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A Bridged Cybersecurity Curriculum with Embedded Stackable Credentials

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Abstract— Supported by a federal grant, The University of Texas Rio Grande Valley (UTRGV) streamlined the Bachelor of Science in Cyber Security (BSCS) and Master of Science in Informatics (MSIN) whereby each degree is broken down into embedded stackable credentials, with a fast-track 4+1 option for students to complete both degrees in 5 years. This paper provides a blueprint of the bridged undergraduate and graduate curricula integrated to provide embedded stackable credentials with fast-track 4+1 option bridging the two degrees. Most of the major-core of BSCS is divided into three embedded stackable credentials, namely, Cyber Security Basics Certificate, Cyber Security Systems Certificate, and Cyber Security Advanced Certificate. After completing the three credentials, a student needs only 9 hours to complete the major-core for the BSCS degree. Similarly, most of the MSIN is divided into two embedded stackable credentials, namely, Graduate Certificate in Cyber Security and Graduate Certificate in Informatics. After completing the two graduate credentials, a student needs only 6 hours of thesis for the thesis route, or 6 hours of designated electives for the coursework option to earn an MSIN degree. A BSCS student with an overall 3.5 GPA or higher and having a GPA of 3.25 or higher in cyber security benchmark courses, is allowed to opt for the fast-track 4+1 option which allows a student to be simultaneously admitted into the Graduate School to take 12 hours of graduate courses from MSIN degree applicable towards completing BSCS, leaving one year's worth of graduate work to earn an MSIN degree. As part of the grant, the curriculum of BSCS degree is aligned with the national standard of National Initiative for Cybersecurity Education - Workforce Framework for Cybersecurity (NICE-WFC) for the students to have an edge in the job market. The three undergraduate certificates and the two graduate certificates are referred to as embedded stackable accelerated credentials since each credential, taking 12 months or less time, is embedded in its respective degree and serves as a stack towards earning the degree. This approach is advantageous for students since one or more credentials may be earned without completing the respective degree which allows a student to have a few credentials targeted for the job market in case the student needs to take hiatus from education and work for a while. Furthermore, a professional already working in the cyber security or informatics field can earn one or more credentials without committing to complete a degree.

Index Terms— Cyber Security, Informatics, NICE-WFC, Fast-Track 4+1, Accelerated Credentials, Embedded Credentials, Stackable Credentials, Convertible Credentials.

I. Introduction, Background, and Goal

The University of Texas Rio Grande Valley (UTRGV) recently overhauled the curricula of the Bachelor of Science in Cyber Security (BSCS) and Master of Science in Informatics (MSIN). As part of the overhaul, each degree has been embedded with stackable accelerated credentials; an accelerated credential is an academic credential earned in 12 months or less time. The effort of overhauling the curricula was supported by a federal grant awarded through Texas Higher Education Coordinating Board (THECB) in early 2022 [1]. The motivation of the grant via THECB was to have an educational institution contribute towards 60x30TX educational goal which is to have 60% or more of 25–34-year-old Texans secure a certificate or a degree by the year 2030 [2]. Increasing the number of accelerated credentials embedded in higher education

degrees is meant to allow students to secure certificates even when some of the students cannot complete a degree due to any reason. This can also be viewed as stackable milestones, or stacks, being achieved while pursuing a degree rather than a binary result of either obtaining a degree or dropping out. Furthermore, dividing a degree over several accelerated credentials allows students/professionals to target their credentials to makeup a more skilled workforce.

An accelerated credential could comprise of any number of credit hours; however, a practical unit is a certificate or a degree. Fragmenting a degree further with smaller accelerated credentials could be meaningless besides causing adverse administrative load. TX60x30 provides good guidance in the sense that it explicitly mentions a certificate or a degree as a credential in their goal.

Typically, a certificate has 12 or more academic credit hours. All developed embedded stackable accelerated credentials, as part of THECB grant, have 12 or more credits.

II. Curricula Components

The two programs targeted for curriculum overhaul were Bachelor of Science in Cyber Security (BSCS) at the undergraduate level and Master of Science in Informatics (MSIN) at the graduate level. The core idea was to make accelerated credentials available to students, completing which will stack towards earning a college degree. If a student earns an accelerated credential, say embedded in the BSCS degree, it immediately provides the student with an edge in the job market while stacking up credit towards earning a college degree. As part of the THECB grant, the following credentials were developed:
- Three embedded stackable accelerated credentials within BSCS degree
- Two embedded stackable accelerated credentials within MSIN degree
- One Fast-Track 4+1 accelerated credential bridging BSCS with MSIN degree
- A suite of accelerated credentials converting industry certifications to college credit

A. Embedded Stackable Accelerated Credentials

The core idea of having embedded stackable accelerated credentials led to dividing most of the BSCS degree into three certificates, formally named as Cyber Security Basics Certificate, Cyber Security Systems Certificate, and Cyber Security Advanced Certificate. A student may opt to earn one, two or all three cyber security certificates independent of pursuing a BSCS degree. However, since the certificates are embedded in the BSCS degree, the student would be stacking up hours towards earning a BSCS degree. After completing the three certificates, a student only needs to do 9 more hours from the core to earn a BSCS degree.

Since each of the three certificates help a student stack up credit towards a BSCS degree, these are referred to as stackable certificates. These certificates are also referred to as embedded certificates since these certificates are not outside of the core curriculum. Students seeking a cyber security certificate must go through the same admission process and must meet the same prerequisite requirements just like the students pursuing a BSCS degree.

Similarly, most of the MSIN degree was divided into two graduate certificates, formally referred to as Graduate Certificate in Cyber Security and Graduate Certificate in Informatics. The

former consists of cyber security designated elective courses whereas the latter consists of a mix of data science, data analysis, and eCommerce side of informatics.

After completing the two graduate stackable certificates, a student needs to complete only 6 hours to earn an MSIN degree. Similar to BSCS, these certificates are not outside the graduate curriculum. A student seeking a certificate only, still needs to be formally admitted into the graduate school and is subject to the same prerequisite requirements.

B. Fast-Track 4+1 Accelerated Credential

The Fast-Track 4+1 program allows a qualified student to complete an MSIN degree in 12 months, hence, classified as an accelerated credential. A student having 90 hours of college credit with an overall GPA of 3.5 and a GPA of 3.25 in cyber security benchmark courses may be qualified for the Fast-Track 4+1 program, which allows a student to take 12-hous of graduate level courses in lieu of undergraduate courses as a senior in BSCS degree. This leaves only 18-hours, or a 12-month equivalent feat, for the student to complete the 30-hour MSIN degree.

C. Convertible Accelerated Credentials

Industry certifications jade a college degree, especially, in certain certification-dependent areas such as cyber security. An industry certification takes a lot of time and effort to be earned. Instead of students earning industry certifications on their own, the curriculum of BSCS degree makes it possible for a student to earn industry certifications as part of their degree. Since student earns college credit as part of taking a course and passing the certification exam for a certification, this mechanism allows the student to convert time & effort spent on an industry certification into college credit. This is referred to as convertible accelerated credential. An industry certification estimated at 60 hours of time & effort is offered through a1-hour certification course, and an industry certification demanding about 180 hours of time & effort is offered through a 3-hour certification course [3].

III. Curricula Groundwork

The curricula groundwork consisted of revamping both the undergraduate and graduate programs in cyber security and informatics making sure that the proposed accelerated credentials provide meaningful units of expertise to a student both to meet industry standards and the expectations of relevant accreditation organizations.

A. Alignment of BSCS with NICE-WFC

In the case of the undergraduate cyber security program, the Bachelor of Science in Cyber Security lacked certain key areas identified in the National Initiative for Cybersecurity Education - Workforce Framework for Cybersecurity (NICE-WFC). Earlier, Texas SB2134 2021-2022 [4] was also introduced calling for cyber security degrees to be aligned with NICE-WFC standard. Comparing the current curriculum with the Knowledge Units (KUs) provided in NICE-WFC documentation, several areas of deficiencies were revealed. These knowledge units, representing deficiencies, were added across the curriculum in new and existing courses. Most of the deficiencies were identified in the areas of mathematical reasoning, enterprise network defense,

computer network defense, information assurance, forensics, architecture, criminal law, and cryptography [5]. Even though SB2134 did not pass, UTRGV proceeded to align its BSCS curriculum with NICE-WFC to add value to its degree and to be ready for an SB2134 type of legislation taking effect in future. Figure 1 shows the general flow of alignment from identifying of areas of deficiencies to embedding the knowledge units in different courses.
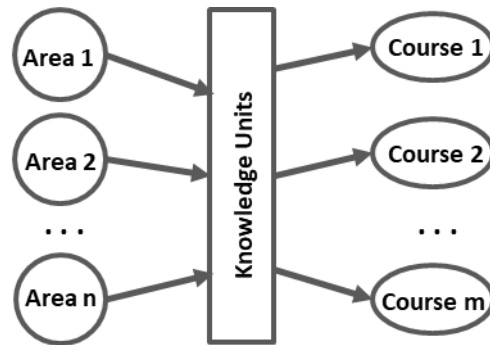

Fig. 1 Addressing Deficiencies in BS Cyber Security Curriculum

B. Addressing Accreditation Concerns of BSCS

The institution aspires to have all its undergraduate engineering, computer science, and cyber security degrees to be accredited by ABET (Accreditation Board for Engineering and Technology). Pursuant to this goal, a capstone project course was added to the updated curriculum of the BSCS degree. Even though the six Educational Student Outcomes (ESOs) prescribed by ABET [6] are addressed by the core courses in the curriculum, adding a capstone project course to the core curriculum brings together all the six ESOs in one course in a polished and refined manner for students to see the relationship among all six ESOs. The capstone specifically focuses on ESO #3 (communication skills), ESO #4 (legal and ethical principles), and ESO #5 (teamwork).

The foundational block in the curriculum of BS in Cyber Security, which used to be almost the same as that of BS in Computer Science, was overhauled to provide foundational knowledge specific to cyber security.

The revamped degree program, besides being aligned with NICE-WFC industry standard, clearly consists of three stacks: basics (foundational knowledge), systems (core systems of cyber security), and advanced concepts (applications). This structure lends itself to be offered as three embedded stackable accelerated credentials.

The new BSCS degree program aligned with NICE-WFC started in Fall 2022 [3].

C. Revamping the Graduate Program

The previous graduate program was Master of Science in Information Technology (MSIT), which had mostly computer science courses with no thesis option. The foundational courses required for MSIT were geared towards preparing students for computer science courses.

To bridge the BSCS degree program to its graduate counterpart, the previous graduate program's structure lacked specific areas to bridge to. The best option to overhaul the graduate program was to restructure the program to provide bigger umbrella to host information technology, cyber security, data science, at the same time allowing to offer courses/options in related fields in future, thereby giving rise to the new program of MS in Informatics (MSIN) consisting of the following salient features:

- Foundational block of required courses in cyber security and informatics
- A block of cyber security related electives
- A block of data science, data analysis, and eCommerce
- Other electives including independent research and special topics for development of new courses
- Thesis option

The structure of the new degree program of MSIN, besides having the above features, provides two stacks: cyber security stack and informatics stack. This structure lends itself to be offered as two embedded stackable accelerated credentials.

The new graduate degree program of MSIN started in Fall 2022 [7].

IV. Implementation

The first, and main, hurdle in the implementation of accelerated credentials was a university rule which did not allow a course to be used for two academic credentials; in our case the two credentials being the embedded accelerated credential and the degree itself. The rule was updated to differentiate between double-dipping of courses in separate credentials compared to our proposed credentials which are embedded in the degree program.

The second hurdle had to do with logistics of how accelerated credentials would be earned. For example, when a student pursuing a BSCS completes the courses corresponding to the Cyber Security Basics Certificate, who would initiate the request for issuing the corresponding certificate. It was recommended by the administration that the best way would be to either have the program coordinator or the student initiate the request. A certificate would then be issued in addition to a relevant note transcribed on the student's transcript.

The undergraduate program is more complicated compared to the graduate program because of all the non-major courses required. The three stacks of accelerated credentials are part of the major core courses. Figure 2 below shows the three embedded stackable accelerated credentials with corresponding number of semester credit hours for each stack. After a student has completed the three stacks, the student only needs to complete 9 hours, consisting of two electives and a capstone project course, from the major core to earn a BSCS degree. Of course, this is assuming that the student has completed courses from other categories, such as general education.

BSCS major core

13 hours: Cyber Security *Basics* Certificate

16 hours: Cyber Security *Systems* Certificate

16 hours: Cyber Security *Advanced* Certificate

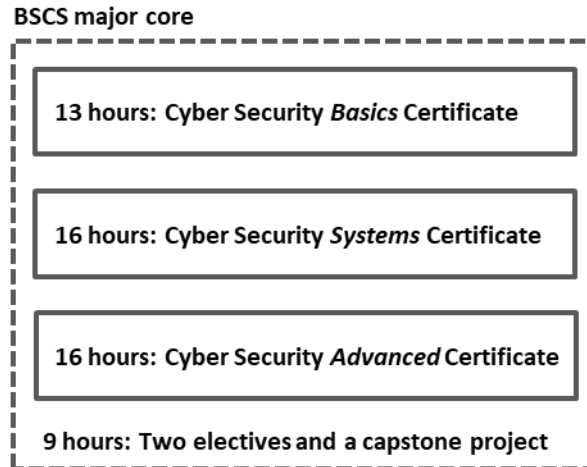9 hours: Two electives and a capstone project

Fig. 2 Three Stackable Accelerated Credentials Embedded in BSCS

The graduate program is straightforward compared to the undergraduate program in the sense that all the courses are from the major. The two stacks of accelerated credentials are 12 hours each. The figure below shows these two credentials. After a student completes the two graduate certificates, the student only requires 6 hours of electives or 6 hours of thesis to earn an MSIN degree. Figure 3 shows the two accelerated credentials embedded in MS Informatics degree.

MSIN

12 hours: Graduate Certificate in Cyber Security

12 hours: Graduate Certificate in Informatics

6 hours of electives for coursework option
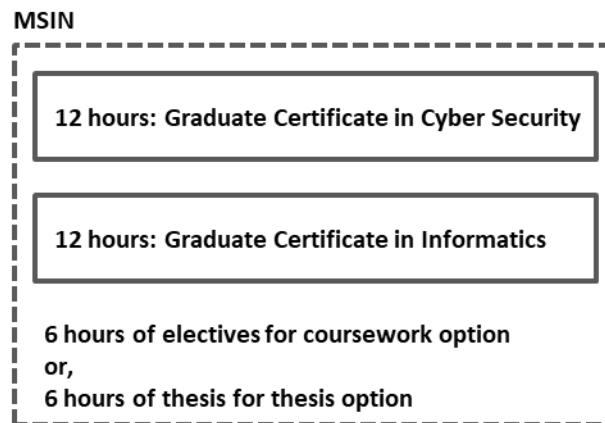or,
6 hours of thesis for thesis option

Fig. 3 Two Stackable Accelerated Credentials Embedded in MSIN

A student does not have to pursue the BSCS degree or the MSIN degree to earn one of the accelerated credentials. As long as a student has secured admission at the appropriate level, the student can pursue a certificate. Of course, the student must clear any prerequisite requirements.

There is an inherent benefit for a normal college bound student in pursuing such degrees with stacks of accelerated credentials even if a student has no intention of pursuing a specific accelerated credential. A student gets the certificate corresponding to the completed accelerated

credential as soon as the required hours are completed. If the student needs to take hiatus from college for some reason, the earned credentials may be used to secure a job. From another perspective, fruits of a student's labor don't go to waste just because the student could not complete a degree. This can also be seen as a safety net for earning credentials by such students as they progress into the degree but have not completed it. This is truer in an undergraduate degree which is quite long compared to a graduate degree. However, having stacks of accelerated credentials at the graduate level is useful as well for the same reasons, and additionally for those students who are in the job market and simply want to earn a graduate certificate focused on a certain area.

Besides implementing the five described accelerated credentials above, the sixth accelerated credential comprises of completing the MSIN degree in 12 months. This is through the Fast-Track 4+1 program which allows qualified students to take 12 hours of MSIN graduate course work applicable to the undergraduate BSCS degree. Figure 4 shows the Fast-Track 4+1 program accelerated credential allowing a student to complete MSIN in 12 months.

Fast-Track 4+1 program

Qualified BSCS senior student:
  90 hours completed towards BSCS
  3.5 or better overall GPA of 3.5
  3.25 or better GPA in benchmark courses

↓

Departmental determination: Student qualified to enter MSIN graduate program

↓

Student takes 12 hours of graduate coursework applicable towards BSCS to complete BSCS

↓

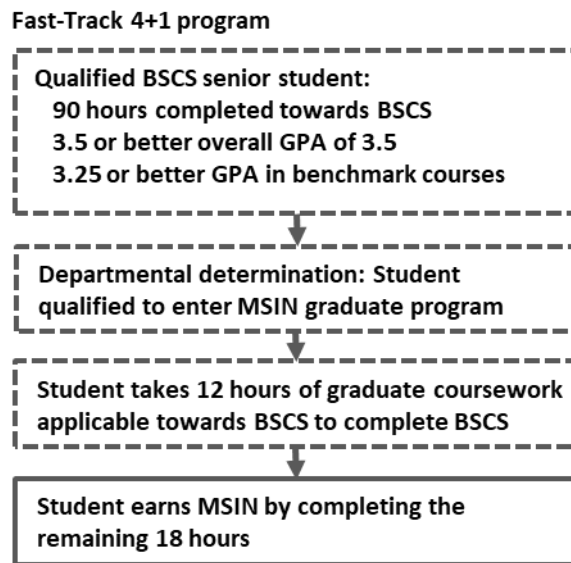Student earns MSIN by completing the remaining 18 hours

Fig. 4 Fast-Track 4+1 Accelerated Credential Bridging BSCS and MSIN

Besides the above six accelerated credentials made available to students, convertible accelerated credentials were also implemented. These consist of students completing an industry certification or a suite of industry certifications to earn college credit. The earned college credit may then be applicable as an elective or a required course for BSCS, depending on the certification. The department maintains a mapping of certifications to the respective cyber security certification course [8].

V. Learning Resources

There is a wide variety of industry certifications that a student may opt for depending on the job that the student may be targeting. There are two required industry certifications that a student must acquire as part of the BSCS core curriculum. These two certifications are taught by

instructors in a classroom setting. The instructors are well-versed in the material for these two certifications. However, an instructor cannot prepare a student for other certifications unless the instructor prepares for such certificitions which is a daunting task given the wide variety of certifications.

A self-paced certification course was created where a student is provided access to online self-paced learning material including sample certification exams to help the student prepare for the targeted certification exam. If the student passes the certification exam, the student gets the respective college credit. The benefit of this approach is that the department can offer wide variety of certifications for students to secure while earning college credit. Furthermore, the students' transcripts maintain record of certifications.

A major portion of the THECB grant for establishing the accelerated credentials enabled the department to purchase licenses for the next 5 years to support student learning via online material on variety of certifications. The licenses are for certifications for self-paced and instructor-led courses. Figure 5 summarizes the acquiring of certifications from different platforms providing a wide mix of industry certifications related to informatics and cyber security.

Item	Source
Online Anytime (OLA) Library -Technical Collection of variety of topics including Network+, Security+, Linux+, CPTE, CISA, CISM, CISSP, CCNA, and CCNP	New Horizons
Online Training Library for Certified Information Privacy Professional (CIPP), Certified Information Privacy Manager (CIPM), and Certified Information Privacy Technologist (CIPT)	IAPP
Digital forensics essentials (DFE)	EC-Council
Ethical hacking essentials (EHE)	EC-Council
Network defense essentials (NDE)	EC-Council
Certified cloud security engineer (CCSE)	EC-Council
Certified ethical hacker (CEH)	EC-Council

Fig. 5 Acquiring Relevant Industry Certifications Online Learning Platforms

VI. Momentum and Limitations

The six embedded stackable accelerated credentials were formally implemented (available for students to pursue) in Fall 2022. At the time of writing this paper (February 2023), less than 5 students have registered solely for a particular accelerated credential. Most of the students opt for pursuing a degree while earning accelerated credentials on the way. Below are the reasons for this outcome:

- Accelerated credentials have the same admission requirements as the degree these are embedded in.

- Prerequisite requirements for taking a course in a degree or in an embedded credential are the same.
- Financial aid only supports students pursuing degrees and not only accelerated credentials. This affects most of the students since at UTRGV, most of the students are under a financial aid program.

The outcome of having few students pursuing solely an accelerated credential was expected well before the accelerated credentials were developed and implemented due to the reasons cited above. The reasons for implementing accelerated credentials, and THECB supporting the effort through a federal grant, are as follows:

- Students who cannot complete a degree, usually have completed sufficient credit hours to qualify for one or two embedded stackable accelerated credentials. This allows such students to have credentials to be relatively more prepared for cyber security jobs.
- The accelerated credentials allow professionals working in the field to earn relevant certifications.
- The embedded stackable credentials provide tangible milestones as a student makes progress through a degree.
- Establishing embedded stackable credentials increases the number of Texans to meet TX60x30 goal, whereby 60% of Texans, between the ages of 25 and 34, should have a certificate or a degree by the year 2030.

Therefore, the expectation was not that a large population will opt to go only for an accelerated credential without pursuing a degree. After a passage of few years, the metric of success will be the number of embedded stackable accelerated credentials earned by the students irrespective of being unable to complete a degree. Previously, such students fell under the category of attrition percentage since the nature of success was binary; either degree is completed or not.

VII. Results and Conclusion

The college administration, specifically, the Dean of the College of Engineering and Computer Science (CECS) and the Office of Curriculum Instruction and Assessment (OCIA) have been closely involved in designing, developing, and implementing the six accelerated credentials. Naturally, the work presented in this paper was attributed with some firsts for the institution, most prominently, embedded stackable accelerated credentials for a degree and the first Fast-Track 4+1 program approved for the institution, even though Fast-Track 4+1 programs exist at other institutions [9].

Other programs in the university, specifically, within CECS, have taken note of the usefulness of the embedded stackable accelerated credentials, and have approached the team for guidance.

The implementation is months old, therefore, it will take some time to judge the result of the project's impact. Specifically, a passage of few years is required to collect data on students earning accelerated credentials without completing a degree.

The availability of self-paced online learning resources for students to prepare for industry certifications is being closely tracked. If this model is successful, this will be expanded to other disciplines in CECS since industry certifications add value to the degrees being offered.

Acknowledgment

References

[1] F. Khan (PI), M. Quweider (CO-PI), K. Crouse (CO-PI), D. Ortiz (CO-PI), *Accelerating Credentials of Purpose and Value Grant Program*, THECB NOGA Award #2020-GE-84425, The University of Texas Rio Grande Valley (UTRGV), January 2022.
[2] Texas Higher Education Coordinating Board (THECB), *TX60x30 project*, https://reportcenter.highered.texas.gov/agency-publication/miscellaneous/thecb-60x30-strategic-plan, [Accessed Feb. 28, 2023].
[3] BS Cyber Security Curriculum, Informatics and Engineering Systems Department, The University of Texas Rio Grande Valley (UTRGV), https://www.utrgv.edu/cyberspace/academics/undergraduate/bscs, [Accessed Feb. 28, 2023].
[4] Texas Senate Bill, *Alignment of Higher Education Cyber Security Programs with National Initiative for Cybersecurity Education – Workforce Framework for Cybersecurity (NICE-WFC) Standard*, https://capitol.texas.gov/BillLookup/history.aspx?LegSess=87R&Bill=SB2134, April 2021, [Accessed Feb. 28, 2023].
[5] NICE-WFC Alignment Proposal, *Financial Impact of Aligning BS in Cyber Security with NICE Workforce Framework for Cyber Security*, Computer Science Department, The University of Texas Rio Grande Valley (UTRGV), March 2021.
[6] Educational Student Outcomes in Cyber Security Programs, https://www.abet.org [Accessed Feb. 28, 2023].
[7] MS Informatics Curriculum, Informatics and Engineering Systems Department, The University of Texas Rio Grande Valley (UTRGV), https://www.utrgv.edu/cyberspace/academics/graduate/msinformatics, [Accessed Feb. 28, 2023].
[8] Convertible Accelerated Credentials, *Industry Certifications Convertible, to College Credit Mapping*, Informatics and Engineering Systems Department, The University of Texas Rio Grande Valley (UTRGV), https://www.utrgv.edu/cyberspace/academics/undergraduate/certification, [Accessed Feb. 28, 2023].
[9] Fast Track Option, The University of Texas at Dallas (UTD), https://catalog.utdallas.edu/2020/undergraduate/policies/graduate-courses/fasttrack, [Accessed Apr. 28, 2023].