Introduction

Motivation: Web application security is critical to e-commerce, e-government and social networking but few texts/labs are suitable for undergraduate students.

Goal: The goal is to enhance the learning experience of undergraduate students in computing through standardized teaching modules and environment in secure web development.

Expected Outcomes

- SWEET (Secure WE dDevelopment Teaching), a set of portable modules to teach security practices in developing web application. SWEET can be downloaded from http://cisjs.pace.edu/~lichen/sweet/
- Successful integration of SWEET in various computing courses.

Method

Virtualization Platform

- SWEET utilizes virtualization technology to configure a computing environment, as in Figure 1, needed for the hands-on laboratory exercises.

Software Architecture

- All software needed for SWEET modules is pre-installed on a Linux virtual computer. The virtual computer includes the following applications: web and application servers: Tomcat, Apache, Java, Web proxy: Paros, Web Scarab, Web security testing: Web Goat, a vulnerable web application (badstore.com), Programming languages: Java, C#, C/C++, VB .NET, Perl, PHP, Ruby, Programming IDEs: Eclipse, NetBeans, Visual Studio, JDK

Outcomes

Audience

- Sophomore to junior undergraduate students who have only taken an introductory level of programming as well as some computer networking concepts.
- Information Systems/Information Technology Masters’ students who have only an introductory background in computing.

SWEET Modules

- Each module introduces web application security or related concepts along with hands-on laboratory exercises illustrating the concepts. The modules include:
  - Tutorials: Linux overview, HTTP and HTML/XML.
  - Teaching Modules: web application development overview; service-oriented architecture overview, introduction to cryptography, secure web communications, threat assessment, security testing, vulnerability management, and Java security.
  - Course Project Topics: automatic web server scanning; online banking security; web application auditing.
  - An example: Figure 2 illustrates an example of a laboratory exercise to conduct security testing on a virtualized web server through the Paros web proxy.

Course Integration

- Each SWEET module is an independent topic. The modules can either be adopted separately in various courses or together in one course.
- We integrated SWEET into three different courses at Pace University and two different courses at New York City College of Technology.

Data Collection

- We collected data to evaluate SWEET over the past three semesters and will continue to collect for course integration information.
- Data collected include student feedback, faculty feedback, course integration information, and student performance through test questions and term projects.

Findings and Impacts

Preliminary Findings

- The table below lists the course information and the student responses of a web based survey (5: strongly agree and 1: strongly disagree).
- The survey questions included positive statements in four categories: lecture materials (mean: 4.10), laboratory exercises (mean: 4.15), mapping between lecture and lab (mean: 4.08), and overall impact of these modules on their learning experience and career (mean: 4.00).

<table>
<thead>
<tr>
<th>Course name</th>
<th>Semester</th>
<th>Number of students</th>
<th>Number of student responses</th>
<th>Mean (Standard deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Web Application Security</td>
<td>Fall 2009</td>
<td>47</td>
<td>30</td>
<td>3.97 (0.95)</td>
</tr>
<tr>
<td>Computer Security Overview</td>
<td>Fall 2009</td>
<td>20</td>
<td>14</td>
<td>4.34 (0.53)</td>
</tr>
<tr>
<td>Internet and Network Security</td>
<td>Spring 2009</td>
<td>11</td>
<td>10</td>
<td>4.35 (0.32)</td>
</tr>
<tr>
<td>Web Application Security</td>
<td>Fall 2010</td>
<td>45</td>
<td>40</td>
<td>4.13 (0.75)</td>
</tr>
<tr>
<td>Computer Security Overview</td>
<td>Fall 2010</td>
<td>34</td>
<td>28</td>
<td>3.92 (0.93)</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>157</td>
<td>122</td>
<td>4.08 (0.81)</td>
</tr>
</tbody>
</table>

Impacts

- The survey results showed that the students invested a significant amount of time (1-3 hours/module on average) in completing their laboratory exercises, liked the modules, and were more interested than before in taking courses or pursuing a career in information assurance.
- Test questions and student projects provided evidence on the improvement of students’ abilities in solving web security problems.
- SWEET modules were disseminated through conference presentations and workshops. Other academic institutions are currently testing the modules and plan for course integration.

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