student learning outcomes approach. Such an effort would create coherence in the discipline, provide a basis for assessing the quality of educational programs and the skills of their graduates, and facilitate articulation between two-year and four-year degree programs.

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Appendix I. INFORMATION ASSURANCE DEGREE NOMENCLATURE

According to the American Association of Community Colleges [13], the overwhelming majority of degrees offered by community colleges are the Associate of Applied Science, Associate of Science, and Associate of Arts. "The Associate in Applied Science (AAS) degree program is designed to lead the individual directly to employment in a specific career. It is strongly suggested that one-third of the work for the AAS degree be in general education. Although the primary objective of the AAS degree is to prepare graduates for immediate employment, a few baccalaureate degree granting institutions have developed four-year degree programs that build on the AAS degree. The associate in arts or science degrees prepare the student to transfer to a baccalaureate degree program. The associate in arts (AA) degree gives emphasis to those majoring in the arts, humanities, social sciences, and similar areas. It is recommended that a substantial component, three-quarters of the work required, of the AA degree program be in general education. The AS degree gives emphasis to those majoring in agriculture, engineering and technology, and the sciences with substantial undergraduate requirements in mathematics and the natural sciences. It is recommended that a large component of the associate in science degree, one-half of the work required, be in general education. Students awarded AA or AS degrees are generally accepted as junior level transfers in baccalaureate degree programs."

A useful description of associate degrees comes from [14] which states:

> "An **associate degree** is an undergraduate academic degree awarded … upon completion of a course of study usually lasting two years…. The **Associate of Science (AS)** degree is … awarded to terminal students or to potential transfer students to a four-year college or university, [with] the areas of concentration usually in mathematics, natural sciences, health sciences, or technology." "The **Associate in Applied Science (AAS)** degree is awarded to students who are permitted to relax some of the general education requirements in order to study more course work in their program area. This kind of degree is for students who intend to enter the work force upon graduation." The Associate in Applied Business (AAB) is similar to the AAS degree except that the program area is in applied business rather than in applied science.

Four-year degrees, both in and outside the US, are generally baccalaureate degrees of some type, but there is a wide variety in the specific type of baccalaureate degree. Many 4-year IA degrees are Bachelor of Arts degrees that may be described as [15]:

> **"Bachelor of Arts (B.A.** or **A.B.)** … is a bachelor's degree awarded for an undergraduate course or program in either the liberal arts, the sciences, or both. Bachelor of Arts degree programs generally last three to four years depending upon the country, academic institution, and specific majors or minors." In the US, curricula "often require a certain minimum number of the total degree credits be drawn from coursework in topical areas historically associated with the liberal arts - such as language, literature, humanities, mathematics, history, and social sciences."

The Encyclopedia Brittanica [16] defines liberal arts as "The contemporary liberal arts comprise studying literature, languages, philosophy, history, mathematics, and science."

Another very common instantiation of a baccalaureate degree is the Bachelor of Science degree that may be described as [17]:

> "A **Bachelor of Science** (**Bc.**, **B.S.**, **BS**, **B.Sc.** or **BSc**) is an undergraduate academic degree awarded for completed courses that generally last three to five years." In the US, the BS is often used in engineering, computer science, mathematics, and the natural sciences. It may also be used in professional studies programs in law, business, and architecture [18].

Outside of the US, it is rare to find a four-year degree program that is not a BS or BA degree.

Other four-year degrees that are used in IA education include the Bachelor of Technology, the Bachelor of Information Technology, the Bachelor of Science in Information Technology, the Bachelor of Computer Information Systems, the Bachelor of Business Administration, the Bachelor of Applied Technology and the Bachelor of Individual Studies. Descriptions of these degrees are given below.

> "The **Bachelor of Technology** (commonly abbreviated as **B.Tech.**) is an undergraduate academic degree conferred after completion of a three or four year program of studies at an accredited university or accredited university-level institution…. In general, the degree is awarded to those who have undertaken a Bachelor of Science degree program which is *additionally* supplemented by either occupational placements (e.g., supervised practica or internships) or practice-based classroom courses. Due to these requirements, the degree normally takes at least four years. In some countries, the degree is awarded following completion of a curriculum which is career oriented, emphasizing practice as opposed to theory. Here, by contrast, occupational placements and practice-based courses are more heavily weighted within the program."[19]

> "A **Bachelor of Information Technology** degree is an undergraduate academic degree that generally requires three to five years of study to acquire. While the degree has a major focus on computers and technology, it differs from a Computer Science degree in that students are also expected to study management and information theory. Therefore, while a degree in computer science can be expected to concentrate on the scientific aspects of computing, a degree in information technology can be expected to concentrate on the business and communication applications of computing, although there is more emphasis on these two areas in the e-commerce, e-business and business information technology undergraduate courses." [20]

> "A **Bachelor of Science in Information Technology**, (abbreviated **BScIT** or **B.Sc IT**), is a bachelor's degree awarded for an undergraduate course or program in information technology. A Bachelor of Science in Information Technology degree program typically lasts three to four years. While this degree mainly based on computer subjects covering all aspects such as software, database, and networking. In general, Computer Science degree focuses on mathematical and theoretical foundations of computing, rather than teaching specific technologies. The degree itself is a Bachelor of Science with institutions conferring degrees in the fields of information technology and related fields. This degree is awarded for completing a program of study in the field of software development, software testing, software engineering, computer networking, web design, databases, and programming." [21]

> "The **Bachelor of Computer Information Systems** is an undergraduate bachelor's degree, similar to the Bachelor of Science in Information Technology, but focused more on practical applications of technology to support organizations while adding value to their offerings. In order to apply technology effectively in this manner, a broad range of subjects are covered, such as communications, business, networking, software design, and mathematics." [22]

> "The **Bachelor of Business Administration** (**BBA**) is a bachelor's degree in Commerce and business administration. In most universities, the degree is conferred upon a student after four years of full-time study in one or more areas of business concentrations. The BBA program usually includes general business courses and advanced courses for specific concentrations." [23]

Wikipedia does not have a reliable definition for a **Bachelor of Applied Technology** (**BAT**) degree. However, Midland College [24] defines the BAT as "the degree of choice for students who have completed the requirements for or who have an Associate of Applied Science (AAS) degree at an accredited college in a technical field. The degree program builds on an occupational/ technical program traditionally offered at community colleges, vocational and technical school, which serves as the major field of study." A recent webinar [25] defined BAT degrees as one of four options: an upside down degree (covering the general education courses that were not covered as part of the AAS degree), a degree consisting of other technological education beyond the AAS degree, a largely business degree, or a combination of the above three degrees.

Wikipedia also does not contain an entry for a **Bachelor of Individual Studies** (**BIS**) that is offered by some institutions. George Mason University [26] defines it as

> "a degree completion program for adult learners. Students create their own interdisciplinary concentrations to meet their own educational needs: to advance professionally, to prepare for graduate or professional programs, or to plan a path toward a career change. The BIS offers students a distinctive educational opportunity that allows them to integrate other college-level learning such as professional or military experiences into university coursework. The advisers and faculty are committed to helping students build on their life experience to create a rewarding degree program."

Bragg & Rudd define an applied baccalaureate degree as "a bachelor's degree designed to incorporate applied associate courses and degrees once considered as 'terminal' or non-baccalaureate level while providing students with higher-order thinking skills and advanced technical knowledge and skills." [25]