Teaching Secure Coding in Introductory Programming Classes

Siddharth Kaza
Blair Taylor
Towson University

http://www.towson.edu/securityinjections
Software Vulnerabilities

- Vulnerability – weakness in the software
- Estimated 1 to 7 defects per thousand lines of code
- For large system with millions of lines of code
  - => thousands of vulnerabilities
Big Three

- Buffer overflow
- Integer overflow
- Input validation

Three programming errors are responsible for 85% of vulnerabilities (SANS, 2006)
Software Security begins with Education

It is our job to teach secure coding
“I think the most critically important part of delivering secure systems is raising awareness through security education.”

Bill Gates, Microsoft
“The ability to write secure code should be as fundamental to a university computer science undergraduate as basic literacy.”

Matt Bishop, UC Davis
“The first and foremost strategy for reducing securing related coding flaws is to educate developers how to avoid creating vulnerable code.”

Robert C. Seacord, CERT
The current state of undergraduate security education…

**Too little, too late**

- Security tracks
- Security classes
- Reaches only a subset of students
- Courses occur late in curriculum
- After students have learned fundamental coding and design
Secure coding education in a perfect world …

Create a Security Mindset

Early and Often
Importance of Curricular Guidelines

- ACM/IEEE Computer Science 2013 Curriculum
  - In CS2013, the Information Assurance and Security (IAS) Knowledge Area (KA) is added to the body of knowledge

- NSA CAE Accreditation
  - The guidelines include mapping to new knowledge units (KUs)
Security Injections @Towson

- 26 Modules
- CS0, CS1, CS2
  - Buffer Overflow
  - Integer Error
  - Input Validation
- Computer Literacy
  - Phishing
  - Cryptography
  - Passwords
- Minimally invasive
- Security Checklists

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Assessment Design and Results

Four primary goals to assess
1. increasing the number of security-aware students
2. increasing students’ security awareness
3. improving students’ ability to apply security principles
4. increasing faculty security awareness

Instruments
- student and faculty surveys
- random sampling of assignments
- qualitative inputs from faculty
- controlled experiments in classrooms
- institutional quantitative data
Results – increase number of security-aware students

- 1,630 survey responses

**Gender**
- Male: 63%
- Female: 34%
- Unspecified: 3%

**Major**
- Computing: 46%
- Other: 32%
- Undecided: 8%

**Ethnicity**
- Caucasian: 59%
- URM: 35%
- Other: 6%

**Standing**
- Freshman: 31%
- Sophomore: 32%
- Junior: 28%
- Senior: 9%
Increase in Student Awareness – Assessment Design

- Two strategies need to be evaluated
  - Test security awareness at the end of foundational courses
  - Test security awareness due to repeated exposure

- All classes were administered a pre-survey and a post-survey
  - Each survey has
    - demographic information
    - general security awareness questions, and
    - questions targeted at the injections (secure coding for CS0,1,2)
Results – Student Awareness

- 1,026 survey responses, 40+ sections, 5 institutions
- Significant increase (p<0.01) in across core courses, CS0, and CS1
  - but not in CS2 (topic fatigue in CS2?)
- These results persisted across majors
Results – Student Awareness

- 384 survey responses, 4 institutions
- Significant increase in all modules in computer literacy
- These results persisted across gender and ethnicity
Increase in Student Ability to Apply - Split Sections

- Another quasi-experimental strategy was to have one integrated section and one control section under the same instructor.

- Pre-surveys and post-surveys were administered in both the sections.

- In addition, a more stringent ‘code-check’ was given at the end.
CS0 and CS1 students (four sections) using the modules are significantly better at Locating, Identifying, and Fixing vulnerabilities.
Outreach

- **Build-a-Lab Program**
  - Requests proposals to design lab modules on security topics
  - Three semesters
    - 1 – Design
    - 2 – Pilot & Revise
    - 3 – Assess

- **Security Ambassadors Program**
  - Identifies faculty from workshops who can acquire a leadership role in teaching with and disseminating the injection modules
    - Year 1 – hold a secure coding workshop in their home institution
    - Year 2 – hold a secure coding workshop/present paper at regional conference (with travel support)
  - Continue to work on cybersecurity education
Secure Programming Logic
Aimed at Seniors in High School
Background

- Need for software developers, need for IA professionals
- Colleges and universities
  - Low numbers of underrepresented populations (UP)
  - High drop out rates
    - underprepared and/or feel that they are underprepared
- High Schools
  - CS AP exam
    - 7% of all AP tests taken
    - 5% of public high schools offer CS AP (2,100 out of 42,000)
  - Lack of instructors
  - CS not required part of the curriculum
  - Situation is worse for Ups: females, African Americans, Hispanics, and urban and rural students
- Pipeline issue
- Meeting the workforce needs depends on reaching all UP
SPLASH goals:

- Increase the interest and participation of students from underrepresented populations in computing and IA majors.
- Prepare students from underrepresented populations for college majors such as computer science, information science, information assurance, and engineering.
- Create a sustainable model for introducing students from underrepresented populations to secure programming.
SPASH plan:

- **Develop a SPASH Learning Environment**
  - pilot-tested learning environment that supports anytime-anywhere learning
  - College credit
  - programming logic course
  - laboratory modules that introduces critical secure coding concepts.

- **Build a SPASH Community**
  - Includes educators and students
  - Tools
  - facilitate recruitment, mentoring, and outreach to ensure a sustainable and successful program

- **Create a SPASH Endurance Component**
  - build a sustainable model that will increase interest and preparedness among high school students lacking access to CS curricula.
SPLASH details

- Piloted Fall 2012, In progress Fall 2013
- Dr. Alfreda Dudley and Dr. Blair Taylor
- COSC175: General Computer Science
- Programming Logic Course
- 4 credits: 3 hours lecture/1 hour lab
- C++
- Software Security/Secure Coding
- [http://pages.towson.edu/btaylor/cosc175/syllabus/syll_175fall13.htm](http://pages.towson.edu/btaylor/cosc175/syllabus/syll_175fall13.htm)
Tools

- Videotaped classes
- Onsite support:
  - Coordinators at each high school
  - Responsibilities included: proctor tests and exams, help with scheduling, consultation, grading, logistical issues, and communication with the SPLASH professor
- A private social networking support group for the SPLASH students (Facebook)
- Near-peer mentors: Two female undergraduate computing students mentors from Towson University
- Email, Skype, Google Hangout, Telephone
Results

- The majority of SPLASH students earned a grade of “B-” or higher.
- Three of the SPLASH students finished in the top 10% of all the students.
- Two of the top three grades in the course were earned by the SPLASH students.
- Some of the most creative projects submitted were by the SPLASH girls.
- Four SPLASH students did not successfully complete the course.
Results

SPLASH Student Grade Distribution

<table>
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<th>Grade</th>
<th>A</th>
<th>A-</th>
<th>B</th>
<th>B-</th>
<th>D</th>
<th>FX</th>
<th>Dropped</th>
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<td>2</td>
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Challenges

- Videotaping and uploading lectures was technically and logistically difficult.
  - The hardware and software used for the pilot did not meet the needs of the project.

- Student workload.
  - For some girls, the course work and time commitment was more challenging than anticipated.

- Time consuming enrollment process.
  - The amount of time spent enrolling SPLASH students in the course was very involved and not anticipated.

- Providing additional student support.
  - In a few cases, students needed more help than their high school coordinator could provide.
    Students’ diverse schedules and geographic locations resulted in frequent one-on-one interventions by the instructor, which is impractical as the course and program scales.

- Particular challenges at the targeted urban female high school included
  - Communication: sometimes the students did not reply to the instructor or high school coordinator.
  - Help-Seeking Behavior: the students from the urban high schools did not seek assistance with any problems they had in the course.
  - Tenacity: Students stopped attending and dropped the course; not one female African-American student enrolled in this course passed and/or completed this course.
Results from Fall 2012 Semester

- **Projects**
- **Comments:**
  - I enjoyed this class much more than I initially thought I would and it really opened the doors to programming for me.
  - I feel much more comfortable about taking future computer science classes.
  - This experience has been very exciting for me. I loved being able to tell people I was taking a class at Towson as a junior! Many of my friends were interested in it so if you continue with this program I'm sure you'd have a lot of girls signing up!
  - I've never taken an online class before and you honestly made it so manageable! Having all of the information on the syllabus was a life-saver. I found the recordings very easy to understand and being able to pause and rewind was definitely a bonus.
  - I showed my parents the programs we did in lab each week; they were really interested in everything I learned how to do.
  - I found the class to be very bearable -- even on top of my regular high school work. It got stressful at times but I don't think any of the work was unreasonable. Your lessons were easy to comprehend and all of the tests and quizzes were straight-forward! I'm very grateful that my first college class was so well organized.
  - I came into the class expecting to learn about C++ as well as programming and left with a greater understanding of computers in general and a lot about memory and other software applications.
References – Security Injections


Other publications can be found at:
http://cis.l.towson.edu/~cssecinj/about/publications/
References - SPLASH