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Meeting the Challenges of Large Online Graduate Cybersecurity Classes in the Age of COVID

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***Abstract*—Designing curriculum and teaching delivery programs that can meet the needs of specialized groups of employers and students is challenging in the best of times. When extra criteria are added, such as making a degree program fully online when also limited with the number of fully qualified faculty due to constrained resources, flexibility is a requirement. This is a case study of one such program development project that saw the design and development of a Master-level program of study in Cybersecurity that was designed at one level of expected faculty resource availability that had to rapidly evolve in a new direction due to significant resource restrictions. Built on a model of maximizing the productivity of a few fully qualified faculty by leveraging less qualified but very capable part-time staff to meet the needs of online delivery of large sections of graduate instruction.**

Keywords—Cybersecurity curriculum, graduate curriculum, online learning, large section classes

I. INTRODUCTION

In Fall 2019, select faculty from three different colleges at "the University" gathered to design a new, fully online Masters in Cybersecurity degree program. These faculty represented the Colleges of Humanities (Department of Sociology and Criminal Justice), Business (Department of Information Systems), and Computing (Departments of Computer Science, Software Engineering and Game Design, and Information Technology). The team quickly developed the program goals, curriculum, and program resource needs. The program was approved in February 2020, with a start date of Fall 2020. The proposal included an expectation of hiring 14 additional faculty members over four years to accommodate projected growth, with the goal of 200 majors by Fall 2024. The program had an ambitious goal to support students seeking to advance current careers and to enable the career transition of those entering the cybersecurity field.

The initial admission criteria required students to have a computing foundation consisting of object-oriented programming, computing infrastructure (computer organization & architecture and operating systems, data communications and networking), and principles of cybersecurity. Students lacking this knowledge were required to take up to three 5000-level foundation courses. The program of study was proposed as:

Required Courses (30 Credit Hours) {staffing department}:

- Cyber Law, Policy, and Enforcement {SCJ}
- Cybercrime Detection, Analysis, and Forensics {SCJ}
- Secure Application Development {SWEGD}
- Securing Enterprise Infrastructure {IT}
- Management of Cybersecurity {IS}
- Mobile and Cloud Security {IT}
- Contingency Planning and Response {IS}
- Cyber Analytics and Intelligence {IT}
- Introduction to Cryptography and Its Application {CS}
- Capstone in Cybersecurity Practicum {IT} or Capstone in Cybersecurity Management {IS}

The Institute for Cybersecurity was established in 2016 as the home for an online, multidisciplinary BS-Cybersecurity program. This program was also created as a collaboration between the same three colleges. The Institute's Executive Director reports to the three Deans and oversees all Cybersecurity degree programs. A Director of Research and Graduate Education and a Director of Undergraduate Education and Outreach, report to the Executive Director. The University has been designated/re-designated as an NSA National Center of Academic Excellence in Cyber Defense Education (or equivalent) multiple times since 2004, including redesignation in 2022.

II. THE CHALLENGE

And then COVID hit. Even though the program was already scheduled to be fully online, the pandemic created issues. In addition to requiring all programs to transition to online instruction, the State Board of Governors suspended all hiring in anticipation of budget shortfalls resulting from a projected decrease in state revenue. The University's

leadership mandated that the program move forward but required the exploration of alternative solutions.

Applications to the program quickly exceeded expectations with over 130 applying for Fall 2020, and an additional 142 for Spring 2021. Within the first group, 33.3% identified themselves as Female, 64% as Male, and 3% did not answer. The pool was also ethnically diverse with 40.9% identifying themselves as Black, 38.3% as White, 5.2% as Asian, 4.3% as Hispanic/Latino, 1.7% as American Indian or Alaskan Native, with 9.6% not answering. A majority (58.1%) of applicants were "career changers" with non-computing undergraduate degrees. An additional 28.2% had computing undergraduate degrees, but only 13.7% had security-related coursework.

The number of applicants and restrictions on hiring required the program's leadership to quickly identify solutions to course instructional staffing. There is a national shortage of cybersecurity faculty [1]; however, the national need for cybersecurity professionals [1, 2, et al.] and corresponding interest in cybersecurity careers mandated that the program move forward.

The constraints on potential solutions to the staffing challenge were as follows:

- Does not involve the hiring of permanent, full-time, faculty.
- Allows unrestricted growth of the degree program.
- Supports regional accreditation guidelines for general and graduate-level instruction.
- Supports the delivery of a fully online curriculum.

III. PROPOSED SOLUTION

To address these challenges, the program's leadership identified several initiatives to be evaluated and implemented, if feasible. Some of these stemmed from faculty experiences teaching massive open online courses (MOOCs) [e.g., 3, 4], while others were obtained from experiences with large, physical classes. These included:

- The migration of the program's 5000-level remediation courses to self-paced, continuing & professional education (CPE) courses,
- As traditional Graduate Teaching Assistants (GTAs) were not available, the use of part-time faculty serving as "Assistant Instructors" to support large class sizes,
- The identification and dissemination of best practices for large online classes and online labs providing experiential learning.

A. Moving Prerequisites to CPE Modules

When the MS-Cybersecurity was implemented, it included 5000-level prerequisite courses to remediate any shortfalls in foundational knowledge. These included:

- Programming Principles - foundational program constructs, and software design & development, object-oriented program constructs, software engineering concepts, and organization requirements.
- Computing Infrastructure - computer networks and system administration, network protocols, traffic analysis, OS fundamentals, and systems management.
- Foundations of Cybersecurity - the roles and composition of the cybersecurity function in the organization, components of the cybersecurity program including administrative and technical roles, responsibilities, and controls.

These foundation courses alone would require up to nine instructors as approximately 75% of accepted students had non-computing undergraduate degrees.

The 5000-level prerequisites were migrated to instructional modules offered through the University's College of Professional Education. These courses were redesigned as self-paced, gated courses with faculty supervision. Students were able to complete modules before the start of the term, removing prerequisites for major coursework. The gates implemented were end-of-module quizzes, requiring students to score at least 70% (multiple attempts possible) before the following topic is available. Each module concluded with a comprehensive exam, requiring students to score at least 70% to receive credit for the module, with only three attempts permitted before requiring the student to retake the course.

During the migration process, the leadership team recommended splitting the infrastructure class into a data communications & networking class and a computer organization, architecture, and operating systems class. This resulted in up to four CPE courses for some students.

In the first term, 26% of accepted students did not need any prerequisites, 15.6% needed one, 19.8% needed two, and 38.5% needed all three. In the second semester, using the CPE-based prerequisites, 18.3% did not require any CPE prerequisite courses, 23.3% required one CPE course, 14.1% required two CPE courses, 9.8% required three, and 23.9% required all four.

B. Assistant Instructors and Very Large Class Sizes

Most instructional faculty are familiar with Graduate Teaching Assistants, typically doctoral students who have been assigned to assist a course instructor in conducting a course and managing its students, with some GTAs serving as teaching faculty themselves. Unfortunately, the University does not have sufficient doctoral students qualified to serve in this capacity. GTAs are commonly used at the undergraduate level; however, the need of the MS-CYBR degree program required assistance at the graduate level, a challenge due to the special qualifications required for teaching in the Graduate College, namely an established record of quality research and teaching.

To address this challenge, the program's leadership incorporated the use of part-time and limited-term faculty. With the current pool of part-time faculty, many of whom had taught corresponding courses at the undergraduate level, the program administrators were able to create a tiered approach to staffing large sections. The institution assigned a single qualified graduate faculty member as the instructor of record (IoR), responsible for primary instruction and course coordination, and one or more "assistant instructors (AIs)". This title was selected over "teaching assistant" as most of the part-time faculty engaged were qualified instructors in their own rights, with an earned graduate degree in security or a closely related field.

AIs were assigned based on course enrollment, providing one AI for each block of students over an initial enrollment of 35 students. For example, for 1-35 students, the Instructor of Record would manage the class alone. For 36-70 students, they would be assigned one AI, with additional AIs for each additional 35 students. Theoretically, enrollment can continue indefinitely.

An unexpected benefit of this approach was the simplification of scheduling for the program. A standard rotation of courses, one online section each, precluded the challenges of adding additional sections and finding additional instructors when late enrollment demand surges or dwindles. It also allowed the standardization of the planned course offerings where all courses are offered each Fall and Spring terms, with a reduced selection offered in the summer.

1) Qualifications and Recruiting of Assistant Instructors

The initial qualifications for the AIs were the same as those for a part-time faculty member, with at least 18 hours of graduate coursework in security or a closely related computing field. Since the program is fully online, AIs can be employed irrespective of location.

Recruiting for AIs began with the existing pools of part-time faculty and extended to an aggressive recruiting program to draw interest in the position. The recruiting program included email solicitations through internal lists, as well as recruiting from alumni of the University's other graduate programs. Additional recruiting involved Handshake postings. To date, 123 individuals have responded to these postings.

The roster of eligible candidates is shared with the departments responsible for staffing the MS-CYBR courses. Instructors are selected based on demand. To date the program has averaged between 75 and 100 students in each course, resulting in the employment of 2 to 3 AIs in each section.

2) Use and Results

Each Instructor of Record (IoR) is permitted to assign responsibilities to AIs as they see fit. Many AIs assist with the tasks traditionally performed by TAs, such as grading and answering student questions. IoRs are encouraged to capitalize on the expertise of their AIs, as many are working industry professionals. AIs were compensated at rates higher than the average part-time faculty, with salaries standardized across the three colleges, to draw additional interest in the positions.

In the first year alone, some classes approached 150 registered students, unusual for graduate programs. Feedback on the use of AIs was overwhelmingly positive.

C. Managing Large Online Classes With Best Practices

In preparing for the transition to large single-section online classes, a review of best practices was performed. While there is a wealth of information on supporting large online undergraduate courses and on teaching online graduate classes, there is virtually nothing on large online graduate classes, save for studies like [5] which focus on program management rather than instruction. Thus, the program had to adapt the existing recommendations from articles on the instruction of large online undergraduate sections. The information found covered setting up the course, managing students, managing grading, and managing labs.

1) Setting Up the Course

The first transition required in setting up a large online course section is to shift the focus from the instructor to the learner [6]. This paradigm shift may require a change in some instructors' perspectives if they prepare course materials to support instruction, rather than the students' learning. This is most commonly identified in the provision of "instructor's notes" to facilitate learning - sharing the notes the instructor uses to deliver a lecture, whereas a learner-focused approach would involve creating student study guides designed to make it easier for the students to learn the material. This is contrary to the approach recommended by [7] who suggests simply approaching a large class with the same creativity and mindset you would a small class, then trying to find a way to make the logistics work. Under this model, "some thrive, some sink and most find it difficult but struggle through" [8]. Reference [9] cautions "instructing up to 150 students in a large online course or 150+ students in a very large online course is different than teaching the same online course with 20–60 students with one instructor or teaching the same course in a traditional on-campus classroom". Reference [6] agrees.

It is also critical to redesign course assignments and timetables to suit a large section and potential delays in grading assignments [10]. The more complex the assignments, the more instructor involvement is required, which can be a logistical challenge in large sections. In modifying assignments, it may be to the instructor's and students' benefit to create simpler, easier-to-grade assignments, capitalizing on the use of TAs/AIs [10]. Reference [11] recommends replacing written activities with objective knowledge checks, especially those that can be automatically graded, an approach supported by others [4, 12, 13]. References [10] and [12] recommend designing assignments to support group activities and peer evaluations to minimize the instructor's workload and transition some evaluation and additional learning to the students as they

experience both completing and evaluating assignments. Reference [9] confirms stating "Group work is an important attribute that prospective employers rate highly when employing graduates… the National Association of Colleges and Employers (NACE) reported that the top three attributes an employer seeks included: (a) problem-solving skills, (b) ability to work in teams, and (c) communication."

In preparing for the start of the semester, it is critical to meet with TAs/AIs and walk through assignments and discuss grading rubrics. When using assignments that require evaluation, the development of clear and salient rubrics is critical [13], as it is important to ensure the evaluation team provides a homogeneous assessment of assignments, regardless of the number of students evaluated. To that end, it is beneficial to assign evaluation responsibilities to minimize any difference in assessment, commonly by assigning each evaluator the same subset of materials to be graded. For example, grader one evaluates the first part of every assignment, rather than grading all of the assignments of part of the class. This provides every student had the same assessment approach to their work.

To stave off the most common student questions, it is recommended that the course include a frequently asked questions (FAQ) page on the course management system (CMS) [14]. This allows the instructors more time to focus on content delivery and assessment, and less time spent repeatedly answering the same questions. By pushing any course Q&A to an electronic forum, students may also find the answers to their questions asked and answered by another student. Encouraging students to answer peer questions, when they know the answer, can further reduce the demands on the instructional team.

2) Managing Students

To mitigate the potential number of questions in large online classes, it is important to manage student expectations and communicate consistently and effectively. It is recommended that instructors seek to improve student-instructor interaction by setting up instructor biographies, with photos. Whenever possible, use videos to introduce the instructional team to the students, and communicate key information to the class, such as introducing the students to the CMS and covering the course syllabus. [6, 7, 13]. Reference [7] also recommends being purposeful in building the social presence of the teaching team, treating students as individuals, and nurturing social connections among them.

Establishing clear online office hours can further provide a method of addressing student concerns [14]. Many online courses focus on asynchronous interaction, via forum posts, recorded lectures, etc. However, providing a set time for students to interact synchronously can support students not used to large online courses. For those faculty who employ quick responses to student messages, this may be unnecessary.

In-class communications can be supported through discussion forums, preferably with threaded discussions for student-instructor communications. Reference [11] advises using threaded discussions judiciously and resisting the temptation to respond to every post. Confidential communications can be accomplished through email or video conferencing. Reminding students of how to contact instructors and ensuring quick responses can help assuage student concerns about the lack of face-to-face interaction [13].

Since they work on their own and must manage their time, students in online courses must have a clear understanding of what is expected of them and when assignments are due [15]. Communicating timeframes and deadlines, and reinforcing them with CMS calendars and reminders becomes paramount.

3) Managing Grading

One of the most significant challenges in managing large courses, online or physical, is dealing with the evaluation of student activities. As the class size swells, the amount of time to assess student performance increases. In addition to considering a shift from subjective to objective evaluations, with a preference for grading by the CMS, [13] also recommends being upfront with students about the grading differential between small and large sections, to manage expectations.

In providing feedback to students from those assignments which are graded by the instructional team, it is recommended to create standardized rubrics and feedback to simplify assessment. Having a list of most common feedback (e.g. "You should have discussed the information from the text, Chapter 1, page 1-5") ensures the graders can quickly copy and paste responses, providing detailed feedback to the student but speeding up the assessment process [4, 11]. Reference [4] also recommends strong time management when grading content from a large online section, stating that "When grading, instructors should schedule a block of uninterrupted time, and use a timer to keep on track".

D. Managing Labs

Like most similar programs, the MS-Cybersecurity includes hands-on labs in many of its courses. Fortunately, the University purchased NetLab+ environments from NDG (https://www.netdevgroup.com/products/). This provides web-accessible, online exercises, with preconfigured lab experiences. Since these environments replaced the physical lab experiences years ago, it was a simple process to create labs for the program. There are other options available, including leasing cloud computing options from Google, Amazon Web Services (AWS) and other vendors. NetLab+ was initially selected as it allows the organization to quickly and easily field preconfigured exercises only requiring a few high-end servers to run the VMWare ESXi environment used to manage the exercises. The NetLab+ virtual machine provides scheduling and automated remote session administration features not found in some cloud services. Students can self-schedule available time and the system will automatically configure labs for the student, and reset for the next student once the session is completed. NetLab+ can

support both ad hoc sessions and persistent sessions allowing the student to save their work for a future session.

These recommendations are summarized in Table I:

TABLE I. SUMMARY OF RECOMMENDED PRACTICES

Course Element	**Recommended Practices**
Course Set Up	• Shift the focus from the instructor to the learner, • Validate design of the course assignments and timetables to suit a large section including designing assignments to support group activities and peer evaluations, • Plan for coordination of instructional team before the start of term, and • Implement a comprehensive and dynamic FAQ to anticipate questions with comprehensive responses.
Managing Students	• Establish student expectations comprehensively for all classroom management areas including communication, service levels for responsiveness to questions, and grading frequency, • Establish clear virtual office hours (when needed) and means and methods of communication including discussion boards and other facilitated means of communication, and • Document and reiterate timing and means of submission for all assignments.
Managing Grading	• Establish expectations on the frequency and quality of grading feedback, • Maximize the use of high-quality *standardized* rubrics to offer maximum feedback with reduced instructor workload, and • Develop strong time-management requirements for IoR and AI grading workloads.
Managing Labs	• Develop scalable and topical hands-on lab experiences using recommended tools, techniques, and learning resources, • Use lab delivery systems that enable student self-scheduling and automated scoring.

IV. CONCLUSION

The overriding message from the literature on large online classes is that instructors must acknowledge their limitations. Realizing the difficulty of managing large online classes using the same approach as smaller, face-to-face classes, the instructor can still delivery high-quality, effective instruction through effective planning, maximizing the use of support personnel (i.e. GTAs, AIs), and incorporating many of the best practices presented here. Faculty can maximize student learning and minimize concerns in large online courses by communicating effectively ensuring all constituents engage in an informed and deliberate manner. One of the innovations discovered in this process was the ability to include industry expertise from practicing Cybersecurity professionals serving as AIs. The stringent requirements for graduate faculty typically exclude such expertise.

The degree program used as the foundation of this study continues to grow, with almost 200 Fall 2022 applicants. The program still only offers 11 sections at a time, with sections growing to almost 150 students.

The future may offer the ability to acquire additional faculty, however, the University's leaders have indicated their preference to continue the current approach, with large online sections, and have encouraged all faculty involved to continue to refine their course approaches and instructional delivery to take advantage to the identified best practices and continue to alleviate the strain on the institution's pool of available graduate-qualified faculty members. It is also the reality in higher education that there are never enough qualified faculty to accommodate the needs of growing programs. The shortage of qualified graduate Cybersecurity faculty and the premium salaries of those available make hiring on limited budgets even more difficult.

REFERENCES

[1] B. Taylor, "Cybersecurity is not a Fad: Why Cyber is a Game Changer for Computer Science Education," SIGCSE '19: Proceedings of the 50th ACM Technical Symposium on Computer Science Education, keynote address, p. 975, February 2019, https://doi.org/10.1145/3287324.3290954.

[2] NCYTE Center, "Faculty Fellowship Program - Mentors and Host Colleges Needed," July 2022, https://ncytecenter.wildapricot.org/widget/event-4868031.

[3] T. Lee, "CCDFs in MOOCs," In "Analysis and Design of Large-scale Online Classes," EDIC research project, pp. 1-15, 2014, https://infoscience.epfl.ch/record/200039/files/EDICProjectReportTaoTotal260614.pdf.

[4] A. Salter, "5 Tips for Handling Grading in Large Online Classes," The Chronicle of Higher Education, October 1, 2015, https://www.chronicle.com/blogs/profhacker/5-tips-for-handling-grading-in-large-online-classes.

[5] J. Singleton, A. Bowser, A. Hux, and G. Neal, "Managing Large-Scale Online Graduate Programs." Online Journal of Distance Learning Administration, vol. XV, no. 1, March 2013, University of West Georgia, Distance Education Center.

[6] R. Berry, "Meeting the Challenges of Teaching Large Online Classes: Shifting to a Learner-Focus," Journal of Online Learning and Teaching, vol. 5, no. 1, pp. 1-6, 2009, https://jolt.merlot.org/vol5no1/berry_0309.htm.

[7] S. Mayes-Tang, "Teaching Extra-Large Classes Online: 5 Principles I'm Following," Medium.com, June 21, 2020, https://medium.com/@SMayesTang/teaching-extra-large-classes-online-5-principles-im-following-c85e1d1c5b86.

[8] W. Al Abiky, "Lessons Learned for Teacher Education: Challenges of Teaching Online Classes During COVID-19, What Can Pre-Service Teachers Tell Us?" Revista Argentina de Clínica Psicológica, 2021, 30, 110-118, DOI: 10.24205/03276716.2020.4011

[9] G. Gay, and K. Betts, "From discussion forums to eMeetings: Integrating high touch strategies to increase student engagement, academic performance, and retention in large online courses," Online Learning, vol. 24, no. 1, pp. 92-117, 2021, https://doi.org/10.24059/olj.v24i1.1984.

[10] A. Salter, "Preparing to Teach a Large Online Course," The Chronicle of Higher Education, October 1, 2015, https://www.chronicle.com/blogs/profhacker/preparing-to-teach-a-large-online-course.

[11] R. Kelly, "Managing High-Enrollment Online Courses," Faculty Focus, January 15, 2013, https://www.facultyfocus.com/articles/online-education/managing-high-enrollment-online-courses/.

[12] M. Loder, "Best Practices for Large-Enrollment Online Courses, Part 2: Managing groups, peer review, and other peer-to-peer interactions," Arizona State University Teach Online Showcase, October 2, 2018. https://teachonline.asu.edu/2018/10/best-practices-for-large-enrollment-online-courses-part-2-managing-groups-peer-review-and-other-peer-to-peer-interactions/, unpublished.

[13] B. Lake "Best Practices for Large-Enrollment Online Courses, Part I: Managing student expectations, leveraging quizzes, and reducing grading load," Arizona State University Teach Online Showcase, September 20, 2018, https://teachonline.asu.edu/2018/09/best-practices-for-large-enrollment-courses-in-canvas/, unpublished.

[14] B. Lake, "Best Practices for Large-Enrollment Online Courses, Part III: Managing instructor-student communication and presence," Arizona State University Teach Online Showcase, July 18, 2019, https://teachonline.asu.edu/2019/07/best-practices-for-large-enrollment-online-courses-part-iii-managing-instructor-student-communication-and-presence/, unpublished.

[15] J. Bocchi, J. Eastman, and C. Swift, "Retaining the Online Learner: Profile of Students in an Online MBA Program and Implications for Teaching Them," The Journal of Education for Business, vol. 79, no. 4, pp. 245-253. March 2004, DOI: 10.3200/JOEB.79.4.245-253.