Development of Peer Instruction Questions for Cybersecurity Education

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Peer Instruction

• Introduced by Eric Mazur, a physicist at Harvard University
• Tested and used in several scientific disciplines including
  o Physics,
  o Biology, and
  o Computer science
• Results of using peer instruction are promising
  o Improving student learning
  o Halving failure rates
  o Increasing student retention in their respective major
Peer Instruction Methodology

• Pre-class preparation by students
  o Reading material
  o Quiz

• In Class, a topic is covered as
  o A question is asked to students
    • Conceptual
    • Multiple choice
  o Two to three minutes for reply
  o Group discussion of students
  o Students reply to the question again
  o Instructor may further discuss the answers

Iterative
Peer Instruction in CS

- 6% higher grades on final exams over traditional lecture style
- 61% reduction in failure rates
  - Theory of Computation, and Computer Architecture
- 31% improvement in student retention
- Instructors find peer instruction effective
- Real learning occurs during discussions among students
- Students recommend that more instructors should use peer instruction
Challenges for Developing Questions

- **Quiz vs. Peer Instruction Questions**
  - Should be conceptual
  - Should facilitate peer discussion

- **Plausible Incorrect Answers**
  - Creating incorrect answers for peer instruction questions that seem plausible
Question Development Methodology

- Concept Identification
- Concept Trigger
- Question Presentation
- Question Development
Concept Trigger

• Provoke a student’s thinking process
• Set the desired direction of peer discussion
• Examples: (Beatty et al. [1])
  o Deliberate ambiguity
  o Trolling for misconceptions
  o Omit necessary information
  o Identify a set or subset
  o Compare and contrast
  o Trap unjustified assumptions
Question Presentation

• Putting concept and concept trigger together
  o Better presentation
  o Easier understanding

• Examples:
  o Scenario
  o Example
  o Diagram
  o Definitional
  o Feature
Example Question # 1

An attacker deletes files on a system, denying access to system users. Which element of CIA triad is violated?

a) Confidentiality
b) Integrity
c) Availability
d) None/Other/More than one of the above
Deconstruction # 1

• Concept trigger
  o None of the above
  o Identify a set or subset
  o Multiple defensible answers

• Question Presentation
  o Example
Example Question # 2

Estimate the fraction of disk blocks affected by formatting a hard disk:

a) 100%

b) 65%

c) 20%

d) Less than 5%
Formatting Flash Drive

Original ➔ After FAT format ➔ After NTFS format ➔ After ext3 format
Deconstruction # 2

• Concept Trigger
  o Omit necessary information
  o Trap unjustified assumptions
  o Trolling for misconceptions

• Question Presentation
  o Feature
    • Understanding disk formatting to guess correct percentage
Example Question #3

After executing these instructions while single stepping inside a debugger on an 80486 processor, what is the value of the 16-bit word at location Loc_10129+5?

a) 168h,
b) 152h
c) 4D4Ch
d) Value is unknown
e) None of the above
Deconstruction # 3

• Concept Trigger
  o None of the above

• Question Presentation
  o Example
Example Question # 4

You obtain a leaked database of unsalted SHA-1 password hashes. What would be the most effective way to obtain as many passwords as possible in a short amount of time?

a) Brute force  
b) rainbow tables  
c) dictionary attack with a large wordlist  
d) passing the hash  
e) birthday attack
Deconstruction # 4

- **Concept Trigger**
  - Interpret representations
  - Strategize only

- **Question Presentation**
  - Scenario
Analysis of Questions

• 172 questions for two cybersecurity courses
  o Introduction to Computer Security (93 questions)
  o Network Penetration Testing (79 questions)

• Goal of Analysis is to identify concept triggers and presentation types in the questions
Presentation types

![Diagram showing presentation types]

- Introduction to Computer Security
- Network Penetration Testing
Presentation-types & Topics

Presentation Types of Questions

- Overview
- Cryptographic Tools
- User Authentication
- Access Control
- Malicious Software
- Denial of Service Attacks
- Intrusion Detection System
- Buffer Overflow
- Firewall
- Software Security

No. of PI Questions (%)
Concept Trigger - Example

<table>
<thead>
<tr>
<th>Concept Triggers</th>
<th>No. of PI Questions (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction to Computer Security</td>
<td>80</td>
</tr>
<tr>
<td>Network Penetration Testing</td>
<td>20</td>
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</tbody>
</table>

Question Presentation - "Example"
Concept Trigger - Scenario

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<tr>
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<td>30</td>
</tr>
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<td>Network Penetration Testing</td>
<td>70</td>
</tr>
</tbody>
</table>

Question Presentation - "Scenario"
Conclusion

• Question development methodology allows instructors to
  o systematically create questions, and
  o smoothly transition from lecture style format to peer instruction

• Analysis of question set
  o example and scenario based questions are often used
  o The use of concept triggers may vary depending on the course content

• Contents will be available at http://www.peerinstruction4cs.org/

• As part of future, evaluate efficacy of peer instruction questions in cybersecurity courses
Questions ??