The INSuRE Project:
CAE-Rs Collaborate to Engage Students in Cybersecurity Research

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Abstract
Since fall 2012, several National Centers of Academic Excellence in Cyber Defense Research (CAE-Rs) fielded a collaborative course to engage students in solving applied cybersecurity research problems. We describe our experiences with this Information Security Research and Education (INSuRE) research collaborative. We explain how we conducted our project-based research course, give examples of student projects, and discuss the outcomes and lessons learned.

Index terms—INSuRE Project, cybersecurity education, National Centers of Academic Excellence in Cyber Defense Research (CAE-Rs), project-based learning.

1 The INSuRE Project

The Information Security Research and Education (INSuRE) research collaborative\(^2\) is a network of National Centers of Academic Excellence in Cyber Defense Research (CAE-Rs) universities that cooperate to engage students in solving applied cybersecurity research problems. Since fall 2012, INSuRE has fielded a multi-institutional cybersecurity research course in which BS, MS, and PhD students work in small groups to solve unclassified problems proposed by the National Security Agency (NSA) and by other government and private organizations and laboratories.

In this paper we describe our experiences with the INSuRE Project. We explain how we conducted our project-based research course, give examples of student projects, and discuss the outcomes, benefits, and lessons learned.

The approximately eighty CAE-R universities\(^3\) include a significant collection of cybersecurity students, educators, and researchers. While the individual universities were “nodes of excellence,” these nodes were not purposefully constellated into a research network. The INSuRE Project created an educational and research network of CAE-Rs. As such, INSuRE is a self-organizing, multi-disciplinary, multi-
institutional, and multi-level collaborative organization.

The central activity of the INSuRE Project is its cybersecurity research course, in which students form small groups that work on research problems of interest to the nation. The NSA and other organizations support the project by contributing suggested problems and by providing technical directors to mentor student groups. The geographically-diverse participants connect and collaborate using a variety of conferencing and data-sharing technologies.

Students benefit from an exciting opportunity to work collaboratively on real-world problems and to interact with experienced technical directors. They learn how to carry out research, including producing fast, incremental, and actionable results in team projects. Benefits to participating government organizations include collaborative work on important problems and access to university faculty and to highly motivated and capable students for possible employment. In addition, faculty benefit from building connections with other researchers, schools, and government organizations.

Melissa Dark (Purdue), and Mark Loepker, NSA Security Education Academic Liaison (SEAL) for Purdue, started the INSuRE Project in 2012. Dark provided the students and Loepker provided the NSA research problems, along with NSA Technical Directors under Trent Pittsenger’s leadership. For more information about INSuRE, see Dark, et al. [5, 7, 8].

2 The INSuRE Course

The first INSuRE course took place in fall 2012 at Purdue, involving five students who formed two groups supported by three technical directors (TDs). With funding from the National Science Foundation, the project added three more schools: University of California, Davis; Mississippi State; and University of Maryland, Baltimore County (UMBC). Many of the INSuRE students are CyberCorps®: Scholarship for Service (SFS®) scholars.

In the following years, the course expanded to include a total of twelve universities, six national labs, and two state organizations. In

| Term       | Univs. | Students | TDs | Groups |
|------------|--------|----------|-----|--------|
| 2012 fall  | 1      | 5        | 3+0 | 1      |
| 2013 summer| 1      | 1        | 0   | 1      |
| 2014 spring| 3      | 33       | 7+0 | 13     |
| 2014 summer| 1      | 1        | 0   | 1      |
| 2014 fall  | 4      | 22       | 7+1 | 8      |
| 2015 spring| 8      | 52       | 7+3 | 21     |
| 2015 fall  | 7      | 42       | 8+8 | 14     |
| 2016 spring| 6      | 72       | 6+9 | 27     |
| 2016 fall  | 8      | 64       | 5+6 | 25     |
| 2017 spring| 7      | 54       | 6+15| 22     |
some years, a small number of private companies participated. For example, the spring 2014 edition included a private defense contractor, Assured Information Security, located in UMBC’s research park. Each partner organization suggested research problems. Table 1 summarizes the growth of the INSuRE course.

Every semester, a rotating subset of the collaborating universities offers a section of the course at their schools. Doing so enables each university to participate at a frequency that suits its needs, while fostering a diverse set of relationships among the schools.

To facilitate collaboration, the project used PURR, an instantiation at Purdue of the open source software platform HUBzero®. Users can share files, publish datasets and computational tools with Digital Object Identifiers, and participate asynchronously in discussion groups across multiple institutions. Individuals and groups participated synchronously in periodic community meetings using the WebEx conferencing software, supplemented by an audio bridge. INSuRE instructors shared experiences and developed common syllabi, handouts, and grading rubrics.

All class activities revolved around student projects. TDs presented their suggested problems. Students submitted bids and formed groups (typically three to five students each). In some schools, instructors assigned groups; in other schools, students self-selected the groups. Each group prepared a proposal, including a literature review, specific aims, and research plan. Formal group presentations to the INSuRE community included progress reports and final reports.

Throughout the course, students interacted with their TD. TDs could check on the status of their groups, including reading a “dashboard” slide summarizing the group’s progress.

Most groups worked on problems suggested by the TDs; some proposed their own “custom” projects or variations of suggested problems. Organizations sometimes proposed the same or a similar project in multiple semesters. Student groups were allowed to continue projects completed in previous terms, or in some cases, revisit a problem addressed by others before.

Once a semester, key faculty and student members from each of the participating schools met in person, together with some of the TDs, to review outcomes, discuss possible improvements, nurture relationships, and plan ahead.

In summer 2016, the project initiated INSuRE-Con, an annual student-organized research conference featuring five competitively-selected project presentations from the INSuRE class.

### 3 Project Examples

To illustrate the type of research carried out in the INSuRE course, we comment briefly on the suggested problem lists and describe several representative projects, including three in some detail.

**Problem Lists.** Partner organizations provided lists of suggested problems covering a wide

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6 [https://hubzero.org/](https://hubzero.org/)

7 [https://sites.google.com/a/uah.edu/insurecon16/proceedings](https://sites.google.com/a/uah.edu/insurecon16/proceedings)
range of topics, including, for example, policy-based stored information management, protection, and access control; software assurance, including machine-assisted semantic understanding of code; cloud computing, including cleaning up data spillage in Hadoop clouds; forensics, including cloud forensics and mobility forensics in the Internet of Things; deriving intelligence from an encrypted VPN stream; protocol analysis and verification; attacking botnets; machine learning for malware classification; vehicular data bus security; and incident response capabilities assessment.

TD Pitsenbarger explained, “The tasks we place on our INSuRE task list represent areas where the organization needs greater insight and past tasks have helped us.” These areas include understanding new technologies (e.g., FIDO authentication), tool development (e.g., control flow integrity), and validation of guidance (e.g., guidance on cleaning up spillages of sensitive data in clouds).

Example 1: Moving Target Defense.

A three-student team from UT Dallas, working together with Argonne National Laboratories, developed a Moving Target Defense (MTD) to protect against probing attacks on web servers [13]. At random bounded intervals between 15 and 60 seconds, the system switched the web server between Apache and Nginx. Dynamically updated IP tables redirected web traffic to the active server. This deception aimed to hinder attacks by constantly changing the target.

To test the effectiveness of their system, the team launched simulated attacks against the web service, with and without MTD protection. With MTD protection, a Word Press application ran normally 76% of the time, experienced lag 14% of the time, and was down 10% of the time. By contrast, without MTD the application ran normally 13% of the time, experienced lag 7% of the time, and was down 80% of the time.

This work suggests that MTD can be a practical and effective defense against web service probing attacks.

Example 2: Analysis of FIDO.

In three separate terms, teams from UMBC, Purdue, and Stevens Institute of Technology analyzed the Fast Identity Online (FIDO) authentication protocol under development by the FIDO Alliance. In spring 2014, a team from UMBC studied the new FIDO protocol, assessing its goals, strengths, and weaknesses. This team complemented the work of another concurrent UMBC team that studied the PICO authentication system. FIDO and PICO offer different approaches toward the eventual replacement of passwords.

Building on the initial UMBC work, in fall 2014, a team from Purdue evaluated the vulnerability of the FIDO Ready (TM) Samsung Galaxy S5 fingerprint reader to a particular spoofing attack [4]. Discovered by a German security research lab, this attack lifted a latent fingerprint. The Purdue team was unable to replicate this attack successfully, though they were able to produce a fingerprint by lifting a latent fingerprint.

Building on the Purdue work, in spring 2015, a team from Stevens studied two attacks on each of four different fingerprint scanners: two FIDO compliant devices (Samsung Galaxy S5, iPhone S5) and two non-FIDO compliant devices (Hamster Area Scanner, Validity Swipe Sensor). For each of these two device categories, one device had a swipe sensor and one device had an area sensor. One attack created a “fake finger;” the other produced a latent fingerprint. The team
was able to carry out each attack successfully on the S5 and on both non-FIDO compliant devices. Differences between FIDO and non-FIDO compliant devices were not due to the FIDO protocol but rather to differences in the strengths of the component authenticators.

Subsequently, NSA removed the problem from the INSuRE problem set because the three student teams had answered all of the questions.

**Example 3: Detecting Intrusions on SCADA Systems.**

A two-student team from Mississippi State University studied machine learning techniques for detecting cyber attacks against industrial control systems [15]. The team worked from a dataset by Pan [11] of cyber attacks and normal behavior from an electricity transmission system. The dataset included alteration and injection attacks against protection relays and Energy Management System (EMS) software. The injection attacks sent illicit network packets to protection relays to cause the relays to operate and open a circuit breaker. The alteration attacks used a Man-in-the-Middle to alter voltage and current sensor data sent from phasor measurement units to the EMS software. The dataset also included instances of single line-to-ground faults at random locations in the simulated transmission system, and changes in system load at random times.

First, the team extracted features from the dataset and applied clustering techniques to learn classes of events. Second, the team built a classifier using the Mamdani fuzzy inference system. Inputs to the classifier comprised a heterogeneous collection of voltage, current, frequency, Snort log, and protection relay log information from one time stamp.

The team validated their work by comparing results to similar classifiers developed from K-means and Fuzzy C-Means clustering algorithms. Their approach outperformed K-means- and Fuzzy C-means-based intrusion detection systems.

**Additional Examples.** In spring 2014, the INSuRE Project negotiated access to Google Glass by some INSuRE students who analyzed its security. A UMBC student team discovered a vulnerability and developed a proof-of-concept demonstration exploit, enabling an adversary to activate the eyewear and capture images without the subject’s knowledge.

Also in spring 2014, a UMBC PhD student led a group working on a custom project to perform a security audit of software developed for the Random-Sample Election Project [5].

A Purdue team investigated information leakage from encrypted output from a Cisco ASA 5506 Virtual Private Network (VPN) appliance. The team discovered a vulnerability in the VPN’s use of Quick UDP Internet Connections (QUIC), an experimental transport layer protocol designed in 2012 at Google. QUIC exposed the length of short communications, such as passwords, even when encrypted, as a result of aligning cryptographic block boundaries to contain packet loss. When Purdue reported the vulnerability, Google responded that the vulnerability is broader than QUIC and also impacts Transport Layer Security (TLS). If Google’s claim is true, the vulnerability could be used to undermine authentication in TLS (for short passwords) and impacts over 96% of all websites. Google and Apple are working with Purdue to create a patch to protect QUIC, TLS, and other transport security protocols vulnerable to leaking encrypted password lengths.

*http://rsvoting.org/*
Working on the problem of commercial solutions for classified, another Purdue team explored the impact of known vulnerabilities on layered solutions. The project analyzed past known vulnerabilities across multiple mechanisms in a layered solution. Given known vulnerabilities, as well as patch times generated by statistical models, the project simulated the performance of a layered security solution. The study also explored if any of the vulnerabilities in the individual mechanisms permitted a breach in the security to persist beyond the application of a patch, thus allowing an attacker to bypass the layered solution even when the vulnerability windows for the layers do not align. The team produced software that, given one or more layers composing a layered solution, identifies windows of opportunity where an attacker could breach any layer as well as the complete layered solution. The sponsoring government organization is currently using this tool.

4 Outcomes and Lessons Learned

From fall 2012 through fall 2016, the INSuRE class produced 140 project reports on 110 separate problems, and taught 356 students (many of whom have been hired by government organizations).

In addition to the works presented at INSuRE-Con, INSuRE projects resulted in refereed conference publications (e.g., [1,2,4,9,10,14]), refereed posters (e.g., [12,13]), and published datasets (e.g., [6]).

In this section we discuss some of the takeaways (outcomes, benefits, lessons learned, and open challenges) from the INSuRE experience, organized from the separate perspectives of educators and government policy makers.

4.1 Takeaways for Educators

We summarize some of the outcomes, lessons learned, and challenges from the perspective of educators.

Outcomes. To improve the course, faculty frequently discussed process and outcomes. In May 2014, students were asked to submit course feedback via an online survey administered through SurveyMonkey. Items included rank-order, Likert scale, and open-ended questions. Students rated the course high on a variety of indicators. The most highly rated elements included developing expertise in a specific topic in cybersecurity, developing qualifications for a job in cybersecurity, and working with a mentor from government or industry. Students identified development of research skills in cybersecurity as an important course outcome. Results of the survey also showed that students found limitations with the electronic communication methods used to interact with other institutions.

In fall 2016, Purdue University conducted a pilot study investigating the effect of the INSuRE course on student research self-efficacy. Research self-efficacy [3] is a self judgement of one’s ability to perform particular research tasks. The study included 17 students (5 undergraduate, 12 graduate) from eight universities that responded to pre- and post-surveys. Each student measured research self-efficacy using a 100-point Likert scale (0 denotes complete uncertainty; 100 denotes complete certainty).

Given the small sample size and relative nature of Likert scores, the team analyzed the data using a nonparametric Wilcoxon Test. Results show that student research self-efficacy improved: pre-test
mean 73.56, median 76.33, interquartile range [65.38–83.54]; post-test mean 83.27, median 86.83, interquartile range [74.54–89.42]. These gains were statistically significant ($z = -2.58$, $p < 0.01$). Cronbach Alpha for each survey was 0.96.

Students gained valuable experiences carrying out research, presenting their work, writing proposals and reports, using tools (including for software analysis), working in groups, building relationships, and communicating succinctly and effectively with their TD. Because the problems touched a broad range of issues, students and faculty gained knowledge outside of their focused areas of expertise. In addition, the course inspired students to tackle challenging problems. For some, it was their first exposure to research. The project-based course helped students learn the need to take the initiative and lead.

Several INSuRE students continued their studies at the PhD level, citing their INSuRE course as an important motivating factor. One university reports that its INSuRE course prompted a faculty member to include one of the INSuRE problems to his research area. This university also reports that the INSuRE course increased the number of students completing capstone engineering projects in cybersecurity and motivated more local companies to engage in cybersecurity projects with the university.

The INSuRE course has benefited from a significant number of female students.

Although the INSuRE research experience inspired most students, a few learned that cybersecurity research is not a path they wish to pursue—a useful discovery for the students.

Lessons Learned. Many factors contributed to the success of groups. To begin, it was helpful to screen students (especially the undergraduates) to make sure they are motivated and ready to engage in research. It was helpful for each team to have a student leader with strong organizational skills. TDs also contributed significantly through their enthusiasm, availability, and probing questions.

Course alumni and alumnae also contributed to project success. Some of them enthusiastically functioned as course assistants, facilitators, and mentors.

In some terms, instructors required each group to provide periodic peer evaluations of a paired group. Doing so provides additional feedback to the evaluated group, and it helps the evaluating group learn the research process. While there can be significant value, such peer evaluations come at a cost of time and effort for students and faculty, and it can be difficult to coordinate across diverse university schedules.

Some schools restricted enrollment to graduate students; others permitted some undergraduates to participate. In mixed classes, more advanced (e.g., PhD) students were usually expected to carry out greater leadership roles than were undergraduates. Many of the instructors found, however, that student performance typically had more to do with student capability and motivation than with degree level.

While most schools offered the INSuRE experience as a dedicated course, others enrolled students as independent study projects or as part of an existing capstone course.

The faculty found the biannual in-person meetings very useful, helping participating universities to improve the course by applying lessons learned. They also fostered stronger personal relationships necessary for effective collaboration.

Challenges. Challenges included dealing with
different time zones and university schedules (e.g., semester vs. quarter systems). Also, while useful, the conferencing software yielded video displays that were limited in comparison to the rich interaction possible through in-person meetings. It requires a significant involvement by the instructor to stay on top of all projects.

One semester is a short period of time to complete a research project, yet one year might be longer than many students are willing to invest.

At many of the universities, grant support was essential to enable a faculty member to be allowed to teach a small specialized research course counting toward his or her official teaching duties. Teaching the INSuRE class often meant not teaching some other course, which might have been a larger required class.

Some centralized support was essential, to organize the network, to maintain a repository of project work, and to manage the collaborative technologies. Financial resources are needed for this centralized support, for hardware and software, for the in-person meetings, for support by a teaching assistant if the class is large, and for instructor time.

The INSuRE course enabled government organizations to stimulate research on projects that they lacked time to pursue.

Aspects of the INSuRE model can be applied to other settings. Inspired in part by the INSuRE Project, UMBC is pioneering a new initiative in which UMBC extends SFS awards to students at nearby Montgomery College and Prince George’s Community College, who will complete their degrees at UMBC. While in community college, the scholars will work collaboratively to help solve IT security problems for their county government.

Securing a sustainable funding model is a challenge. One option is a subscription model in which companies and organizations contribute in return for access to students and their work on problems. Another model is a charity model in which sponsors (e.g., government) fund the program for the national good. INSuRE welcomes the opportunity to explore future relationships with government, industry, foundations, and other groups to continue the outstanding student work nurtured by INSuRE.

5 The Future

The INSuRE Project has inspired and educated students in cybersecurity, empowered them to think freely, and engaged them in research problems related to national security. It has also strengthened the CAE-R network and helped government organizations, including by motivating students to pursue government service. The course is being offered again in spring 2017. INSuRE’s continued success will depend on strong external support from government, industry and foundations, and internal support from universities.
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References

[1] Alabi, T. and J. Beckman and M. Dark and J. Springer. Toward a Data Spillage Prevention Process in Hadoop Using Data Provenance. In Proceedings of the 2015 Workshop on Changing Landscape in HPC Security (CLHS ’15), 2015.

[2] Alves, T. and R. Das and T. Morris. Virtualization of Industrial Control System Testbeds for Cybersecurity. In Second Annual Industrial Control System Security (ICSS) Workshop at the 2016 Annual Computer Security Applications Conference (ACSAC-2016), December 2016.

[3] K. J. Bieschke, R. M. Bishop, and V. L. Garcia. The Utility of the Research Self-Efficacy Scale. Journal of Career Assessment, 4(1):59–75, 1996.

[4] Chong, R. C. and M. Dark and R. Linger, R. and M. Bishop. The FIDO INSuRE (Information Security Research Education) Project: An Agile Research Experience. In Colloquium for Information Systems Security Education (CISSE), pages 1–7, 2015.

[5] Dark, M. Innovation in Graduate Cyber Education Project INSuRE. In 2014 National Initiative for Cybersecurity Education (NICE) Conference, 2014.

[6] Dark, M. and B. Curnett. Longitudinal Password Data Set Varying with Policy. Purdue University Research Repository, 2015. doi:10.4231/R72V2D12
[7] Dark, M. and L. Stuart. Innovation in Cybersecurity Research Traineeship in the INSuRE Project. In *Proceedings of the 7th Annual Southeastern Cyber Security Conference (SCSS)*, 2015. Huntsville, AL.

[8] Dark, M. and M. Bishop and R. Linger and L. Goldrich. Realism in Teaching Cybersecurity Research: The Agile Research Process. In *Information Security Education Across the Curriculum*, pages 3–14. Springer, 2015.

[9] Falk, C. A Model and Tool for Public Cloud Provider Risk Assessment. In *Proceedings of the 7th Annual Southeastern Cyber Security Summit (SCSS)*, 2015. Huntsville, AL.

[10] Nair, Sandeep and Sudip Mittal and Anupam Joshi. OBD SecureAlert: An Anomaly Detection System for Vehicles. In *IEEE Workshop on Smart Service Systems (SmartSys 2016)*, May 2016.

[11] S. Pan, T. Morris, and U. Adhikari. Developing a Hybrid Intrusion Detection System Using Data Mining for Power Systems. *IEEE Transactions on Smart Grid*, 6(6):3104–3113, Nov 2015.

[12] Raut, Amit and Pravav Sharma. Machine Learning and Malware Classification. Research, Innovation and Scholarship Expo (RISE), 2014. Poster, Boston.

[13] Shehab, Omar. Locality of Different Clock Hamiltonians for Unitary Evolution of Deutschs Algorithm. QuICS Workshop on Quantum Information and Computer Science, March 2014. Poster, University of Maryland, College Park.

[14] Michael Thompson, Marilyne Mendolla, Michael Muggler, and Moses Ike. Dynamic Application Rotation Environment for Moving Target Defense. *Resilience Week (RWS)*, September 2016.

[15] Tomlin, L. and M. Farnam and S. Pan. A Clustering Approach to Industrial Network Intrusion Detection. In *Proceedings of the 2016 Information Security Research and Education (INSuRE) Conference (INSuRECon-16)*, 2016. 

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