

A CRADLE-TO-GRAVE APPROACH TO RETAINING STUDENTS IN INFORMATION SECURITY PROGRAMS

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Abstract

We introduce our approach to retaining students specifically in Information Security programs that are a blend of academics, hands-on in-class exercises and out-of-class events and projects. Many of these students do not understand the complexity of Information Security degree programs; they only know that they are interested in security-related projects and careers. Thus, a large upfront effort is to educate eager students on all the different domains of security and keep them engaged with coursework and exercises over the next four years. Having such a plan in place allows faculty to assess students on more than course assignments and requirements, which proves to be very beneficial for potential employers as they ask faculty about specific students. We introduce three different periods in the timeline of a security student, why these periods are so important, and what we implement to ensure maximum retention of these students while they are absorbing the maximum amount of security knowledge from our degree program. The goals of our approach is to generate excitement about security and our degree program, have the students actually do more than what is expected of them in coursework, and compete with one another on several different levels while enjoying the learning process.

Keywords: Retention, Information Security, Information Assurance, Recruitment.

1 INTRODUCTION

We have seen explosive growth in our Computer and Network Security (CONS) program over the past two years partly because of the obvious need for these professionals both in the public and private sector, but also because of the some of the recruitment and retention strategies we have implemented. New student registration in the CONS program has increased from 80 total undergraduate students to 135 in two years. The CONS program is housed within the College of Business and Information Systems so it naturally has close ties to applied programs with a heavy business process background. The program itself has pillars in four distinct areas that provide a strong foundation before taking the core CONS courses.

1. **Business Management, Project Management, and Ethics:** These courses ensure that our CONS students realize that the core functionality of their future career placement is directly tied to supporting and optimizing a business infrastructure and the goals that drive that business. Security is not configured and implemented in a vacuum. These courses provide a great amount of framework for the later security courses.
2. **Programming:** Our students take two semesters of C programming in a Linux environment where not only are they learning C syntax, but also common Linux commands that they use throughout their time in the program. They also take two semesters of web programming where they learn both client-side and server-side programming techniques that are later leveraged in security courses.
3. **Operating Systems:** Our students take dedicated courses in both Windows and Linux to familiarize themselves with common system administrative tasks. Most of the security tools that are used in industry are in both environments.
4. **Networking:** Our students take two semesters of networking as a foundation before taking the web application and network penetration testing courses and the intrusion detection and prevention course in the CONS program. These two networking courses introduce theoretical and hands-on networking.

We assume no knowledge of any of these four areas when students first enter the program. We approach each class from the ground up to ensure all necessary material is explicitly covered. It is beneficial to have students excited about security topics right away, but also critical that they fully understand why these underlying courses are so important.

Section 2 introduces related work to undergraduate retention strategies and successful approaches for such endeavors. Section 3 covers our retention activities for all students in our Computer and Network Security undergraduate program. Section 4 covers initiatives that we dedicate to incoming freshmen students and section 5 introduces retention efforts for all other students broken out by grade level. We conclude in section 6.

2 RELATED WORK

Habley and McClanahan found that in spite of the attention paid to college student retention, only 47.2% of campuses have established an improvement goal for retention of students from the first to second year, and only 33.1% of campuses have established a goal for improved degree completion [2].

Two factors that made a moderate or higher contribution to attrition are amount of student financial aid available and student-institution fit [2].

Tinto introduces five conditions that are supportive of student learning and retention as expectations, support, feedback, involvement, and relevant learning [9]:

- First, students are more likely to persist and graduate in settings that hold high and clear expectations for student achievement [9].
- Students need to be clear about what is expected of them and what is required for successful completion of both courses and programs of study [9].
- Second, support is a condition that promotes student retention such as basic skill courses, tutoring, study groups, and academic support programs such as supplemental instruction is an important condition for their continuation in the university [9].
- Third, students are more likely to succeed in settings that provide faculty, staff, and students' frequent feedback about their performance [9]. Feedback also takes the form of classroom assessment techniques such as the use of learning portfolios [9].
- Fourth, academic and social integration means students are more likely are they to persist and graduate [9]. The more frequently students engage with faculty, staff, and their peers, the more likely that they will persist and graduate [9].
- Finally, the more students find value in their learning, the more they see it as connected to their interests, the likely they will become involved in learning and in turn learn more and persist more frequently [9].

Lau surmised that student retention is ultimately driven by three separate parties on any campus: first, administrators must provide financial support and physical facilities that are appropriate for higher education students; faculty members must engage students by using innovative instructional techniques; and students must be motivated to participate actively in their own learning process [3].

Sidle and McReynolds found that student-faculty interaction in and out of the classroom has been shown to promote student academic integration and, ultimately, persistence [8].

Studies confirm that students who enrolled in freshmen-year experience courses tend to complete more

credit hours, earn higher cumulative grade point averages, and return to the institutions at higher rates than students who did not enroll in such first-term courses [8].

Beal and Noel completed a national survey, entitled "What Works in Student Retention," conducted by the American College Testing (ACT) Program and the National Center for Higher Education Management Systems to identify, analyze, and compile information about campus action programs and efforts for improving student retention in higher education in 1979 [1].

Findings include most important factors influencing student retention, information on campus organization for retention by type of institution, and major action programs [1].

Murtaugh et al. performed survival analysis that was used to model the retention of 8,867 undergraduate students at Oregon State University between 1991 and 1996, which found attrition increased with age, and decreased with increasing high school GPA and first-quarter GPA [6].

Non-residents had higher attrition rates than did resident and international students, and students taking the Freshman Orientation Course appeared to be at reduced risk of dropping out [6].

Martinez introduced successful strategies to improve student retention which include:

- Successful outcomes of retention strategies; management of the process, that is, how the colleges got started and who took the lead;
- How pre-enrollment issues were managed; initial student assessment that worked best in matching students to courses; identification of students at risk of dropping out; induction and student motivation as methods to help students settle in;
- The role of tutoring; curriculum strategies for retention, including curriculum audit, course development, curriculum structure and timetabling, learning support, and learning;
- How teachers can improve and develop their courses; other effective support provided to students, including direct costs of study, financial advice, travel costs, child care costs, and counseling services;
- Student tracking and follow-up, including manual and computerized systems; and resource allocation and target setting [4].

Nagda et al. found that promoting student-faculty research partnerships that target first-year and sophomore undergraduates positively impacted retention when integrating students into the core academic mission[7].

McDowell et al. argue that pair programming produces more proficient, confident programmers that are not only more successful in the specific programming course, but also better positioned to succeed in college as a whole [5].

3 INITIATIVES FOR ALL STUDENTS

We strongly encourage all of our CONS students to take part in the Association for Computer Machinery (ACM) Computer Club that we have on campus during every semester because it provides an opportunity for students of all expertise levels to gain hands-on experiences in hardware, operating systems, networking, and software. Our ACM Computer Club is broken into three sub-groups: 1) programming; 2) gaming; and 3) security. Students can be active in any of three groups simultaneously and there's a general meeting held once a month where each sub-group provides an update on their projects.

The primary goal for the security branch of the Computer Club every year is to host a campus-wide Capture the Flag (CTF) competition. There is a tremendous amount of work that goes into preparing for this CTF competition in the months before the actual event day. Students organize, plan, develop, and test the hosts, networks, and scoring for the entire CTF competition. Many students spend numerous hours working on this project because they want to ensure the event is a success; the ownership that students take of the CTF is a great retention factor.

Another major part of the security branch of the Computer Club is to do fundraising for an annual trip as a large group. For the past two years we have attended DEFCON, which is the premiere black hat conference in the world. This past year we had a group of ten from our institution attend the conference. The technical security knowledge shared at this conference is as strong as any other gathering. It provides students an opportunity to interact with others that share a common interest and take part in projects and presentations that cannot be replicated in the classroom or laboratory. DEFCON is a very low cost gathering for what the attendees take away from it. Many students cannot afford a summer trip that includes airfare, hotel, food, and other costs for a five day trip. Therefore, we also raise funds for regional security events like ChicagoCon, which is only two days long and is within driving distance.

A large percentage of our students help setup, test, administer, and tear down for the North Central Region of the Collegiate Cyber Defense Competition (CCDC) that we host every spring. This involves a great amount of hands-on work in physical hardware, network configurations, firewall rule sets, and multiple operating systems. The students learn a great deal without being tied down to a lecture meeting and are allowed to work on the CCDC infrastructure in the weeks leading up to the two-day competition. We break them out into teams of 4-5 students and task them with making sure each of the separate team networks and workstations are up and functioning as expected. This emphasizes team work and troubleshooting for each team without a faculty

specifying exactly what has to be done for each step of the processes.

Our institution's CCDC team is made up of 8-10 CONS students. This group meets approximately 2-4 hours per week all year long in preparation of the spring regional and national competitions. It is a goal of almost every CONS student to be on the CCDC team. This team is selected by faculty appointment and performance in the CONS core classes and out of class projects.

We also organize several on-campus presentations from IT security professionals in our classes. This provides real world stories to our students so they can clearly see the rationale of the coursework in the CONS program. Many of the presenters are graduates of our institution, so it is easy for our current students to relate to the material and background of the speaker. Many of these presentations lead to technology internships for our students, and ultimately, career placement.

4 ESPECIALLY FOR FRESHMEN

Our freshmen students take part in Computer Club activities that we have on campus as soon as they get settled in the college environment. There are many activities at the beginning of the semester aimed at welcoming new member; especially new students that don't have the technical background of older students. Some of these activities aren't technical in nature. We traditionally hold a scavenger hunt around campus with teams of differing age students so freshmen not only become more comfortable with campus, but also meet older students that share a common interest and can act as a mentor.

During the last month of the first semester for freshmen students, we hold a registration workshop in which we are available to answer questions specifically about course selections for the spring semester and help students develop a schedule. This registration workshop is the last activity we do as part of the GS 100: University Experience course that all freshmen take during their first semester on campus. GS 100 sections are divided by major, so we can cover all the academic aspects of the CONS degree during these weekly one-hour sessions. We also cover out-of-class topics related to security such as the latest viruses, worms, and other malicious software and the effect on IT infrastructure. These GS 100 sessions are also a time for students to drive the discussions with issues that are relevant to all attendees.

Starting in fall 2009, we are implementing a series of one-credit courses so our freshmen have security-related courses during the first semesters they are on campus. This is a retention strategy to engage our students in CONS-related courses every semester they are at our institution. These one-credit classes help lay the foundation for the skill set required in later courses. Currently we offer one-credit classes in Technology

Ethics, Scripting, Linux, and an Emerging Topics course. We use the Emerging Topics course as a placeholder to offer a one-credit class that is dedicated to the latest security news; this is also a way to engage security students early in their academic career. We are offering a one-credit course on DEFCON for spring 2010 that fully investigates the background and history of the 17 years DEFCON has been held. We will have the students research and present on the numerous activities, contests, villages, and presentations that are made available at DEFCON every year.

We expose our students to industry conferences and workshops, such as DEFCON, during their first semester as a mechanism to show how wide reaching IT security has become in every industry.

Our freshmen students also help setup and administer the North Central Region of the CCDC. The students help setup each team's workstations and depending on each student's background and interests, can also help configure and test the competition network. There is a wealth of experience that is gained by helping setup, monitor, and tear down this multi-day competition. Most of the freshmen that assist with CCDC are primarily physical labor for setup, competition administration, and tear down. They deliver business inject memos to each team and complete other tasks to ensure the event runs smoothly. Students are generally very interested in helping with these hands-on events like this outside of course meeting hours.

5 APPROACH TO RETURNING STUDENTS

We developed specific retention strategies for our CONS students for each year they are part of the program. Some of these activities persist from year to year while others are specific for that year in the program.

5.1 Sophomore Year

The academic highlight for our second year students is the CIS 245: Information Assurance Fundamentals course they take in the fall. The goal of this course is to expose the students to as many areas of security as possible. We attempt to touch briefly on topics related to:

- Hardware and physical security approaches and how important they are to the overall security posture of an installation,
- Operating system hardening best practices and the most common port numbers and services for a wide variety of operating systems,
- Basics of networking in preparation of later courses in ethical network hacking and intrusion detection and prevention,
- System software that is executed locally on a client machine and is susceptible for reverse engineering,

- Web software and the basics of the HTTP protocol and the security implications of session management, and user-on-user attacks,
- Legal aspects of information assurance including disclosure, bug releases, and “hacking for charity”,
- Supporting technologies such as domain vs. workgroup networks, intrusion detection and prevention system placements in the architecture, and defensive coding practices,
- IT's place in the business world and how IT is intended to be a support mechanism for the core business functions,
- Best approaches to communicate technical knowledge to non-technical management-level personnel,
- Guest speakers to provide a wide range of views.

This course is the first opportunity that our CONS students get to investigate the different areas of information assurance. Prior to this class, most students are only interested in network penetration testing simply because they haven't been made aware of all the other areas of information assurance.

Our second year students are also far enough into their academic studies to take part in our institution-wide Student Research Initiative (SRI). This program awards students \$300-500 for completing a research project that interests them and is supported by a faculty member. The goal of the SRI is not to have undergraduate students complete faculty research, but rather it is a way for undergraduate students to gain experience in research during their undergraduate studies. Given this, the vast majority of projects are mostly exploratory studies by students in domains that interest them. Some of the CONS program SRI projects in the past have included:

- Internet Traffic Analyzer via Honey Pot
- Cookie Generator Predictor
- A Security Overview of Cloud Computing
- Archiving Malicious Software for Decompiling
- Running a Capture the Flag (CTF) Competition

A small percentage of these SRI projects have lead to students authoring technical research papers that were submitted to conferences. The main outcome of this SRI program is to excite and engage our students into research. The SRI program is open to all majors on campus and is provided by the Center of Excellence in Computer Information Systems.

At the conclusion of the second year, our CONS students are well-equipped to find an internship in general IT such as programming, networking, or help desk. These internships earn up to three academic credits and provide a wealth of experience for our students before they start the CONS core classes.

5.2 Junior Year

The third year is by far the busiest for students in the CONS program. Academically, this is the year that they take the four core CONS classes. We purposely offer these core classes at this point in the CONS program to ensure students have not only taken an exhaustive set of electives in programming, operating systems, and networking, but also so students can't simply drop into the CONS core and take what they perceive to be hacking courses. Each semester's courses are co-requisites of each other. This ensures that a CONS student gets through these four core classes in the same year. These classes are each offered once per year in the following rotation.

- Fall Semester
 - CIS 414: Computer Security Fundamentals: This course covers the well-known operating system vulnerabilities of several Windows and Linux distributions. Operating system hardening best practices is an important part of this course. This is also the course where we cover encryption.
 - CIS 422: Software Security: This course covers security implications of web applications. The main points of this course include session management, access control, and well-known web attacks like Cross-Site Scripting (XSS), Cross-Site Request Forgery (CSRF), and SQL Injection. By inspecting these attacks, the students become aware of appropriate defensive programming techniques that should be implemented.
- Spring Semester
 - CIS 416: Network Security: This course is the main course that many of our CONS students are interested in. This is our network penetration testing course that covers the five steps of performing a penetration test on a network: 1) Reconnaissance; 2) Scanning; 3) Gaining Access; 4) Maintaining Access; and 5) Covering Tracks.
 - CIS 420: Intrusion Detection & Prevention: This course is the defensive networking that we offer at the same time the students are learning offensive techniques in CIS 416. This course is split into three distinct sections. First, we cover all the theoretical material of firewalls, DMZs, NAT network devices, and proxies. Next, we spend a lot of hands-on time installing open source intrusion detection systems (IDS) such as SNORT in Linux. We finish the course with a hands-on installation and configuration of open source firewalls like M0n0wall in Linux.

We set the rotation so that a CONS student must take a full semester before getting to the offensive CIS 416 course. This was done deliberately as we had several years of non-CONS students only taking that course and we had very little time to stress how important it was to not use those tools and techniques "in the wild".

The core classes are split evenly between classroom lectures and hands-on laboratory exercises. This is a great learning environment for our students, but requires heavy faculty workload to ensure that the hands-on exercises are worth substituting in place of a lecture. It is common to spend five times as much time creating and testing the exercises as it does for the students to complete the exercise. Our classes meet twice weekly for 75-minutes each, so a realistic estimate is over six hours to create a weekly exercise.

We also ensure that ethics are a starting point in each of these courses. In addition to the one-credit Technology Ethics class that all CONS student take earlier in the program, ethics is explicitly covered in each core class. Furthermore, each student must read, sign, and abide by a White Hat Agree (WHA) that specifies exactly what is allowed and not allowed with the tools and techniques covered in the core classes. One main item from the WHA is that all tool execution must happen in our isolated Information Assurance Laboratory (i.e. "Hacker Lab").

Students in the CONS core are also very active in the ACM Computer Club, being on the CCDC team or helping with the event's preparation and execution, and preparing for an internship specifically in Information Assurance after completing the core classes.

5.3 Senior Year

The last year in the CONS program is generally used to complete elective hours; often times in digital forensics or database programming. We offer a two-course sequence in digital forensics where both the legal side of digital forensics is covered in addition to the tools used in the profession.

Several students will also continue researching in an interest area from the core classes or an internship. These independent research experiences are taken for credit under the guidance of a supervising faculty member. By the time a student has completed the first three years of the CONS program, they are well equipped to execute research and have identified an exact area of interest. The majority of our students, approximately 70% are interested in network security so Honey Pot-like projects are always popular.

We also provide informational sessions for our seniors about graduate school options. Our institution has a Master's and Doctorate degree in Information Assurance, but we also discuss the pros and cons of staying at the same institution for multiple degrees.

6 CONCLUSIONS

These new initiatives have been enjoyable and interesting for students in every grade level and the faculty that take part. Partly because of the high school recruiting events that we have in place and the publicity and notoriety of a security program, our new student enrollment has increased dramatically in the past two years as introduced in figure 1.

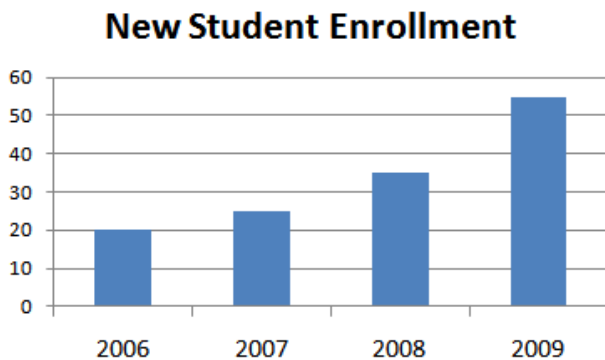


Figure 1. Four Years of New CONS Students

The CONS program is the largest major in the College of Business and Information Systems that has a sole focus. Our institution has just over 1,300 students on-campus, so the CONS programs is a large portion of the on-campus population's chosen academic program. We expect new student enrollment to continue to increase with 75 new students per year as our goal within the next three years.

Not only has there been a large increase in the number of new students into the CONS program, but a large percentage of these students are persisting in the program. This has resulted in our total headcount for the degree program to increase sharply, too, as introduced in figure 2.

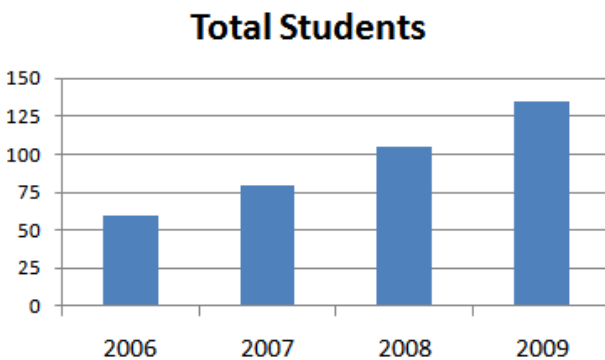


Figure 2. Four Years of Total CONS Students

Although more students is definitely a great indicator for the CONS program, laboratory and faculty capacity are also becoming issues. We pride our courses in being

capped at a maximum of 20 students per class. This ensures we get to know our students personally and lecture times are more intimate and foster group discussions. We will have to reevaluate our courses as the large new student groups of 2008 and 2009 enter the CONS core classes. We will have to increase the capacity of each section of each course or add sections of each course.

Our current Information Assurance laboratory that we use for all of the CONS core classes has 20 workstations. We are moving to a more virtualized environment to allow 24/7 access to the laboratory resources, but we are limited to 20 students on days that we want to hold class in the lab.

Regardless of the route taken to accommodate the increased number of students, decisions about faculty load and laboratory size and usage will need to be made.

We are currently reviewing all CONS courses and activities to further enrich the educational experience for our students. A strong academic program highlighted with hands-on technical exercises outside of the classroom that facilitate healthy competition has a dramatic impact on student headcount. We now want to make sure our program is as rigorous as can be for these engaged students.

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