A "DIVERGENT"-THEMED CTF AND URBAN RACE FOR INTRODUCING SECURITY AND CRYPTOGRAPHY

Motivation

Curriculum

CTF

Storyline

Security Jeopardy!

Urban race

Why?

Using the material
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Why?

Using the material
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Expanding the security pipeline

Introduce students to computer security early

Camps and classes
  - CyberDiscovery, CyberPatriot, CyberAcademy, GenCyber

Capture-the-Flag (CTF) security games
  - picoCTF, hs-CTF, abctf

This work

Combined camp and CTF for introducing security topics in an engaging way

Focus on intrinsic motivation
  - Scaffolded CTF game to cultivate confidence and competence
  - Urban Race to augment learning with physical activity
  - Embedded fictional storyline to blend real and virtual world

Goal: Create a positive first experience with computer security
Expanding the security pipeline

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Overview

Curriculum goals
- Data encoding and cryptography
- Security concepts and tools

Structure
- 5 modules and a movie ("The Imitation Game")
- No prior experience assumed

Modules

Module #1: Motivation
- Importance of cryptography and security in history

Module #2: Data encoding
- Information in the digital age
- Binary, hexadecimal, ASCII, barcodes, QR codes, steganography

Module #3: Simple ciphers
- Transposition ciphers
- Columnar transposition, Scytale
- Substitution ciphers
- Monoalphabetic substitution (Caesar, simple)
- Polyalphabetic substitution (Vigenere, Enigma)

Module #4: Modern ciphers
- Public-key cryptography
- Domination set problem

Module #5: Cryptographic protocols
- Man-in-the-Middle attacks

Lecture format

Alternating lecture and collaborative practice
- Each team given a puzzle made up of sub-puzzles
- Individual members solve a sub-puzzle
- Solutions combined
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Storyline

Security Jeopardy!

Urban race

Why?

Using the material
CTF

Format

- 24 scaffolded challenges
- Given in sets during the week based on daily module
- Designed to cultivate confidence and competence
- Simple, common gameplay mechanism
- Decode message to find the key that unlocks a file
- Focus on technical skills being developed

Example

116 104 101 32 107 101 121 32 102 111 114 104 32 105 115

```
the key for the seven th is
```

Example

```
the key for june
thirteenth is
```
Format

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Example

the key for the event

this is
Example

…the key for June is the thirteenth.
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CTF
Storyline
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Why?

Using the material
Storyline

**Idea**
- Embed CTF challenges into a familiar, contemporary story
  - Provide extra level of engagement
  - Challenges open up individual parts of story
  - "Divergent" series by Veronica Roth

**Why Divergent?**
- Familiar to this generation
  - Books > 30 million copies
- Relevant plot to overall CyberPDX GenCyber camp
  - Use and abuse of technology
  - Diversity theme
  - Female protagonist
  - Importance of people with diverse skills and expertise
  - Computer security subplot amenable to adaptation

**Plot**
- Story of 5 clans
  - Dauntless, Abnegation, Erudite, Candor, Amity
- "The Traitor" short story
- Divergent as told through the eyes of Four
- Four suspects plan to eliminate Abnegation
- Works to break into computer systems of Dauntless and Erudite leaders to thwart plan
- Uses shoulder surfing, backdoors, trojans, and rootkits

**CTF adaptation**
- Four has disappeared just before camp
- Tris contacts campers for help
  - Clues include a USB key with an electronic diary on it and some printouts of encoded messages
  - Printouts encode keys to unlock diary entries
  - From Four's control room security training
  - Training that is now being given to students
  - Tris asks campers to find out what Four was working on

**Challenges**
- Encoded messages are CTF challenges
  - Printouts containing scaffolded levels
  - Must decode each to reveal key
  - Key unlocks an individual diary entry
  - Difficulty steadily increases
Idea

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• Provide extra level of engagement
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Why?

Using the material
Security Jeopardy!

Revisiting curricular goals

- Introduce cryptography
  - Done via CTF challenges
- Introduce security concepts and tools
  - Attempt to inspire curiosity and appreciation for computer security
  - Best done in context in a memorable way
  - Use engagement in story and plot device of the diary
  - Four’s first-person account of penetration testing

Mechanics

- Diary set in preceding month
- Each entry describes a method Four employs
- Tools and techniques central to computer security
  - Jeopardy! mechanic
    - Actual tool or technique not disclosed directly
    - Puzzle within a puzzle
    - Students research an aspect of computer security to identify Four’s method

Example entry

- April 20
- While perusing a piece of malware, I came across a backdoor written in C. Below are some notes I took:

Story

Follow Four and figure out how he...
Revisiting curricular goals

Introduce cryptography
  • Done via CTF challenges

Introduce security concepts and tools
  • Attempt to inspire curiosity and appreciation for computer security
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Example entry

June 25

Before getting caught on Max's computer, I managed to get a packet trace revealing Max's network connections to, among other things, Erudite servers. Since the Erudite have likely blocked many incoming connections to their systems, it will be helpful to find out which services are available. Manually checking each potential network address and port would take me forever, but I've learned that there are many automated tools that can help. One such tool is called nmap. It is a network scanner that will automatically probe a network to see what servers and services are open. While that will be clearly helpful, what I really need is something to tell me what is open "and" vulnerable. For that, there is another tool that people in the past used. The scanner I found that does this was released in 1998 and is quite tenable (pun intended):

UNSESS
Story

Follow Four and figure out how he...

- Uses a surveillance camera to obtain Max’s password
- Installs a backdoor to maintain access to Max’s computer
- Discovers an intrusion detection system protecting the computer
- Exfiltrates data covertly from the system
- Covers his activity to avoid detection

- Breaks the encryption employed on Max’s files
- Attempts to monitor all network traffic
- Is caught via the use of a fake program
- Attempts to subvert Max’s hardened replacement computer
- Employs a social engineering attack that fails as a result of a password manager

- Attempts a session hijacking attack that fails due to script blocking and encryption
- Performs anonymous reconnaissance on Erudite systems
- Exploits vulnerabilities to move laterally within the Erudite network
- Uncovers an air-gapped system at the heart of the Erudite plan
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Why?

Using the material
Urban race

Live story
Capstone activity
CTF storyline leads to climax in the present
  • Pivot from scheduled lecture to live action
  • Students inserted into plot directly
  • 2 hour Urban Race finale

Story setup
Tris relays urgent message from Four
  • Trapped outside of Erudite control room
  • Protected by puzzles to ensure only Erudite get in
  • Requires advanced cryptography skills
  • Knowledge of the Erudite (PSU) campus
  • Must be solved quickly with under 10 incorrect attempts
  • Gives each team Four's Twitter handle

Race
Modeled after CitySolve, ChallengeNation, Amazing Race
  • Tris relays a set of cryptographic clues given to Four
  • Once decrypted, clues send teams throughout campus
  • Communication with "virtual" Four to relay answers

Four-bot
Four as a Twitter bot
  • Gives illusion of interacting with the actual character
  • Takes answers and updates storyline state
  • Each team given independent story instance
  • Allows each team to "save the city"
  • First place team quietly given extra challenge
    • Leads to a lock box and special prize
Live story

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You should ask for help. Only 6 incorrect guesses left. Key six?

That key was wrong as well. You've gone through half of your guesses. I think you might want to change strategies. Key six?

You did it! It's unlocked. I'm shutting it down. Thank you for all of your help!

I'm leaving you a little something as a thank you. I think you can figure out where to get it! goo.gl/N5Fd80

That's it. You're done. Go Home!

Thanks m8

thx m8 <3

xoxo lmao
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Why?

Using the material
Why?

Flow

Coined in 1990 by Mihaly Csikszentmihalyi
- Single-minded focus on a task that aligns a person's emotions and motivation with objective at hand
- Characterized by deep enjoyment, creativity, and a total involvement with life
- Powerful intrinsic motivator

Key in making engaging learning experiences
- Often brought out in CTF events and games


Designing for Flow

Employ known triggers for flow
- Within CTF
  - Clear goals
  - Balance of challenge and skill level
  - Immediate feedback
  - Rich environment
- Additionally in urban race
  - Risk
  - Common, shared goal
  - Constant group communication

Success?

2016 CyberPOX Urban Race Winners

(Available unicorn)
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Steven Kotler, "The Rise of Superman", 2014
Success?

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An elusive unicorn...
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Offerings
CyberDiscovery Portland State (7/2018)
Portland State New Beginners (9/2018, 7/2016)
Luna and Canal College (11/2018)
Lincoln High School (4/2016)
CyberPDX (7/2018)

For teachers
All course material available at:
- https://cyberd.oregoncf.org
For access to source code to customize CTF or Urban Race
- Contact wuchang@pdx.edu
Play the game
- Copies of CTF challenges
- Demo mini-urban race with prizes after session

CyberPDX student evaluation
64 18th grade students [32 female, 32 male]
1 = strongly disagree
5 = strongly agree
I am more comfortable learning about cybersecurity. 4.24
I learned a lot about cybersecurity. 4.53
I enjoyed learning about cybersecurity. 4.36
I enjoyed the projects and activities at this camp. 4.40
I would like to learn more about cybersecurity. 4.02

Specific feedback
Students
- I liked the crypto challenges a lot because it was really satisfying to figure out the hidden codes.
- Solving the crypto challenges I thought that it was extremely well put together and was equally challenging and fun. The problem-solving and creativity part of this thread is something that everyone on our team enjoyed and appreciated.
- The cryptography was a lot of fun to crack and solve.

Teachers
- Love the puzzle within a puzzle books and material.
- Students definitely got into this.
- The interconnectedness built into the progressive challenges was superbly handled and the students loved it and persevered.
- Well planned and implemented. My students were able to apply their knowledge and had fun.
Offerings

CyberDiscovery Portland State (7/2015)
Portland State New Beginnings (9/2015, 7/2016)
Lewis and Clark College (1/2016)
Lincoln High School (4/2016)
CyberPDX (7/2016)
CyberPDX student evaluation

54 10th grade students (32 female, 23 male)
   1=strongly disagree
   5=strongly agree

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• Example