UNDERSTANDING THE HOW AND THE WHY: EXPLORING SECURE DEVELOPMENT PRACTICES THROUGH A COURSE COMPETITION

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Secure development is difficult

Distribution of vulns by severity over the years 2001 to 2021.
Many solutions exist!

‣ Secure tools
‣ Secure training/education
‣ Better integration of security

How do we help companies prioritize solutions?
We need to understand why and how different types of vulnerabilities get introduced, found, and fixed?
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Prior work

- Analyzed code submitted to BIBIFI
Build it, Break it, Fix it (BIBIFI)

Secure programming competition:

- **Build-it**
  - Build to a secure spec with open choices
  - Earn points for performance and functionality

- **Break-it**
  - Other teams’ code made available
  - Submit exploits against other teams

- **Fix-it**
  - Update their code to fix submitted vulnerabilities

[Ruef et al., 2016]
Prior work

- Analyzed code submitted to BIBIFI
  - 94 projects
- Building in-depth taxonomy of vulnerabilities
- Uncovering characteristics of vulnerabilities
- Unable to uncover
Prior work

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- Building in-depth taxonomy of vulnerabilities
- Uncovering characteristics of vulnerabilities
- Unable to uncover how
Prior work

- Analyzed code submitted to BIBIFI
- Building in-depth taxonomy of vulnerabilities
- Uncovering characteristics of vulnerabilities
- Unable to uncover how and why
Research questions

- What type of vulnerabilities do developers introduce and why?
- What types of vulnerabilities are found during review and why?
- Why and how do developers fix different types of vulnerabilities?
Methods

- Used BIBIFI in 3 week long course
  - Spent approx. 1 week in each phase
- 14 teams composed of undergrads
  - Juniors/seniors
  - Participants had minimal security/development experience
- Participants were not expected to have prior security exp
  - Took core systems course
  - Had short lectures on security and threat modeling
Methods

‣ Collected fine-grained data
  ▶ Design documents (multiple times)
  ▶ Snapshots of code as they developed
  ▶ Submitted exploits and fixes
  ▶ Commit messages throughout build, break, fix
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- Analyzed data using:
  - Manual code review for vulnerabilities
  - Qualitative coding
IoT smart home

- Runs user scripts
- All data protected by RBAC
  - Customizable by special users and data owner
  - Other users receive permissions
Overview of vulnerabilities

No implementation

Failed to implement necessary AC requirement

Misunderstanding

Implemented security; misunderstood requirement

Mistake

Implemented security; made programming mistake
Research questions

‣ What type of vulnerabilities do developers introduce and why?
‣ What types of vulnerabilities are found during review and why?
‣ Why and how do developers fix different types of vulnerabilities?
Impact of design on security

- Teams with detailed initial designs tended to introduce fewer vulnerabilities
  - Specifically No Implementation and Mistakes
- Teams with detailed initial designs tended to stick with them
  - Even if the initial design had a vulnerability
  - Especially prevalent with Misunderstandings
Impact of timeline on security

- Teams with fewest vulnerabilities tended to work on security throughout
- Teams that waited to work on security ran out of time
  - Resulting in many vulnerabilities
Impact of timeline on security

- Days into build round
  - Fewest vulns overall
  - T1
  - Fourth most vulns overall
  - T11

- Functionality commits
- Security commits
Research questions

‣ What type of vulnerabilities do developers introduce and why?
‣ What types of vulnerabilities are found during review and why?
‣ Why and how do developers fix different types of vulnerabilities?
Different vulnerabilities are discovered differently

- No Implementations found when looking broadly for related problem
  - Found one access control vulnerability while attempting to exploit another
- Mistakes were found through broad testing
  - Emulating the use of a fuzzer
- Misunderstandings required targeted testing
  - Many left unexploited
Research questions

‣ What type of vulnerabilities do developers introduce and why?
‣ What types of vulnerabilities are found during review and why?
‣ Why and how do developers fix different types of vulnerabilities?
Different vulnerabilities are fixed differently

- Half of No Implementations left unfixed at end of study
  - Rearchitecting whole system
- Misunderstandings were rarely fixed until exploited
  - But were overwhelmingly fixed once exploited
Implications

‣ Vulnerabilities differ in more than content
  ‣ No “one size fits all” solution
‣ Importance of best practices
  ‣ Incremental development
  ‣ Detailed design
‣ Including security experts at beginning of development cycle

Questions:
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I am on the job market this year!