Section: PUBP

Web Application Penetration Testing Course For Developers

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Problem Statement:

There is a large difference in priorities and skillset between penetration testers and code developers, leading to a troubling amount of insecure web applications and difficulty communicating vulnerabilities to application teams. While developers are constantly told to follow secure coding practices, oftentimes even utilizing security focused development frameworks, they rarely prioritize secure coding practices. (Secure Code Warrior, 2022) Perry et al. (2023) prove that insecure code is going to become even more common as AI code assistants become more popular because developers are over confident in its ability to write secure code. This problem will continue to grow if developers do not start taking cyber security and secure coding practices more seriously. In one study, 68% of participants stated that they only did secure code training because of a compliance need or recent exploit. (Security Journey, 2024)

Personally, I believe that developers do not take more cyber security training programs largely because of the gap in cyber security courses. These courses and programs fall into two categories based on my experiences as a penetration tester responsible for teaching application teams how to test and remediate vulnerabilities. First, developer focused resources are too high level to be helpful. These courses may teach the basics of specific misconfigurations or exploits, but they do not provide many opportunities for developers to walk away with knowledge that can be applied to their current applications. In one study, developers stated that training is not hands on, and/or it is taught in a vacuum. (Secure Code Warrior, 2022)

The second category of resources are targeted towards penetration testers, meaning the course is extremely in depth, requires specialized tools, and a massive time investment from the audience. As an example, PortSwigger's Cross-Site Scripting section includes 30 labs with each solution video ranging from 50 seconds to over 20 minutes. If a developer wanted to learn the risks, remediation, and how to exploit XSS at a basic level, they would have to parse through multiple pages of documentation and choose between 50 second videos with zero context/explanations or 20+ minute videos explaining testing methodologies and edge cases per lab. Lastly, these walkthrough videos do not use tools that are available to developers in the average corporate environment. (PortSwigger, 2025)

Most developers are limited to tools focused on the development lifecycle due to the risks associated with scanning applications incorrectly. (Young, 2025) We can see evidence of this in the Fortra (2024) survey, stating that 24% of cyber security professionals don't use penetration testing tools and an additional 33% only use open source tools. This makes sense as cost was the second most important factor when considering penetration testing software. While this survey was aimed at cyber security professionals, we can assume that developers would have the same or lower buy-in to cyber security tools. An additional issue with utilizing new tools is the time commitment. Velez (2020) reports on the many struggles that junior developers face when attempting to install programming tools. This issue compounds the current time limitations that developers deal with in modern frameworks. Rajapakse et al. (2021) supports this point by proving that DevOps workflows do not allow for the time commitment of SAST and DAST tools.

From my own experience researching this topic, I often find the second type of courses do not cover a wide range of topics. Generally, these courses are aimed at teaching exploitation, but do not cover policy based findings or misconfigurations, such as response header infractions. Please see the figure below showing a summary of my own opinions and analysis after completing other courses that are publicly available. Please note that this is a high level view of these courses and is not intended to be an in-depth review of each course. The purpose is not to disparage other courses, but to instead point out gaps or audience/tool differences that I hope to fill with my solution.

Course Name	Length	Tools Utilized	Pros	Cons
DIY Web App Pentesting Guide	Medium Article	Kali, Recon-ng, whatweb, nmap, Nikto, SQLMap	Showed how to catch low hanging fruit with scanners	Most developers cannot openly scan their applications or install tools like nmap. Only checked a few items in the application.
OWASP Web Security Testing Guide	100+ Pages	30+ tools and scripts used throughout the site.	The most comprehensive penetration guide online.	Information overload for the average developer. Does not show application behavior outside of full compromise.
Web App Testing	11 Hours	Burp	Covers each vulnerability in great depth.	Does not cover a wide range of vulnerabilities. Did not explain risks and remediation outside of test cases.
Ethical Hacking 101	2.75 Hours	Burp, Zap.	Used multiple test applications to show the risks of each vulnerability	Did not explain application behavior in partial exploitation situations or remediation.
Penetration Testing Course for Beginners	5 Hours	Burp, SQLMap, Nikto	Showed real world testing for vulnerabilities.	Only showed one or two examples per vulnerability covered, leaving the assessors to their own devices for further payload development. Did not cover full scope of risks associated with each vulnerability.
PortSwigger	270+ Labs	Burp, SQLMap, python scripts.	Smaller scope than the OWASP training, but with hands on training and better explanations. The number one resource for web application penetration testers to learn beginner to advanced exploitation.	Targeted towards web application penetration testers, meaning the material gets very detailed and covers many edge cases.
How to Analyze Code for Vulnerabilities	1.3 Hours	IDE	Podcast format, allowing for digestable explanations and discussions.	Almost entirely high level powerpoint bullets without many additional resources for devs to review.
Secure Coding – Best Practices (also for non developers!)	57 Minutes	Provides tool examples, but not required.	Covers a healthy range of topics with short exploit examples and blanket mock code snippets. Provides further training resources at the end.	Lacks context and true examples of application code, resulting in infromation that is hard to convert to our current applications.
Web Application Penetration Testing Tutorial	4.5 Hours	Burp, Fiddler, nmap, NetSparker	Shows a wide range of misconfigurations and high priority security vulnerabilities. Even opens the video with what the coures lacks(SQLi and Session Hijacking). The closest course to what I am trying to acheive with this project.	Does not target dev teams, meaning the course does not encourage a checklist and frequent test of your own applications. Additionally, missing a handful of misconfigurations that are extremely common in modern web apps.
Programming Foundations: Secure Coding	2 Hours	None	Great high level overview of secure practices throughout the entire lifecycle of a project.	Requires monthly membership. Entirely explained using animated content, does not show a single code snippet or exploit example.
Developing Secure Software	1.5 Hours	None	High level overview of many concepts ranging from coding practices to security testing. Easily digestable powerpoint format.	Almost entirely powerpoint bullet points, no real information for an app team to action on without doing their own third party research on each topic.

Figure 1: Course Comparison (Steele, 2025)

I believe this pushes away most developers that were willing to commit a small amount of time to upskilling their cyber security knowledge. According to one study, 44% of respondents stated the reason for not taking secure coding courses is because they were not aware of a good course and another 44% blamed time constraints. (Robinson & Russo, 2024) It is important to note that the solution described below may not solve the issues covered in this 88% of respondents because time constraints and course quality may be subjective. Ultimately, I believe that this gap in training material is the reason we continue to see an increase in vulnerabilities every year, even though most developers receive annual penetration tests on their applications and secure coding training. (Tribbey & Winterfeld, 2023) If application teams were capable of testing their environments and implemented security checks on a regular basis, we would most likely see a decrease in the 31% of critical vulnerabilities and 52% of lower priority vulnerabilities that go unremediated. (Lamar, 2025)

Solution Statement: Updates from progress report 3 are blue in this section.

This project will teach developers to test their own applications for vulnerabilities via a training course dedicated to quickly learning penetration testing tactics for common vulnerabilities in order to increase the security of modern web applications.

Specifically, I plan on teaching developers how to test their applications from a similar set of material that penetration testers use to conduct assessments. Most web application penetration testers utilize a checklist with a set of vulnerabilities to test, payload lists, and an intercepting proxy tool to bypass client side controls. My goal is to use a similar framework that excludes complex attack types and unnecessary overhead. My target audience is developers who are looking for a way to reproduce findings or test new code for vulnerabilities before pushing to production. However, I will be providing third party links and suggestions on how to learn more as we go through the checklist for the audience members that would like to take penetration testing to the next level. For a complete explanation of my solution, please (**See Appendix D**) "My Solution" section.

Lastly, I would like to explain my methodology for evaluating the effectiveness of this solution. It is easy to express the need for this course when reviewing the widespread security flaws across the internet. As an example, Pacheco (2020) found that only 2% of the top 1000 visited sites have a properly implemented Content-Security-Policy (CSP). In a few minutes, we could teach developers how to build a strong CSP to prevent exploitation of cross-site scripting and framing attacks. However, measuring the full impact and objective results of this course would require a set of developers who plan to complete the whole course and a much larger time window to analyze actions taken based on the material. Most firms would not allow developers to share vulnerabilities with external parties due to reputational risk, causing some limitations in our ability to test the effectiveness of this course on true corporate applications. Since we do not have enough time in this class to both complete the penetration testing course and test its effectiveness from start to finish, I will ask developers with varying ranges of security knowledge to review the material and provide feedback. If they have time, I will encourage them to test the material on their own applications or test applications. Additionally, they can complete specific, non-malicious, passive checks on public applications. Participants will document any vulnerabilities found using the course material, allowing us to prove the effectiveness on our sample audience. This feedback will include how effective they think the course will be once completed, and their level of confidence checking these items in their own applications. Additionally, since part of this course is based on changing the behavior of application teams, I will be asking the individuals what action items they plan on implementing into their own teams based on the course. Application owners can provide feedback explaining the value this course adds compared to current solutions in their own environments, such as company required training and code review checklists. This will give us perspective from the full range between security professionals and developers with no security background. Hopefully, this will result in a clear picture of the potential impact the complete course will have on a true audience. The figure below shows multiple survey questions in a bulleted format. Please (**See Appendix B)** for the updated pre and post training surveys.

-Which videos did you watch?
-Did the videos teach you about new vulnerabilities?(Yes/No)
-Did the videos improve your understanding of risks and remediation guidance for the vulnerabilities shown?
-Did you use the methodologies shown in the videos to find vulnerabilities in an application? If not, skip down to the next section of questions.
-If Yes: How was your experience attempting to follow the videos? Please provide feedback on the pros and cons of the material, explanations, and format.
-If Yes: Were you able to identify any vulnerabilities or misconfigurations in the application you tested?(Yes/No) If so, what were they?
-On a scale of 1-10, how confident are you that you could test your enterprise application for the common web application vulnerabilities covered in the videos that you watched?
-Do you believe that an application team could reasonably follow this entire series and identify vulnerabilities in their environment related to the checklist items covered in the videos?(Yes/No)
-Would you recommend app teams implement this testing on a regular basis?(Yes/No) If so, how often should app teams conduct these tests?
-Would it be beneficial for entire dev teams to watch this series?(Yes/No) Why or why not? Please note that this question is focused on long term outcomes.

Figure 2: Evaluation Survey, abridged format (Steele, 2025)

Completed Tasks (Last 2 Week):

- Completed the checklist items and GitHub documentation for the session management, miscellaneous, and optional checklist items. Please visit the following repository to view all work papers: https://github.gatech.edu/zsteele3/ZS6727Summer2025
- Next, I continued to add notes and outlines for the video series to prepare content throughout the videos.
- Afterwards, I prepared, filmed, and edited the session management items, miscellaneous checks, introduction, outro, and multiple optional videos. This resulted in video training material covering 8 checklist items, not including the optional course videos. The new video content is over 110 minutes long. To see the current course video series with detailed video descriptions and timelines, visit: https://www.youtube.com/watch?v=oNDEU_uNtzI&list=PLqPCUirqsN_x_seY51DiivfV-CjgJDKUp
- Encouraged more people to complete the pre and post training surveys and continued to interview participants after completing the surveys. (**See Appendix B**)
- Cleaned up course content based on interview feedback.
- Added real-world examples using public write ups for each vulnerability in the long payload list GitHub page.

Tasks for the Next Project Report:

Over the next two weeks, I will continue reviewing feedback and compiling plans for how to make the course better based on the information gathered in the surveys and interviews. Additionally, I will work on the final presentation and final paper for the course. Lastly, I plan on speaking with web application managers to see how we could implement this course on a broader scale.

Questions I have or Issues I'm running into:

None.

Methodology Paragraph Summary:

During the first few weeks, I built the structure of all required documents and created the video order to ensure I have a pathway to follow with a clear understanding of the final outcome. Afterwards, I spent a few hours preparing and creating the documentation required for each video in order. For example, when it was time to film the SQL injection video, I built out the payload list, checklist, and found the exact labs and tools that will best demonstrate how to test for SQL injection. This methodology provides a clear path forward after every action item and makes it easy to see the work completed each week along with what is coming in the following weeks. It is important to note that some videos and deliverables may need to be completed out of order due to required resources or time to complete. For example, the introductory video cannot be completed before building out the course materials because that video will display the completed checklist and GitHub to give the viewer an idea of what we will be doing for the remainder of the course. I started sending out surveys to developers, penetration testers, and other technology professionals to see how they have utilized parts of the course. More information will be provided in the evaluation section.

Timeline:

Week #	Description of Task	Status
W1	Installed VM, required tools and test apps.	Completed
W1	Created checklist template and first section.	Completed
W1/W2	Created GitHub and payloads page outline. https://github.gatech.edu/zsteele3/ZS6727Summer2025	Completed
W2	Created the outline for the video series.	Completed
W2	Created YouTube channel and uploaded placeholder video.	Completed
W3/W4	Built out the response headers and cookies checklist and GitHub pages.	Completed
W3	Recorded video for continuous review, response headers, and cookie testing.	Completed
W4	Conducted research on secure coding practices and filmed Video 3 - Best coding practices/remediation.	Completed
W4/W5	Created course evaluation survey and excel sheet showing pros/cons of current solutions.	Completed
W5/W6	Complete GitHub pages and checklist for all payload based exploits covered in the checklist.	Completed
W5/W6	Film videos 7(XSS) through 12(Login pages).	Completed
W6	Reach out to developers for evaluation of material up to this point.	Completed
W6	Re-evaluate checklist items based on studies of most common vulnerabilities.	Completed
W7/W8	Completed videos 13(Session Management) to Video 16(Outro).	Completed

W8	Make changes to past material based on developer feedback.	In Progress
W8	Filmed multiple optional videos.	Completed
W7/W8	Interview survey respondents.	In Progress
W8	Add real world write ups for each vulnerability in the long payload list document.	Completed
W9/W10	Review the entire project for places that may need improvement to make the series more cohesive.	Not Started
W9/W10	Speak with team managers to get the course implemented in app teams work flow.	Not Started

Evaluation: Updates from progress report 3 are blue in this section.

The solution section of my final paper **(See Appendix D)** details the reasoning behind every checklist item and how they were chosen to ensure maximum coverage given the limited time a developer will spend testing. As a brief summary, the items in the checklist were picked based on the percentage of vulnerabilities identified in those categories based on recent research papers and the time it takes to test the items. For example, Cross-Site Scripting is one of the more time consuming findings, but it was chosen due to the severity of exploitation and commonality reported by a penetration testing firm. (Freeman, 2023) An example of a check that is less time consuming is reviewing the Content-Security-Policy (CSP) response header. This is further discussed in both the progress report solution section and final report solution section.

After proving the checklist items are common vulnerabilities and high priority risks, we then have to evaluate the effectiveness of the payloads utilized in the course. The payload lists came from years of professional experience using my own flowcharts and payload lists to manually penetration test over 150 applications. I was unable to find any research explaining the success rate of specific payloads. However, the checklist items, course content, and payload lists are only effective if the viewers test their applications using the methods shown in the videos. For this reason, we came up with the two survey system explained below.

I plan to evaluate the success and effectiveness of this course by surveying multiple developers, application owners, and penetration testers with varying levels of development and cyber security knowledge. First, the participants will fill out a pre-training survey that sets a baseline for their current skill set and understanding of web application penetration testing. Additionally, there are questions asking about their opinions on current penetration testing and secure coding courses. This survey will be sent out before any participants have seen the course content. **(See Appendix B)**

After completing the first survey, the participants will receive the second survey along with links to all course material. The purpose of this survey will be to gather feedback to decide on future additional content, issues with past content and confidence in the material. Additionally, we hope to understand the action items that they plan on taking in their own teams, and encourage hands-on practice with the course material to identify vulnerabilities within test environments. Most developers would need approval before testing their code for some of the vulnerabilities covered in the course, and most likely could not share the results with us. However, all developers are empowered to test the material on training applications or complete non-malicious passive checks on public facing applications. This allows us to document the vulnerabilities that our audience was able to gather after completing sections of the course, measuring the effectiveness of the payload lists and testing methodologies. Our sample audience includes many

participants that have never searched for web application vulnerabilities, proving that anyone can follow along with the material even if they do not have any prior pentesting or code development experience. Lastly, I will speak with all participants to extract any information that was not provided in the surveys. The results of the survey should display a clear improvement in the individuals' understanding of the vulnerabilities and ability to test their own applications based on the videos that they watched. (**See Appendix B**) for the full pre-training and post-training surveys.

This approach does have multiple limitations. First, it is very difficult to create an unbiased survey that fully encompasses the information that the researcher hopes to gain. Due to time constraints, the survey may not be perfectly unbiased and the questions may have room for improvement to better extract information from the participants to help achieve the goals mentioned previously. Next, participants do not have any incentive to complete the survey, leaving us with a low completion rate. However, it is important to note that the survey has only been in participants hands for a short period of time so this may change. Lastly, the participants may be biased because of their relationships with me. I was able to mitigate this by giving the survey to multiple people with instructions to pass the survey around to their entire teams. Since the other team members do not know who I am or the purpose of these surveys, hopefully we will see less bias results.

Currently, 25 individuals have completed the pre-training survey and 16 have completed the post-training survey. Almost 70% of respondents have 0 years of experience in penetration testing and a similar majority have less than 10 years of experience as a developer and penetration tester combined. These statistics show that I need to diversify my participants to get a more accurate picture of the average computer science professional. Without digging into the results completely, we are seeing overwhelmingly positive responses and real improvement in developers ability to discover vulnerabilities. (**See Appendix C**) The complete set of survey statistics and appendix will be included in the final report.

Please (**See Appendix D**) evaluation section for a more detailed write up.

Report Outline:

Please (**See Appendix D**) for the full report.

References:

Specific penetration testing payloads and remediation guidance will be linked throughout the GitHub repo and checklist resources section. The references below are all utilized in this document.

Secure code warrior survey finds 86% of developers do not view application security as a top priority. Secure Code Warrior. (Apr 05, 2022). https://www.securecodewarrior.com/press-releases/secure-code-warrior-survey-finds-86-of-developers-do-not-view-application-security-as-a-top-priority

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Robinson, C., & Russo, D. (2024, June). Secure Software Development Education 2024 Survey. https://www.linuxfoundation.org/hubfs/LF%20Research/Secure_Software_Development_Education_2024_Survey.pdf?hsLang=en

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Young, L. (2025, May 19). *Penetration testing risks: Understanding the potential dangers of vulnerability assessments*. VaultMatrix.com. https://www.vaultmatrix.com/penetration-testing-risks-understanding-the-potential-dangers-of-vulnerability-assessments/

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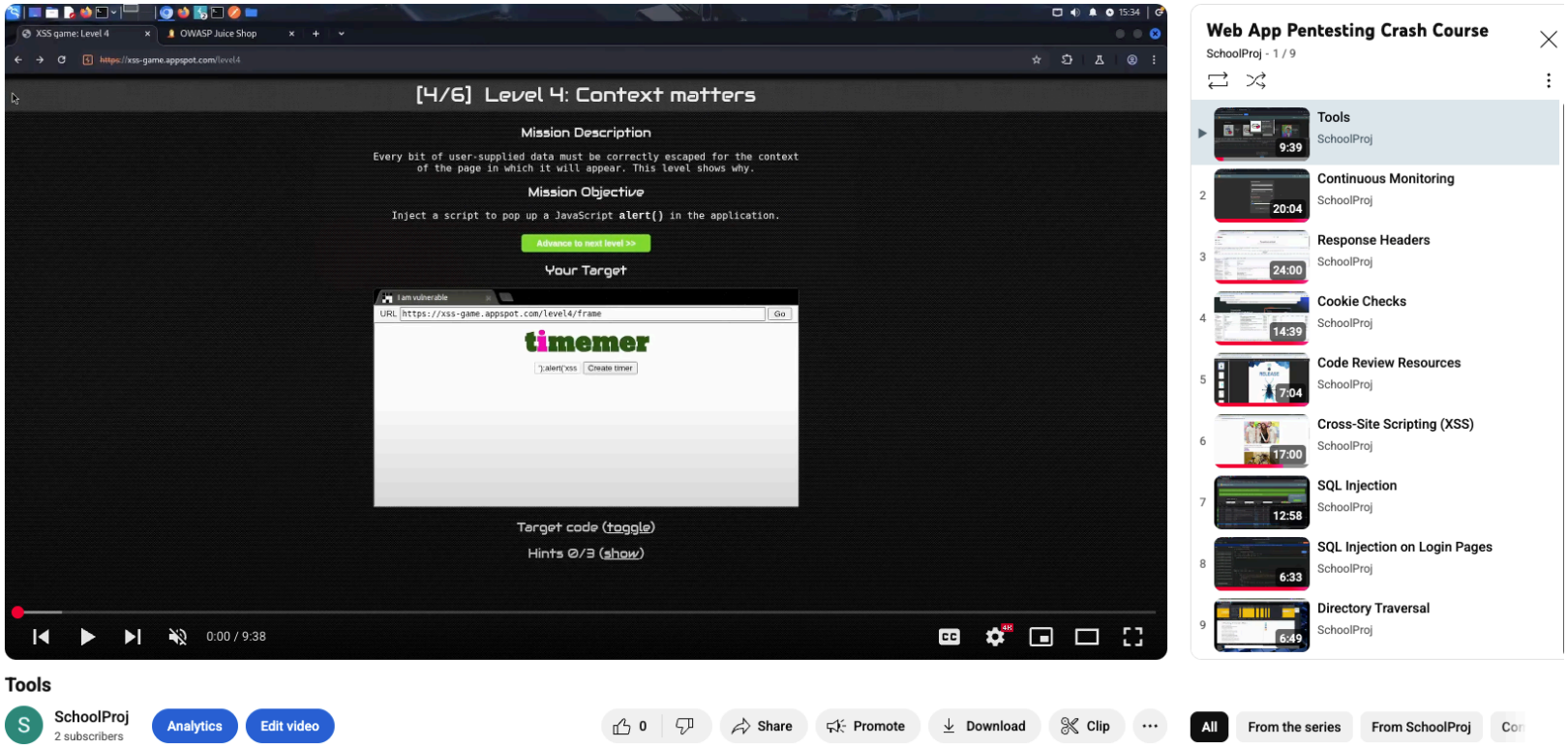
Rajapakse, R. N., Zahedi, M., & Babar, M. A. (2021, July 19). *An Empirical Analysis of Practitioners' Perspectives on Security Tool Integration into DevOps*. arxiv - Cornell University. https://arxiv.org/pdf/2107.02096

Freeman, C. (2023, November 14). *Understanding XSS: Why cross-site scripting still matters: Black duck blog*. Understanding XSS: Why Cross-Site Scripting Still Matters | Black Duck Blog. https://www.blackduck.com/blog/why-cross-site-scripting-still-matters.html

Appendix A: Web Application Penetration Testing Course for Developers (Steele, 2025)



Appendix A Figure 1: Course Playlist

	Pass	Rating	Description	Resources
				We encourage app teams to update the checklist and Payload lists with language specific links and company policies to ensure future developers follow the companies requirements.
Continuous Review				
Error Messages are Properly Handled		Low	Error messages should be short and generic. Do not show stack traces or informative messages to the user.	https://cheatsheetseries.owasp.org/cheatsheets/Error_Handling_Cheat_Sheet.html
Autocomplete Disabled on Sensitive Input Fields		Low	Disable autocomplete on fields such as email, password, and security questions by setting autocomplete="off"	https://www.w3schools.com/howto/howto_html_autocomplete_off.asp
Sensitive Information is Masked		Medium	Sensitive Information should be masked to mitigate shoulder surfing attacks.	https://labex.io/tutorials/javascript-mask-a-value-28489
Sensitive Information Not in URL		Medium	Do not send sensitive information in GET request parameters.	https://cwe.mitre.org/data/definitions/598.html
Unneccessary Methods are Disabled		Low	Do not allow unsafe methods such as Trace or Connect on any endpoint. Disable DELETE, POST, etc. if not needed on the endpoint.	https://cyberwhite.co.uk/http-verbs-and-their-security-risks/
HTTP Disabled		High	Enforce HTTPS for all connections.	https://blog.matrixpost.net/redirect-from-http-to-https-using-the-iis-url-rewrite-module/
Response Headers				
Content-Security-Policy		Medium	Does not include unsafe directives, wildcarded directives, or wildcards in subdomains.	https://developer.mozilla.org/en-US/docs/Web/HTTP/Reference/Headers/Content-Security-Policy https://csp-evaluator.withgoogle.com/
HSTS Response Header		Low	Use Strict-Transport-Security: max-age=63072000; includeSubDomains; preload. Only use preload if required.	https://developer.mozilla.org/en-US/docs/Web/HTTP/Reference/Headers/Strict-Transport-Security
Caching Headers		Low	Use Cache-Control: no-store. Less strict controls: Expires: 0, Cache-Control: no-cache	https://developer.mozilla.org/en-US/docs/Web/HTTP/Reference/Headers/Cache-Control https://www.rfc-editor.org/rfc/rfc9111.html
Information Leak Headers		Informational	Remove unneccessary response headers, such as: Server, X-Powered-By, X-AspNet-Version.	https://support.waters.com/KB_Inf/Other/WKB202501_How_to_disable_the_Server_HTTP_header_in_Microsoft_IIS
CORS Headers		Low	Do not set Access-Control-Allow-Origin to wildcard or allow reflected arbitrary origins/subdomains.	https://www.freecodecamp.org/news/exploiting-cors-guide-to-pentesting/#heading-exploitable-cors-cases
Cookies				
HttpOnly		Low	Prevents JavaScript from accessing the cookies, mitigating some XSS risks.	https://developer.mozilla.org/en-US/docs/Web/HTTP/Reference/Headers/Set-Cookie
Secure Flag		Low	Ensures cookies are only sent over HTTPS.	https://developer.mozilla.org/en-US/docs/Web/HTTP/Reference/Headers/Set-Cookie
SameSite Lax or Strict		Informational	SameSite cookies control cross-site request behavior to prevent CSRF. Lax: Cross-site requests will only send cookies in GET requests. Strict: Cookies will not send in any cross-site requests.	https://developer.mozilla.org/en-US/docs/Web/HTTP/Reference/Headers/Set-Cookie https://portswigger.net/web-security/csrf/bypassing-samesite-restrictions
Narrow Path		Informational	Sensitive/session cookies must have a restrictive path set to prevent other applications on the same server from using this cookie.	https://owasp.org/www-project-web-security-testing-guide/latest/4-Web_Application_Security_Testing/06-Session_Management_Testing/02-Testing_for_Cookies_Attributes
Narrow Domain		Informational	Sensitive/session cookies should have a narrow domain, set to a specific subdomain when applicable.	https://developer.mozilla.org/en-US/docs/Web/Security/Practical_implementation_guides/Cookies
Injections/Payloads Required				
Cross-Site Scripting(XSS)		Critical	The application should encode user input when reflected to the UI.	https://cheatsheetseries.owasp.org/cheatsheets/Cross_Site_Scripting_Prevention_Cheat_Sheet.html https://learn.microsoft.com/en-us/aspnet/core/security/cross-site-scripting?view=aspnetcore-9.0
SQL Injection		Critical	Use parameterized queries to prevent SQL injection via user input.	https://cheatsheetseries.owasp.org/cheatsheets/SQL_Injection_Prevention_Cheat_Sheet.html https://cheatsheetseries.owasp.org/cheatsheets/Query_Parameterization_Cheat_Sheet.html
SQL Injection on Login Page		Critical	Login pages must use parameterized queries.	https://unix.stackexchange.com/questions/391866/regex-for-password-restricting-special-characters
Directory Traversal		High	User Input must be validated and canonicalized before being used to retrieve files from the server.	https://portswigger.net/web-security/file-path-traversal
OS Command Injection		Critical	Do not place user input directly into system command executions.	https://developers.redhat.com/articles/2023/03/29/4-essentials-prevent-os-command-injection-attacks#4_ways_to_prevent_os_command_injection_attacks
Login Page				
Weak Passwords Not Allowed		Medium	Enforce strong password policies.	https://www.cisa.gov/secure-our-world/use-strong-passwords
User Enumeration Not Possible		Medium	Ensure the application does not reflect different messages for valid or invalid users.	https://owasp.org/www-project-web-security-testing-guide/latest/4-Web_Application_Security_Testing/03-Identity_Management_Testing/04-Testing_for_Account_Enumeration_and_Guessable_User_Account
Account Lockout Enabled		Medium	Lock user accounts after X number of failed login attempts to prevent brute-force attacks.	https://owasp.org/www-community/controls/Blocking_Brute_Force_Attacks
Multi-Factor Authentication in Use		Low	Require multi-factor authentication at login.	https://auth0.com/blog/different-ways-to-implement-multifactor/

Appendix A Figure 2: Course Checklist

Cross-Site Scripting (XSS):

https://portswigger.net/web-security/cross-site-scripting

Enter the following payloads into user input fields and see how they are reflected in the application. If user input is reflected back unencoded and unfiltered, especially in javascript, then XSS is likely.

Alert() can be replaced with print() if your application is filtering out alert().

```
<b>test</b>
<script>alert(1)</script>

<img src=1 onerror=alert(1)>

javascript:alert(document.cookie)

"onload="alert(1)

${alert(1)}

alert`1`

'-alert()-'
```

SQL Injection

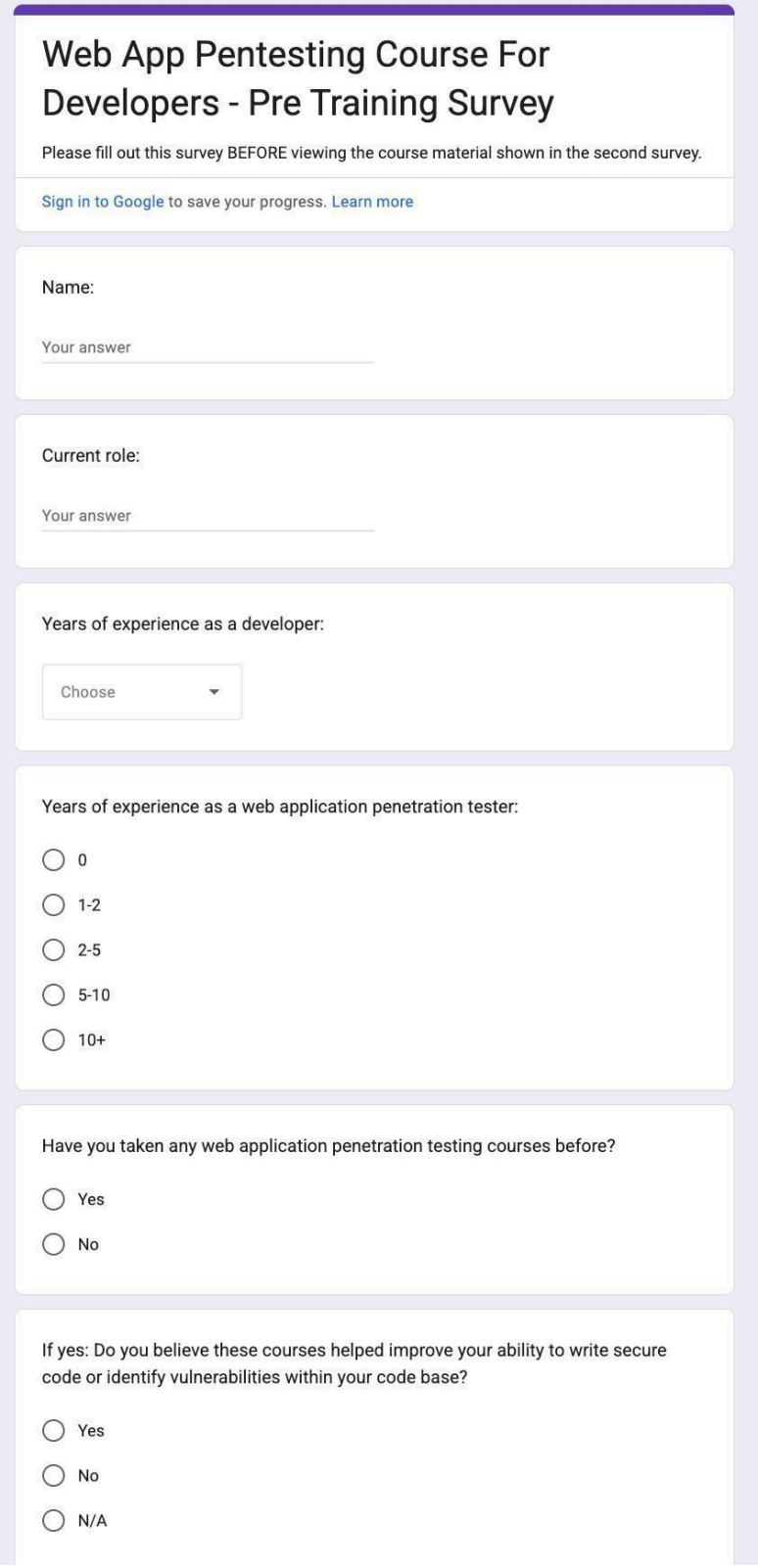
Review the following site for a cheat sheet showing specific requirements and payloads for the most common databases. This will help tailor the following payloads to your environment. For example, if your application uses MySQL, replace the `--` in the commands below with `#`.

https://portswigger.net/web-security/sql-injection/cheat-sheet

```
' followed by: ''

Oracle Concat: foo'||'bar
Microsoft Concat: foo'+'bar
PostgreSQL Concat: foo'||'bar
MySQL Concat: foo' 'bar

' OR 1=1 -- followed by: ' OR 1=2 --
' order by 1 -- followed by: ' order by 100 --
(SELECT 1) followed by: (SELECT 2)

'||pg_sleep(10)--
' OR sleep(5) OR '
'||pg_sleep(5)||'

SLEEP(1) /*' or SLEEP(1) or '" or SLEEP(1) or "*/
```

Appendix A Figure 3: Short Payload List XSS and SQLi Sections

Appendix B: Pre and Post Treatment Surveys



Web App Pentesting Course For Developers - Pre Training Survey

Please fill out this survey BEFORE viewing the course material shown in the second survey.

Sign in to Google to save your progress. Learn more

Name:

Your answer

Current role:

Your answer

Years of experience as a developer:

Choose

Years of experience as a web application penetration tester:

- 0
- 1-2
- 2-5
- 5-10
- 10+

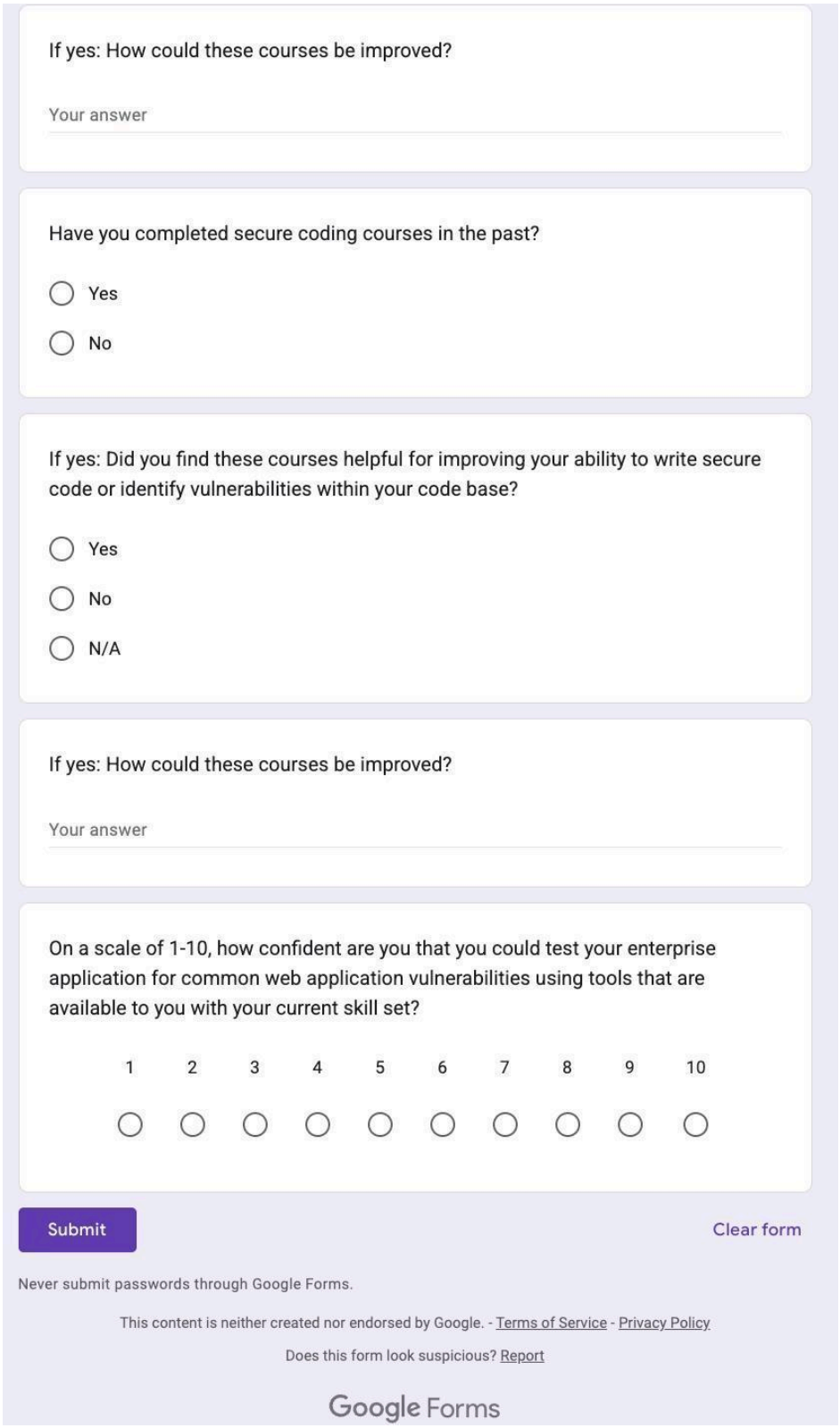
Have you taken any web application penetration testing courses before?

- Yes
- No

If yes: Do you believe these courses helped improve your ability to write secure code or identify vulnerabilities within your code base?

- Yes
- No
- N/A

Appendix B Figure 1: Pre-Training Survey



Appendix B Figure 2: Pre-Training Survey Cont.

Web App Pentesting Course For Developers - Post Training Survey

Please complete the pre training survey first. After, view the material below and fill out this survey.

Video Playlist: https://www.youtube.com/watch?v=oNDEU_uNtzI&list=PLqPCUirqsN_x_seY51DiivfV-CjgJDKUp

Checklist: https://github.com/SchoolProjZS2025/SteeleCapstone2025/blob/main/PracticumProjectChecklist.xlsx

Payload list: https://github.com/SchoolProjZS2025/SteeleCapstone2025/blob/main/ShortPayloadList.md

Sign in to Google to save your progress. Learn more

Name:

Your answer

Years of experience as a developer:

- ◯ 0
- ◯ 1-2
- ◯ 2-5
- ◯ 5-10
- ◯ 10+

Years of experience as a web application penetration tester:

- ◯ 0
- ◯ 1-2
- ◯ 2-5
- ◯ 5-10
- ◯ 10+

Please watch at least two videos in the series before answering the questions below. If possible, follow along using your own application, a test app, or public sites(non-malicious passive checks only).

Please note that the tools video is only showing tools that can be used for testing and the code analysis video does not show any vulnerability testing.

- ◯ Ack

Appendix B Figure 3: Post-Training Survey

Which videos did you watch?

- [ ] Tools
- [ ] Continuous Monitoring
- [ ] Response Headers
- [ ] Cookie Checks
- [ ] Code Review Resources
- [ ] Cross-Site Scripting
- [ ] SQL Injection
- [ ] SQL Injection on Login Pages
- [ ] Directory Traversal
- [ ] OS Command Injection
- [ ] Login Page Checks
- [ ] Session Management
- [ ] Clickjacking
- [ ] File Upload
- [ ] Horizontal Priv Esc
- [ ] Vertical Priv Esc

Did the videos teach you about new vulnerabilities?(Yes/No) Feel free to elaborate.

Your answer

Did the videos improve your understanding of risks and remediation guidance for the vulnerabilities shown?

- ◯ Yes
- ◯ No

Did you use the methodologies shown in the videos to find vulnerabilities in an application? If not, skip down to the next section of questions.

- ◯ Yes
- ◯ No

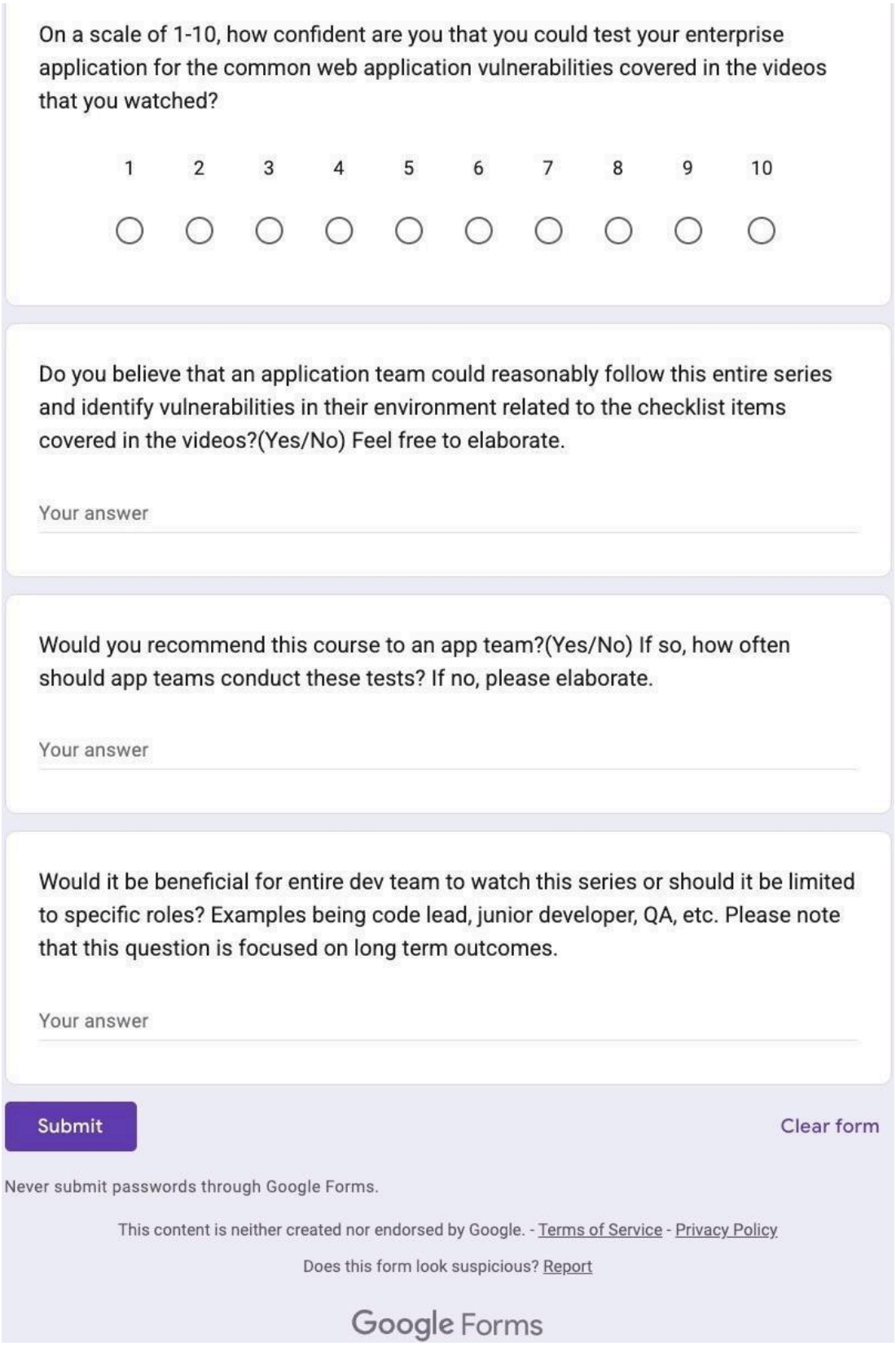
If Yes: How was your experience attempting to follow the videos? Please provide feedback on the pros and cons of the material, explanations, and format.

Your answer

If Yes: Were you able to identify any vulnerabilities or misconfigurations in the application you tested?(Yes/No) If so, what were they?

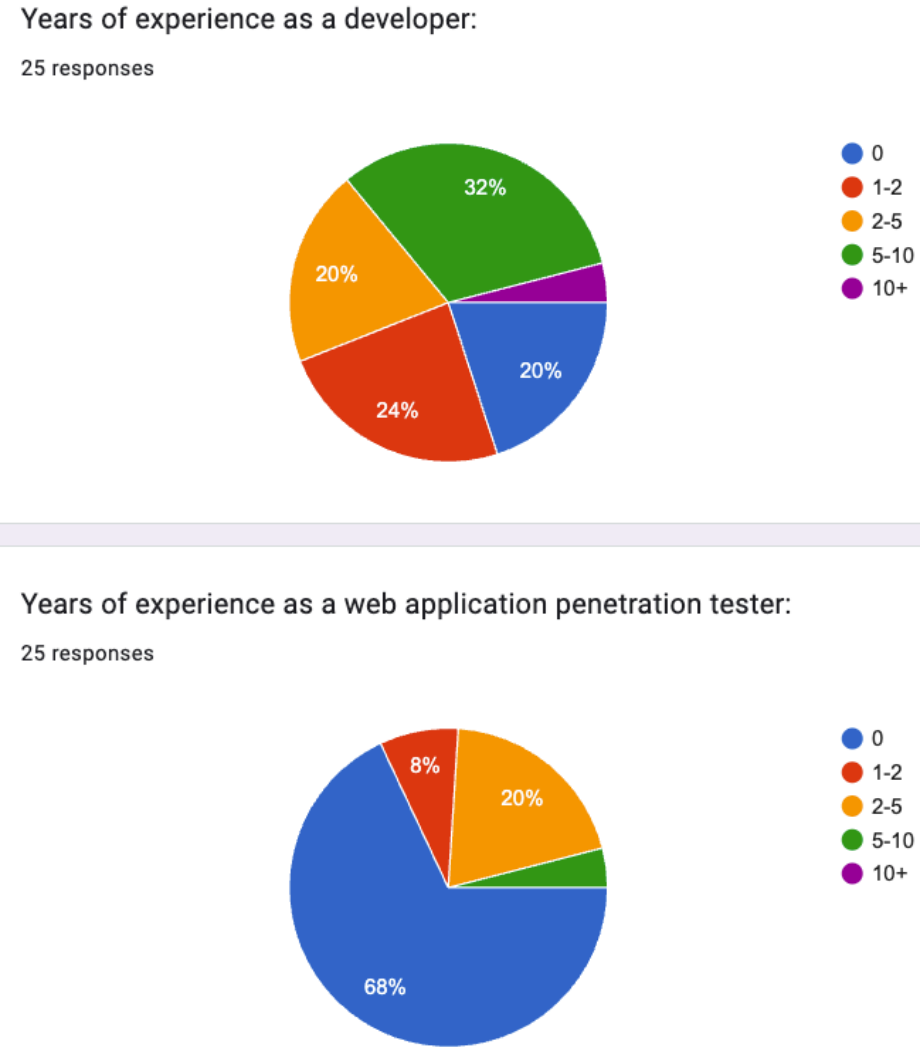
Your answer

Appendix B Figure 4: Post-Training Survey Cont.



Appendix B Figure 5: Post-Training Survey Cont.

Appendix C: Survey Results

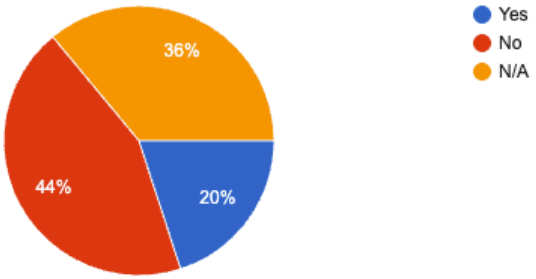


Appendix C Figure 1: Respondent Work Experience

If yes: Did you find these courses helpful for improving your ability to write secure code or identify vulnerabilities within your code base?

Copy char

25 responses



If yes: How could these courses be improved?

13 responses

Secure coding courses could be improved by: showing how to learn more after seeing their few examples.

PPT training does not give us any hard facts to use in our own code.

Actual labs and some type of grounding in real world examples. Conversation about outliers and an understanding beyond isolated examples is also helpful.

Appendix C Figure 2: Secure Coding Course Comments

Would it be beneficial for entire dev team to watch this series or should it be limited to specific roles? Examples being code lead, junior developer, QA, etc. Please note that this question is focused on long term outcomes.

16 responses

I think the entire team can benefit in their roles from the concepts covered in this course. Perspective helps everyone do their job better be it delivering code or testing it.

I believe entire development teams would benefit from this series.

The whole dev team at least once.

Could help the team understand why best practices are important to follow.

Code leads especially because they gate keep when code can be added to production.

everyone could benefit from this course

Appendix C Figure 3: Post Training Comments

Do you believe that an application team could reasonably follow this entire series and identify vulnerabilities in their environment related to the checklist items covered in the videos?(Yes/No) Feel free to elaborate.

16 responses

Yes
yes
Y
Yes.
Yes, it was laid out in an easy way to focus on testing and not so much going in to the details that you don't need to identify security risk from the developer perspective.

Would you recommend this course to an app team?(Yes/No) If so, how often should app teams conduct these tests? If no, please elaborate.

16 responses

Yes
Yes, and a I think best practice would be performing these tests at a minimum one a month (depending on the iteration speed of a team's application) but ideally some of this testing could be automated and could occur much more frequently
Yes, at least on a annual basis and on new code in a testing environment before pushing to production.

Appendix C Figure 4: Post Training Comments

Appendix D: Current Final Paper Progress

Introduction

The technology industry has rapidly grown over the last two decades, creating a massive digital attack surface for threat actors. Companies across the globe have attempted to combat these potential threats by providing their development teams with security training and introducing secure coding methodologies, such as the Secure Development Lifecycle (SDL). Additionally, cyber security departments have continued to introduce new roles and mitigating tools, but a large amount of these controls only serve as a bandaid to protect against bad coding practices and architectural design issues.

Developers and security professionals may feel as though their organizations are continuing to introduce redundant controls and training courses, but it is not fixing the overarching problem. Trend data shows that the number of CVEs found each year continues to rise. (Armstrong et al., 2024, p.12) To compound this issue, only 69% of critical vulnerabilities are remediated while an astonishing 48% of lower priority vulnerabilities receive patches. (Lamar, 2025) This tells us that application teams are continuing to see new vulnerabilities while struggling to remediate previously identified issues. Companies should be focused on reducing these vulnerabilities at the source, as data breaches are now averaging almost $5M per incident. (IBM, 2024) Even when companies do not experience a data breach, they could be paying hundreds of thousands of dollars for vulnerable code. (Security Journey, 2024)

I believe that giving developers hands-on experience with identifying web application vulnerabilities in their own applications will reduce the amount of insecure code that gets deployed to production and will help the app teams understand the importance of secure coding practices. The purpose of this project is to research the current penetration testing programs available online to identify potential reasons why developers do not take these courses more often. Then, create a solution that fills the gap in current training courses. Specifically, by creating a new penetration testing course designed for developers.

While this course is not going to be explicitly teaching secure coding practices, it will be teaching application teams how to identify common vulnerabilities in their code and the risks associated with these vulnerabilities. This will also assist with the team's understanding of the “why” component as they continue researching how to thwart attacks and write secure code. This solution is not a complete replacement for a true penetration test, but it will undoubtedly help uncover vulnerabilities for the 68% of companies that do not do annual or bi-annual penetration tests. (Palatty, 2025) Additionally, we will be providing language specific remediation advice in some cases, but the course will mostly focus on language agnostic remediation advice because studies show that 79% of developers preferred the idea of a language agnostic secure coding course. (Robinson & Russo, 2024, p.20)

Problem Statement

There is a large difference in priorities and skillset between penetration testers and code developers, leading to a troubling amount of insecure web applications and difficulty communicating vulnerabilities to application teams. While developers are constantly told to

follow secure coding practices, oftentimes even utilizing security focused development frameworks, they rarely prioritize secure coding practices. (Secure Code Warrior, 2022) Perry et al. (2023) prove that insecure code is going to become even more common as AI code assistants become more popular because developers are over confident in its ability to write secure code. This problem will continue to grow if developers do not start taking cyber security and secure coding practices more seriously. Security Journey (2024) found that 68% of participants stated that they only did secure code training because of a compliance need or recent exploit.

Personally, I believe that developers do not take more cyber security training programs largely because of the gap in cyber security courses. These courses and programs fall into two categories based on my experiences as a penetration tester responsible for teaching application teams how to test and remediate vulnerabilities. First, developer focused resources are too high level to be helpful. These courses may teach the basics of specific misconfigurations or exploits, but they do not provide many opportunities for developers to walk away with knowledge that can be applied to their current applications. In a Secure Code Warrior (2022) study, developers stated that training is not hands on, and/or it is taught in a vacuum.

The second category of resources are targeted towards penetration testers, meaning the course is extremely in depth, requires specialized tools, and a massive time investment from the audience. As an example, PortSwigger's Cross-Site Scripting section includes 30 labs with each solution video ranging from 50 seconds to over 20 minutes. If a developer wanted to learn the risks, remediation, and how to exploit XSS at a basic level, they would have to parse through multiple pages of documentation and choose between 50 second videos with zero context/explanations or 20+ minute videos explaining testing methodologies and edge cases per lab. Lastly, these walkthrough videos do not use tools that are available to developers in the average corporate environment. (PortSwigger, 2025)

Most developers are limited to tools focused on the development lifecycle due to the risks associated with scanning your application. (Young, 2025) We can see evidence of this in the Fortra (2024) survey, stating that 24% of cyber security professionals don't use penetration testing tools and an additional 33% only use open source tools. This makes sense as cost was the second most important factor when considering penetration testing software. While this survey was aimed at cyber security professionals, we can assume that developers would have the same or lower buy-in to cyber security tools. An additional issue with utilizing new tools is the time commitment. Velez (2020) reports on the many struggles that junior developers face when attempting to install programming tools. This issue compounds the current time limitations that developers deal with in modern frameworks. Rajapakse et al. (2021) supports this point by proving that DevOps workflows do not allow for the time commitment of SAST and DAST tools. From my own experience researching this topic, I often find the second type of courses do not cover a wide range of topics. Generally, these courses are aimed at teaching exploitation, but do not cover policy based findings or misconfigurations, such as response header infractions. Please (**See Appendix A**) showing a summary of my own opinions and analysis after completing other courses that are publicly available. Please note that this is a high level view of

these courses and is not intended to be an in-depth review of each course. The purpose is not to disparage other courses, but to instead point out gaps or audience/tool differences that I hope to fill with my solution.

I believe this pushes away most developers that were willing to commit a small amount of time to upskilling their cyber security knowledge. According to one study, 44% of respondents stated the reason for not taking secure coding courses is because they were not aware of a good course and another 44% blamed time constraints. (Robinson & Russo, 2024) It is important to note that the solution described below may not solve the issues covered in this 88% of respondents because time constraints and course quality may be subjective. Ultimately, I believe that this gap in training material is the reason we continue to see an increase in vulnerabilities every year, even though most developers receive annual penetration tests on their applications and secure coding training. (Tribbey & Winterfeld, 2023) If application teams were capable of testing their environments and implemented security checks on a regular basis, we would most likely see a decrease in the 31% of critical vulnerabilities and 52% of lower priority vulnerabilities that go unremediated. (Lamar, 2025)

My Solution

This project will teach developers to test their own applications for vulnerabilities via a training course dedicated to quickly learning penetration testing tactics for common vulnerabilities in order to increase the security of modern web applications. Achieving this goal requires creating a penetration testing course that fills the gap between in-depth hacking courses and high level overviews of web application vulnerabilities. Unlike most available resources, we will target an audience of developers who are looking to give their application a light penetration test and configuration sanity check. The goal of this solution is not to make developers top level penetration testers or experts in secure coding practices. The goal is to create a course that developers will actually utilize to reduce vulnerabilities within their own applications. However, this course will also provide third party resources in the event that the viewer wants to dive further into specific topics.

Specifically, this project includes a checklist with the most common attack types and misconfigurations, payloads for the injection attacks, and a video series showing developers how to utilize the material in their own environments with multiple different tool alternatives. The course material works together to provide the developers with enough information to quickly jump to different vulnerability types, then learn each testing methodology as needed. Additionally, we provide a page dedicated to resources for secure coding practices with the goal of giving the application teams a starting point for building out their own requirements based on the context and language of their application. The figure below shows the regex filtering portion of this page. As shown, we point the developers in the right direction, but expect them to provide their development teams with guidance that better fits their needs and company policies. As previously stated, this course was not made to teach secure coding practices, but we included this segment because it is important that an application team fixes their vulnerabilities at the root of the problem. Additionally, this material can benefit the application teams even if they do not continue into the penetration testing segment. Ideally, the code leads would agree on the

guidance in this section and require all developers familiarize themselves with the requirements. (**See Appendix B**) for more course content.

Regex Filtering

If you would like to see true malicious payloads, visit the following link. This may help determine what characters should be allowed in your specific context.
https://github.com/swisskyrepo/PayloadsAllTheThings

The following regex filters may cause a denial of service.
Source: https://pentesterlab.com/badges/codereview

```
/^dev-(\w+)+\d+\.website\.com$/
(a+)+
([a-zA-Z]+)*
(a|aa)+
(a|a?)+
(.*a){x} for x \\> 10
```

Allowed regex:

```
^[a-zA-Z0-9 ]*$
```

Figure 1: Regex Filtering Section of Secure Coding Practices Page

To make this course as effective as possible, we needed to identify the best set of vulnerabilities to cover in a reasonable amount of time. The material for our course was selected by evaluating a combination of time to conduct the test, difficulty of testing, impact, and how common the vulnerability is found in modern applications. It would not be a great use of the developer's time to learn a difficult attack type that is rarely found in applications, especially if this vulnerability does not carry severe risks. The items covered in this course fall into a few different categories, creating a checklist that has great coverage and, in some cases, allows the developer to learn one testing technique that can be applied across multiple items.

First, the checklist was populated with vulnerabilities and misconfigurations that are easy to find, requiring a small amount of time to test, regardless of likelihood and impact. This includes reviewing cookie attributes, response headers, and looking for incorrect application behavior throughout the testing window. This was the first set of test cases to enter our scope because these simple checks can heavily reduce the impact of high priority findings. As an example, a Content-Security Policy (CSP) can be quickly reviewed manually, or using online tools, to determine if the CSP is complete and safe. This powerful response header is responsible for preventing cross-site scripting (XSS), clickjacking, and other framing attacks. However, according to Pacheco (2020), it is only implemented correctly on 2% of the top 1000 most visited sites. Reviewing this checklist item will take far less time than attempting cross-site scripting across the application, and it can heavily reduce the risk of XSS in some cases. The

checklist also includes lower impact findings, such as information leak response headers because the CSP and information leak response headers can be checked at the same time.

	Pass	Rating	Description	Resources
				We encourage to ensure futur
Continuous Review				
Error Messages are Properly Handled		Low	Error messages should be short and generic. Do not show stack traces or informative messages to the user.	https://cheats
Autocomplete Disabled on Sensitive Input Fields		Low	Disable autocomplete on fields such as email, password, and security questions by setting autocomplete="off"	https://www.v
Sensitive Information is Masked		Medium	Sensitive Information should be masked to mitigate shoulder surfing attacks.	https://labex.i
Sensitive Information Not in URL		Medium	Do not send sensitive information in GET request parameters.	https://cwe.m
Unneccessary Methods are Disabled		Low	Do not allow unsafe methods such as Trace or Connect on any endpoint. Disable DELETE, POST, etc. if not needed on the endpoint.	https://cyberv
HTTP Disabled		High	Enforce HTTPS for all connections.	https://blog.m
Response Headers				
Content-Security-Policy		Medium	Does not include unsafe directives, wildcarded directives, or wildcards in subdomains.	https://develc https://csp-ev
HSTS Response Header		Low	Use Strict-Transport-Security: max-age=63072000; includeSubDomains; preload. Only use preload if required.	https://develc
Caching Headers		Low	Use Cache-Control: no-store. Less strict controls: Expires: 0, Cache-Control: no-cache	https://develc https://www.r
Information Leak Headers		Informational	Remove unneccessary response headers, such as: Server, X-Powered-By, X-AspNet-Version.	https://suppo crosoft_IIS
CORS Headers		Low	Do not set Access-Control-Allow-Origin to wildcard or allow reflected arbitrary origins/subdomains.	https://www.fi
Cookies				
HttpOnly		Low	Prevents JavaScript from accessing the cookies, mitigating some XSS risks.	https://develc
Secure Flag		Low	Ensures cookies are only sent over HTTPS.	https://develc
SameSite Lax or Strict		Informational	SameSite cookies control cross-site request behavior to prevent CSRF. Lax: Cross-site requests will only send cookies in GET requests. Strict: Cookies will not send in any cross-site requests.	https://develc https://portsw
Narrow Path		Informational	Sensitive/session cookies must have a restrictive path set to prevent other applications on the same server from using this cookie.	https://owasp Session_Mar
Narrow Domain		Informational	Sensitive/session cookies should have a narrow domain, set to a specific subdomain when applicable.	https://develc

Figure 2: Quick to Verify Section of The Checklist

After implementing checks for the previously mentioned items, our next step was to include vulnerabilities that require payloads inserted by an attacker. These vulnerabilities are largely based on common technology stacks and functionality within modern applications. As an example, relational database models made up 4 of the top 5 database models in May 2025. (DB-Engines, 2025) Since database injections are time consuming and difficult to fully exploit, we chose to exclude noSQL injection attacks, allowing us to focus on SQL injections. The other most common finding in this section of the checklist is XSS, making up 19% of Synopsys's high risk vulnerabilities from 2022 assessments. (Freeman, 2023)

Finally, the checklist was populated with common vulnerabilities and misconfigurations that do not require malicious payloads. The goal was to test any items that were not covered in the previous two sections. We grouped checklist items together based on location in the application or attack vector commonalities. As an example, when reviewing the login page, we wanted to cover Multi-Factor authentication (MFA) as only 34% of medium sized firms have implemented MFA. (Worthington & Ozsahan, 2025) MFA implementation may be difficult depending on the architecture of the application, but it is a simple check that could prevent attackers from completely compromising a user's account. Another test case covered in this section is account lockout after numerous bad attempts. Developers can quickly test their applications account lockout controls without any tools. According to Longstreet (2024), 35% of identity-related incidents were related to brute force attacks. While account lockout is not a 100% solution to this issue, it will heavily reduce the likelihood of an attacker brute forcing a user's credentials.

Using a similar testing methodology, we also check for user enumeration, a vulnerability found in over 93% of applications in one survey. (Maceiras et al., 2024) A combination of these 3 tests can severely reduce the likelihood of account takeover.

After establishing a set of vulnerabilities and misconfigurations to test, it was critical to build out the course in a way that would meet our goal of filling the gap between current solutions. To do this, we had to prioritize speed and conversational teaching over complete coverage and strict formatting. As an example, when covering response headers, it made more sense to explain testing methodology for all response headers up front since they would be tested the same way. Next, each item was tested individually by explaining risk, showing real examples, then providing remediation guidance. For comparison, Portswigger Academy (2025) and HackTheBox (HTB Academy, n.d.) both choose to teach response header misconfigurations and remediation during the modules related to their respective exploits. The purpose of their structure is to teach the entire context and multiple edge cases related to an exploitable vulnerability. For example, CSPs are covered after teaching the basics of XSS in the HackTheBox course to show more advanced situations once the basics have been covered. However, my structure is easier to follow without having the underlying context that a penetration tester would have. If an application team tells a developer to test and fix their CSP, the developer would have to know that the CSP is most likely covered in the XSS section of HackTheBox because a CSP is most commonly used to thwart XSS attacks. With my course, the developer could jump to the exact moment we teach CSPs by looking at the checklist. Additionally, this same video introduces the developer to the other response headers that could be reviewed at the same time. Lastly, instead of showing multiple examples of misconfigured CSP exploitation, we instead focus on speed by providing third party resources that are allowed on most company networks to assist with testing and remediating the issue if the app team wants to dig in further.

Throughout the video series, we encourage the viewer to create new test cases based on their applications tech stack and company's risk appetite. While the course largely focuses on predefined test cases and vulnerabilities, we do teach the viewer how to build their own payload lists and test cases to become self-sufficient. As an example, if the viewer decided to add an additional checklist item for a specific type of NoSQL injection, they could watch the optional video explaining how to accurately add and test new items. This would teach them where to look for payloads and testing guidance, then they could follow a standard methodology that ensures the viewer can catch low hanging fruit related to that new checklist item.

Evaluation

The solution section of this paper covers more details about the likelihood and risks associated with the vulnerabilities and misconfigurations covered in the course. I believe the combination of selected items would result in the highest reduction of risk and most coverage possible given the limited time frame of the practicum course and avoiding resource overload for the developers taking the course. After proving the checklist items are common vulnerabilities and high priority risks, we then have to evaluate the effectiveness of the payloads utilized in the course. The payload lists came from years of professional experience using my own flowcharts

and payload lists to manually penetration test over 150 applications. I was unable to find any research explaining the success rate of specific payloads. This is one of the biggest limitations with our ability to evaluate the payloads used throughout the course. The best way to measure the effectiveness of these payloads would be to test a large amount of applications using a set list of payloads. Then, determine which payloads have the highest success rate by tallying the payloads with the most coverage of different contexts and the payloads that caused the abnormal behavior leading to full compromise of the endpoint. This idea will be covered more in the limitations section.

With that said, this course is only useful if audience retention is high and viewers take action in their own environments. Since we did not have the time or resources to survey the long term implications of this course, we decided to survey professional developers, penetration testers, application owners, team managers, and other technology focused professionals. First, the participants completed a pre-training survey that sets a baseline for their current skillset and understanding of web application penetration testing by asking about their work history and confidence testing applications. Additionally, we asked for their opinions on current penetration testing and secure coding courses. This survey was sent out before any participants received the course content. (**See Appendix C**)

A common theme amongst developers with zero penetration testing experience was a high confidence in their ability to test applications for common vulnerabilities. In fact, multiple developers placed their confidence on a 1-10 scale higher than some of the penetration testers that were surveyed. Dunning & Kruger (1999) explain that people who are unskilled in a subject will often overestimate their performance and ability, while participants with stronger skills will likely recognize their limitations. We see evidence of this in the interviews discussed later.

After, the participants received the second survey along with links to all course material. The purpose of this survey was to gather feedback to decide on future additional content, issues with past content and confidence in the material. Additionally, we wanted to understand the action items that they plan on taking in their own teams, and encourage hands-on practice with the course material to identify vulnerabilities within test environments. Most developers would need approval before testing their code for some of the vulnerabilities covered in the course, and most likely could not share the results with us. However, all developers are empowered to test the material on training applications or complete non-malicious passive checks on public facing applications. This allowed us to document the vulnerabilities that our audience found after completing sections of the course, measuring the effectiveness of the payload lists and testing methodologies. Our sample audience includes many participants that have never searched for web application vulnerabilities, proving that anyone can follow along with the material even if they do not have any prior pentesting or code development experience. (**See Appendix C**) for the full post-training survey.

Lastly, I spoke with some participants to extract any information that was not provided in the survey. I interviewed developers with zero penetration testing experience that put their confidence rating above a 7. After speaking with these developers to see where this confidence

came from, most of them said the course was a wake up call. Even though the course is designed to be an introduction to the concepts with quick testing methods, multiple developers said they were not familiar with a few of the concepts covered in the videos. To summarize my interview with Carlos Lopez, he stated that he put a high confidence rating in the pre-training survey because he spent time fuzzing and user testing new code in a past role. However, he tested an application alongside the response header video and quickly realized that these headers were foreign to him. While he had seen the response headers plenty of times, he was unsure of the attributes they could use and what would deem safe/unsafe configurations. In his post-training survey results, he lowered his confidence in pentesting the checklist items he learned about in the videos because it showed him that he clearly had a lot to learn.
Another interesting interview came from the most outspoken penetration tester to take the survey. The figure below shows Christopher Lamp's pre-training survey answers. His main complaint with secure coding courses and penetration testing courses are the lack of context and comprehensive understanding of the topics. Essentially, his comments are completely going against the entire idea of my course. He does not want to see a crash course with little context, he wants comprehensive learning focused on the root of the issue itself.

How could penetration testing courses be improved?	Honestly - a lot of times they cover one thing or the other and miss some practicality and nuance. Additionally, they kind of go over things vaguely sometimes and don't actually get in to the core of how root issues are created. An example: Sometimes a course will cover dynamic pentesting and say 'look, this is vulnerable because the script tags execute arbitrary JS.' This doesn't actually explain XSS from a code-base perspective, and doesn't teach you what to look for or how to fix it from the developers persective (filtering input to match only things that are required for the field server-side, performing HTML encoding on things that are going to be reflected back to the UI, utilizing a CSP as a defense-in-depth measure, etc.)
How could secure coding courses be improved?	Sometimes they cover what the issues are at a high level and say 'Don't do this'. An example would be something like using a built-in query builder in .NET. This doesn't actually teach you the root of the issue or help you understand what exactly went wrong and how to prevent it for SQL Injection. If you always use a query builder you're probably safe, but there are times that you can't to write an optimized query - and then without knowing the actual foundation, you'll potentially write vulnerable code.

Figure 3: Christopher Lamp Pre-Training Survey

After reviewing the problem statement, my project idea, and reviewing multiple course videos, Christopher began to understand the use case behind this course. He followed the SQL injection videos to identify two SQL injection vulnerabilities on a test application called Altoro Mutual. Christopher stated that the videos were easy to follow with little required legwork, making it easy to focus on testing. When asked if he would recommend the course and who should be watching, he wrote " Yes, if more app teams found low hanging fruit or easy to find vulnerabilities, it could significantly reduce the amount of vulnerabilities found during pentests and help remediate issues before code is shipped out. Catch it earlier in the SDLC. They should do it every time they make a change that requires a CR in an enterprise environment, so any new variables added to an API, any changes to the UI, etc. that could introduce new risks."

Followed by “It should be used by anyone that is actually writing code and shipping out changes. This could be code leads, intermediate and junior devs and other people actually writing code.” This sentiment was carried amongst most of the people that completed the post-training survey.

Summarize survey results here.

This evaluation approach has multiple limitations. First, it is very difficult to create an unbiased survey that fully encompasses the information that the researcher hopes to gain. Due to time constraints, the survey may not be perfectly unbiased and the questions may have room for improvement to better extract information from the participants to help achieve the goals mentioned previously. Next, participants do not have any incentive to complete the survey, leaving us with a low completion rate and a few participants that did not take the survey seriously. From my estimations, the surveys were sent to over 75 people, leaving us with less than 50% completion rate. Lastly, the participants may be biased because of their relationships with me. I was able to mitigate this by giving the survey to multiple people with instructions to pass the survey around to their entire teams. Since the other team members do not know who I am or the purpose of these surveys, it may have helped reduce any bias in the results. Unfortunately, this led to a different issue. Since I did not ask participants for contact information, I had a difficult time tracking down a few participants that only provided their first names. This made interviewing those participants more time consuming.

Limitations

The biggest limitation with this course is the overall coverage of the material. Since the goal of this project was to fill the gap in training courses, we chose accessibility over coverage. The idea behind this project was that if an application team implemented our checklist and light testing, they would be able to identify and remediate vulnerabilities without the time sink required to complete a more comprehensive course, such as PortSwigger Academy (2025). We are very clear upfront that this course is not a comprehensive penetration test. To completely ensure adequate coverage, an application team must get a full web application penetration test from a professional pentester. On the other hand, if the company wanted their own in-house security team, they would have to utilize one of the previously mentioned resources because this course does not teach a comprehensive testing methodology for a wide range of situations or edge cases that rarely result in identifying a vulnerability. As an example, the XSS section of our course did not cover CSP bypass or unicode character substitution. First, we did not cover CSP bypass because potential XSS can be identified without getting full exploitation. Second, using unicode characters to bypass filters has an extremely low success rate. If we spent the time to cover similar situations across the entire list of checklist items, we would have doubled or tripled the overall length of the course.

Additionally, this course does not cover the full set of topics that would be covered by an in-depth course and it does not have the complete list of checklist items that would be found on a true penetration test. These additional checklist items were not included for two reasons. First, we did not want to scare developers away by making the course too long. Second, some test

cases require a full understanding of the application, vulnerability, and test case due to the “out of the box” thinking that comes with some situations. As an example, during a true penetration test, the tester is responsible for identifying potential business logic bypasses and attempting to exploit those situations using any relevant attacks. While these attacks are fairly common, it is very difficult to teach someone how to adequately test for these vulnerabilities because each situation has its own unique variables, making blanket advice difficult. Third, some of the vulnerabilities and test cases left off the checklist require uncommon technology stacks, or have a low success rate. In my opinion, that did not warrant the required time sink from the development team. One item in this category is web socket vulnerabilities. Murley et al. (2021) found that WebSockets are only used in 7.3% of the top 1000 sites. Their research reveals 74.4% of WebSockets do not verify the Origin header and 14.1% are accessible over unencrypted channels. This means out of 1000 websites, less than 55 are not validating the Origin header and less than 11 are accessible over unencrypted channels. Unfortunately, this research does not discuss the breakdown of WebSocket functionality, meaning we cannot estimate the number of applications in that set of 55 that would see true impact from these misconfigurations. However, these statistics do prove that WebSocket usage is too uncommon for us to include it in our testing. We do encourage application teams to read the resources provided in the code analysis GitHub page because it could lead to additional test cases, like WebSockets, that the application team may have been missing out on.

The final limitation with this course is the buy-in required from application teams to truly meet its full potential. In a perfect world, we would get application teams to carve out time for this course and track specific metrics. This would allow the dev team to fully test the entire checklist and it would help us track the material that works best. Over time, we could cut out the lowest success rate payloads in exchange for new payloads that may work more often. Lastly, we could recreate specific content based on long term feedback from the users. Unfortunately, as proven by multiple studies mentioned in the problem statement, application teams continue to cite time as the biggest constraint preventing them from security testing their applications.

Future Work

In the future, I will compile all survey feedback to revamp the entire course in a way that is more user friendly. For example, payload lists need to include more context and flow charts, allowing the reader to quickly understand what they are testing, why, and how to flow through the payloads in the correct order depending on the applications behavior. While the videos do follow this flow, we want users to have a similar experience using just the documentation. Next, I will continue to add lower priority checks to the checklist so that application teams can ensure better coverage of their applications. These items will be included based on feedback from survey participants and interviews with development teams. Additionally, future surveys will include better questions to assist with the previously mentioned future work. It will also aim to track metrics to show how the course is being used, allowing us to solve multiple problems mentioned in the limitations section, including better payload lists and more time efficient testing. Lastly, I plan to engage multiple application teams to discuss buy-in. I believe that the management team can heavily influence the priorities of their development team by shifting incentives and

time allotment. I am excited to see where this course goes as more users continue to complete the surveys and share their experiences.

Conclusion

I started this project with the goal of creating a web application penetration testing course for developers, in hopes that more development teams would test their applications for common vulnerabilities. Studies proved my original hypothesis true, developers did note a gap in current courses. Their issues were often due to courses providing little value or requiring a massive time investment from the viewer. I believe that my course fills the gap by showing viewers how to test their applications for vulnerabilities while providing useful remediation guidance and avoiding information overload. Most survey respondents provided positive and useful feedback on the course, but a wider audience will need to provide input to reduce any bias. I will continue to work on this project to accommodate the audience in any way possible because a better user experience means that more users will continue to use this course. One of the biggest limitations with this course is the lack of buy-in from management. Developers continue to cite short deadlines as the reason for not making security a priority. While my course does help reduce the time to learn and test an application, we would like to see more management teams allocate time for security testing to reduce the vulnerabilities seen in production.

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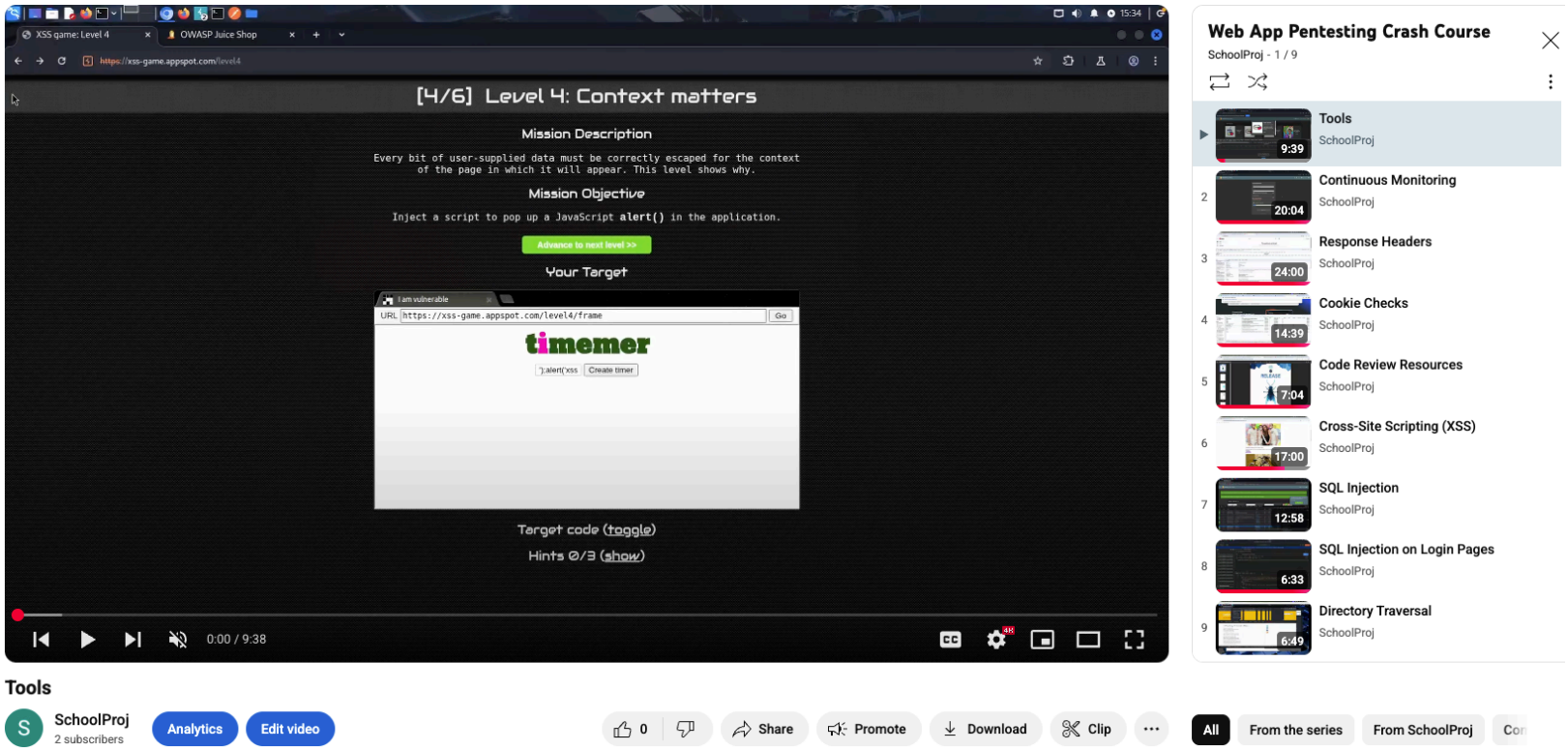
Appendix A: Course Comparison (Steele, 2025)

Course Name	Length	Tools Utilized	Pros	Cons
DIY Web App Pentesting Guide	Medium Article	Kali, Recon-ng, whatweb, nmap, Nikto, SQLMap	Showed how to catch low hanging fruit with scanners	Most developers cannot openly scan their applications or install tools like nmap. Only checked a few items in the application.
OWASP Web Security Testing Guide	100+ Pages	30+ tools and scripts used throughout the site.	The most comprehensive penetration guide online.	Information overload for the average developer. Does not show application behavior outside of full compromise.
Web App Testing	11 Hours	Burp	Covers each vulnerability in great depth.	Does not cover a wide range of vulnerabilities. Did not explain risks and remediation outside of test cases.
Ethical Hacking 101	2.75 Hours	Burp, Zap.	Used multiple test applications to show the risks of each vulnerability	Did not explain application behavior in partial exploitation situations or remediation.
Penetration Testing Course for Beginners	5 Hours	Burp, SQLMap, Nikto	Showed real world testing for vulnerabilities.	Only showed one or two examples per vulnerability covered, leaving the assessors to their own devices for further payload development. Did not cover full scope of risks associated with each vulnerability.
PortSwigger	270+ Labs	Burp, SQLMap, python scripts.	Smaller scope than the OWASP training, but with hands on training and better explanations. The number one resource for web application penetration testers to learn beginner to advanced exploitation.	Targeted towards web application penetration testers, meaning the material gets very detailed and covers many edge cases.
How to Analyze Code for Vulnerabilities	1.3 Hours	IDE	Podcast format, allowing for digestable explanations and discussions.	Almost entirely high level powerpoint bullets without many additional resources for devs to review.
Secure Coding – Best Practices (also for non developers!)	57 Minutes	Provides tool examples, but not required.	Covers a healthy range of topics with short exploit examples and blanket mock code snippets. Provides further training resources at the end.	Lacks context and true examples of application code, resulting in infromation that is hard to convert to our current applications.
Web Application Penetration Testing Tutorial	4.5 Hours	Burp, Fiddler, nmap, NetSparker	Shows a wide range of misconfigurations and high priority security vulnerabilities. Even opens the video with what the coures lacks(SQLi and Session Hijacking). The closest course to what I am trying to acheive with this project.	Does not target dev teams, meaning the course does not encourage a checklist and frequent test of your own applications. Additionally, missing a handful of misconfigurations that are extremely common in modern web apps.
Programming Foundations: Secure Coding	2 Hours	None	Great high level overview of secure practices throughout the entire lifecycle of a project.	Requires monthly membership. Entirely explained using animated content, does not show a single code snippet or exploit example.
Developing Secure Software	1.5 Hours	None	High level overview of many concepts ranging from coding practices to security testing. Easily digestable powerpoint format.	Almost entirely powerpoint bullet points, no real information for an app team to action on without doing their own third party research on each topic.

Appendix A Figure 1: Strengths and Weaknesses of Other Solutions

Appendix B: Web Application Penetration Testing Course for Developers (Steele, 2025)



Appendix B Figure 1: Course Playlist

	Pass	Rating	Description	Resources
				We encourage app t follow the companie
Continuous Review				
Error Messages are Properly Handled		Low	Error messages should be short and generic. Do not show stack traces or informative messages to the user.	https://cheatsheet
Autocomplete Disabled on Sensitive Input Fields		Low	Disable autocomplete on fields such as email, password, and security questions by setting autocomplete="off"	https://www.w3sch
Sensitive Information is Masked		Medium	Sensitive Information should be masked to mitigate shoulder surfing attacks.	https://labex.io/tut
Sensitive Information Not in URL		Medium	Do not send sensitive information in GET request parameters.	https://cwe.mitre.c
Unneccessary Methods are Disabled		Low	Do not allow unsafe methods such as Trace or Connect on any endpoint. Disable DELETE, POST, etc. if not needed on the endpoint.	https://cyberwhite.
HTTP Disabled		High	Enforce HTTPS for all connections.	https://blog.matrix
Response Headers				
Content-Security-Policy		Medium	Does not include unsafe directives, wildcarded directives, or wildcards in subdomains.	https://developer.r https://csp-evaluat
HSTS Response Header		Low	Use Strict-Transport-Security: max-age=63072000; includeSubDomains; preload. Only use preload if required.	https://developer.r
Caching Headers		Low	Use Cache-Control: no-store. Less strict controls: Expires: 0, Cache-Control: no-cache	https://developer.r https://www.rfc-ed
Information Leak Headers		Informational	Remove unneccessary response headers, such as: Server, X-Powered-By, X-AspNet-Version.	https://support.wa
CORS Headers		Low	Do not set Access-Control-Allow-Origin to wildcard or allow reflected arbitrary origins/subdomains.	https://www.freecc
Cookies				
HttpOnly		Low	Prevents JavaScript from accessing the cookies, mitigating some XSS risks.	https://developer.r
Secure Flag		Low	Ensures cookies are only sent over HTTPS.	https://developer.r
SameSite Lax or Strict		Informational	SameSite cookies control cross-site request behavior to prevent CSRF. Lax: Cross-site requests will only send cookies in GET requests. Strict: Cookies will not send in any cross-site requests.	https://developer.r https://portswigger
Narrow Path		Informational	Sensitive/session cookies must have a restrictive path set to prevent other applications on the same server from using this cookie.	https://owasp.org/ ting/02-Testing_fo
Narrow Domain		Informational	Sensitive/session cookies should have a narrow domain, set to a specific subdomain when applicable.	https://developer.r

Appendix B Figure 2: Course Checklist

Injections/Payloads Required				
Cross-Site Scripting(XSS)		Critical	The application should encode user input when reflected to the UI.	https://cheatsl https://learn.m
SQL Injection		Critical	Use parameterized queries to prevent SQL injection via user input.	https://cheatsl https://cheatsl
SQL Injection on Login Page		Critical	Login pages must use parameterized queries.	https://unix.sta
Directory Traversal		High	User Input must be validated and canonicalized before being used to retrieve files from the server.	https://portswi
OS Command Injection		Critical	Do not place user input directly into system command executions.	https://develop mand_injectio
Login Page				
Weak Passwords Not Allowed		Medium	Enforce strong password policies.	https://www.ci
User Enumeration Not Possible		Medium	Ensure the application does not reflect different messages for valid or invalid users.	https://owasp. ng/04-Testing_
Account Lockout Enabled		Medium	Lock user accounts after X number of failed login attempts to prevent brute-force attacks.	https://owasp.
Multi-Factor Authentication in Use		Low	Require multi-factor authentication at login.	https://auth0.c
Session Management				
Session Fixation Not Possible		Medium	Issue fresh session cookies after login.	https://owasp.
Session Dies After X Minutes		Low	Invalidate session after X number of minutes.	https://learn.m
Logout Button Works		Low	Invalidate session upon logout.	https://cheatsl
All Functions Require Authentication		Critical	Review all application pages/functions to ensure only valid users can access the page and execute functions.	https://learn.m
Miscellaneous				
Clickjacking		Low	Use X-Frame-Options: DENY or frame-ancestors CSP directive to prevent clickjacking attacks.	https://cheatsl https://portswi
File Upload		High	Only allow necessary file types. Virus scan each file and rename upon upload.	https://github. https://hacktri https://www.co
Horizontal Privilege Escalation-IDOR		Critical	Ensure users cannot access resources that belong to other users.	High level: htt In depth: https https://portswi
Vertical Privilege Escalation-MFLAC		Critical	Ensure unauthorized users cannot execute privileged functionality.	https://owasp. esting_for_Pri https://cheatsl

Appendix B Figure 3: Course Checklist Cont.

Cross-Site Scripting (XSS):

https://portswigger.net/web-security/cross-site-scripting

Enter the following payloads into user input fields and see how they are reflected in the application. If user input is reflected back unencoded and unfiltered, especially in javascript, then XSS is likely.

Alert() can be replaced with print() if your application is filtering out alert().

```
<b>test</b>
<script>alert(1)</script>

<img src=1 onerror=alert(1)>

javascript:alert(document.cookie)

"onload="alert(1)

${alert(1)}

alert`1`

'-alert()-'
```

SQL Injection

Review the following site for a cheat sheet showing specific requirements and payloads for the most common databases. This will help tailor the following payloads to your environment. For example, if your application uses MySQL, replace the `--` in the commands below with `#`.

https://portswigger.net/web-security/sql-injection/cheat-sheet

```
' followed by: ''

Oracle Concat: foo'||'bar
Microsoft Concat: foo'+'bar
PostgreSQL Concat: foo'||'bar
MySQL Concat: foo' 'bar

' OR 1=1 -- followed by: ' OR 1=2 --
' order by 1 -- followed by: ' order by 100 --
(SELECT 1) followed by: (SELECT 2)

'||pg_sleep(10)--
' OR sleep(5) OR '
'||pg_sleep(5)||'

SLEEP(1) /*' or SLEEP(1) or '" or SLEEP(1) or "*/
```

Appendix B Figure 4: Short Payload List XSS and SQLi Sections

Before testing the files below, try uploading calc.exe from a Windows computer. If it successfully uploads, start the remediation procedures. If calc.exe does not upload, or if you want to test further, attempt to upload the files below.

XXE

XXE File: Test.xml Please note that the file called below should be replaced with a valid Linux file if the Web Server is Linux based.

```
<?xml version="1.0"?>
<!DOCTYPE test [
<!ELEMENT test ANY >
<!ENTITY test SYSTEM "file:///c:/Windows/system.ini" >]><test>&test;</test>
```

SVG File: test.svg https://portswigger.net/web-security/xxe/lab-xxe-via-file-upload

```
<?xml version="1.0" standalone="yes"?>
<!DOCTYPE test [ <!ENTITY xxe SYSTEM "file:///etc/hostname" > ]>
<svg width="128px" height="128px" xmlns="http://www.w3.org/2000/svg" xmlns:xlink="http://www.w3.org/1999/xlinl
<text font-size="16" x="0" y="16">&xxe;</text>
</svg>
```

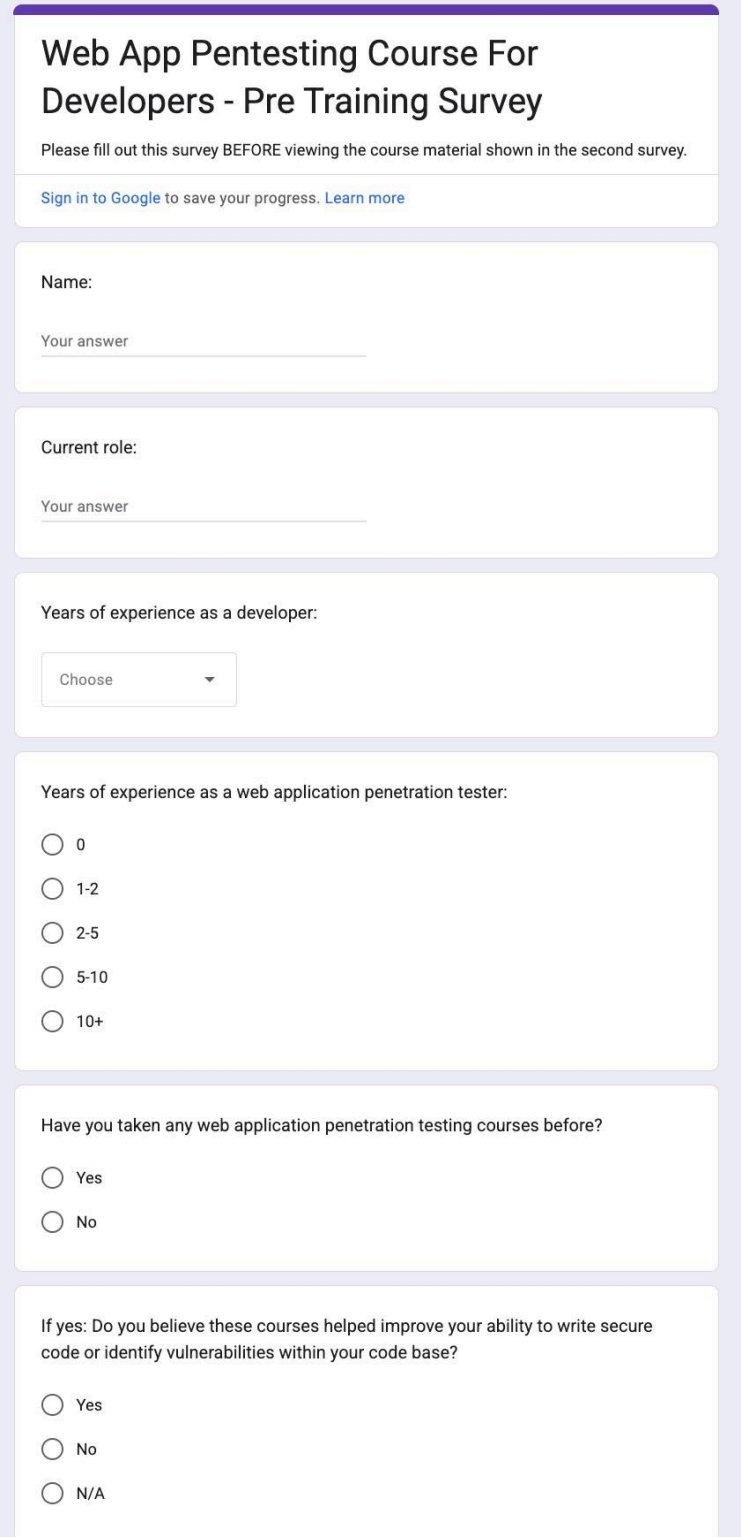
XSS

SVG file: testabc.svg https://github.com/makeplane/plane/security/advisories/GHSA-rcg8-g69v-x23j

```
<svg xmlns="http://www.w3.org/2000/svg" width="400" height="400" viewBox="0 0 124 124" fill="none">
<rect width="124" height="124" rx="24" fill="#000000"/>
   <script type="text/javascript">
      alert(0x539);
   </script>
</svg>
```

Appendix B Figure 5: XXE and XSS Test Files

Appendix C: Pre and Post Treatment Surveys



Web App Pentesting Course For Developers - Pre Training Survey

Please fill out this survey BEFORE viewing the course material shown in the second survey.

Sign in to Google to save your progress. Learn more

Name:

Your answer

Current role:

Your answer

Years of experience as a developer:

Choose

Years of experience as a web application penetration tester:

- 0
- 1-2
- 2-5
- 5-10
- 10+

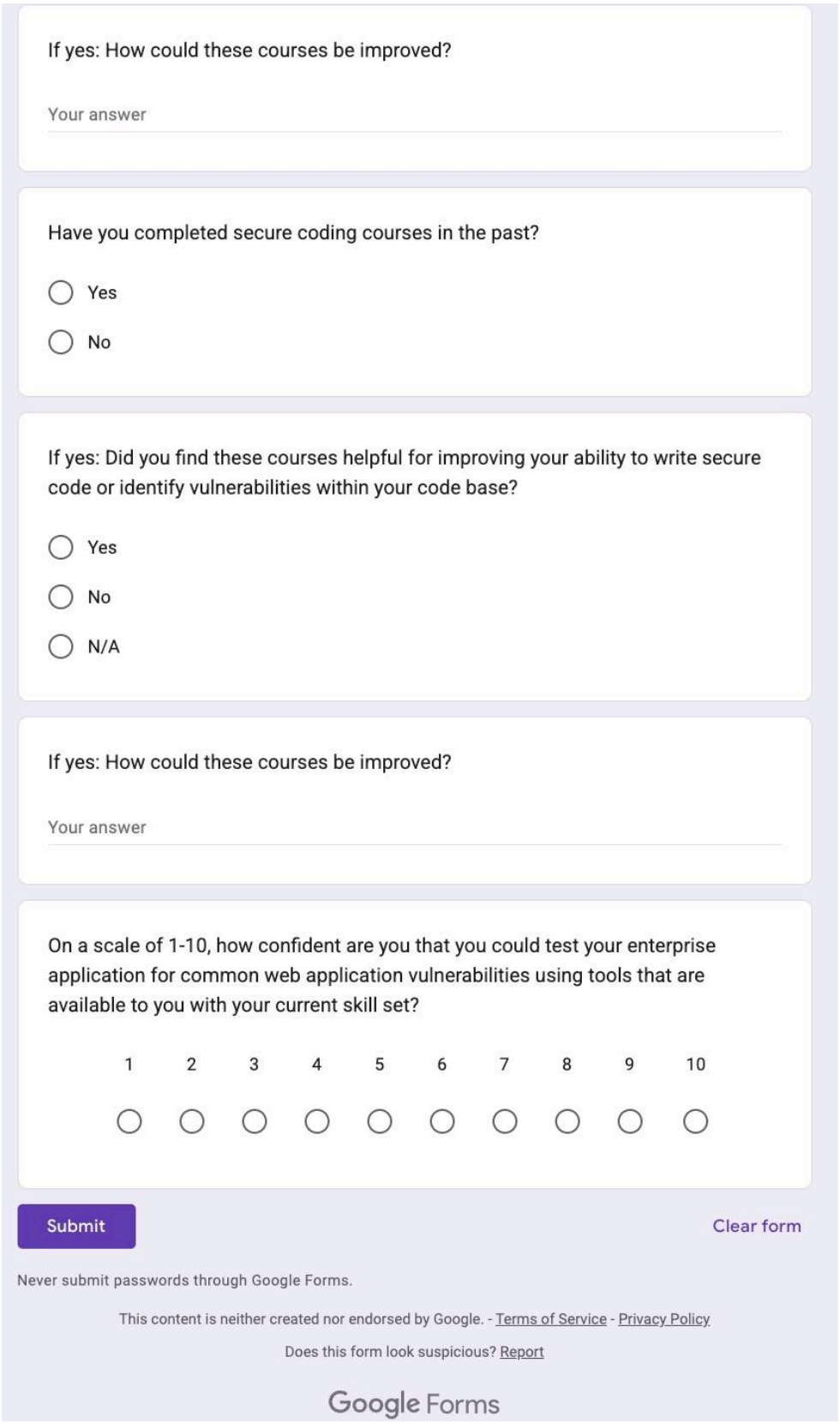
Have you taken any web application penetration testing courses before?

- Yes
- No

If yes: Do you believe these courses helped improve your ability to write secure code or identify vulnerabilities within your code base?

- Yes
- No
- N/A

Appendix C Figure 1: Pre-Training Survey



Appendix C Figure 2: Pre-Training Survey Cont.

Web App Pentesting Course For Developers - Post Training Survey

Please complete the pre training survey first. After, view the material below and fill out this survey.

Video Playlist: https://www.youtube.com/watch?v=oNDEU_uNtzI&list=PLqPCUirqsN_x_seY51DiivfV-CjgJDKUp

Checklist: https://github.com/SchoolProjZS2025/SteeleCapstone2025/blob/main/PracticumProjectChecklist.xlsx

Payload list: https://github.com/SchoolProjZS2025/SteeleCapstone2025/blob/main/ShortPayloadList.md

Sign in to Google to save your progress. Learn more

Name:

Your answer

Years of experience as a developer:

- ◯ 0
- ◯ 1-2
- ◯ 2-5
- ◯ 5-10
- ◯ 10+

Years of experience as a web application penetration tester:

- ◯ 0
- ◯ 1-2
- ◯ 2-5
- ◯ 5-10
- ◯ 10+

Please watch at least two videos in the series before answering the questions below. If possible, follow along using your own application, a test app, or public sites(non-malicious passive checks only).

Please note that the tools video is only showing tools that can be used for testing and the code analysis video does not show any vulnerability testing.

- ◯ Ack

Appendix C Figure 3: Post-Training Survey

Which videos did you watch?

- [ ] Tools
- [ ] Continuous Monitoring
- [ ] Response Headers
- [ ] Cookie Checks
- [ ] Code Review Resources
- [ ] Cross-Site Scripting
- [ ] SQL Injection
- [ ] SQL Injection on Login Pages
- [ ] Directory Traversal
- [ ] OS Command Injection
- [ ] Login Page Checks
- [ ] Session Management
- [ ] Clickjacking
- [ ] File Upload
- [ ] Horizontal Priv Esc
- [ ] Vertical Priv Esc

Did the videos teach you about new vulnerabilities?(Yes/No) Feel free to elaborate.

Your answer

Did the videos improve your understanding of risks and remediation guidance for the vulnerabilities shown?

- ◯ Yes
- ◯ No

Did you use the methodologies shown in the videos to find vulnerabilities in an application? If not, skip down to the next section of questions.

- ◯ Yes
- ◯ No

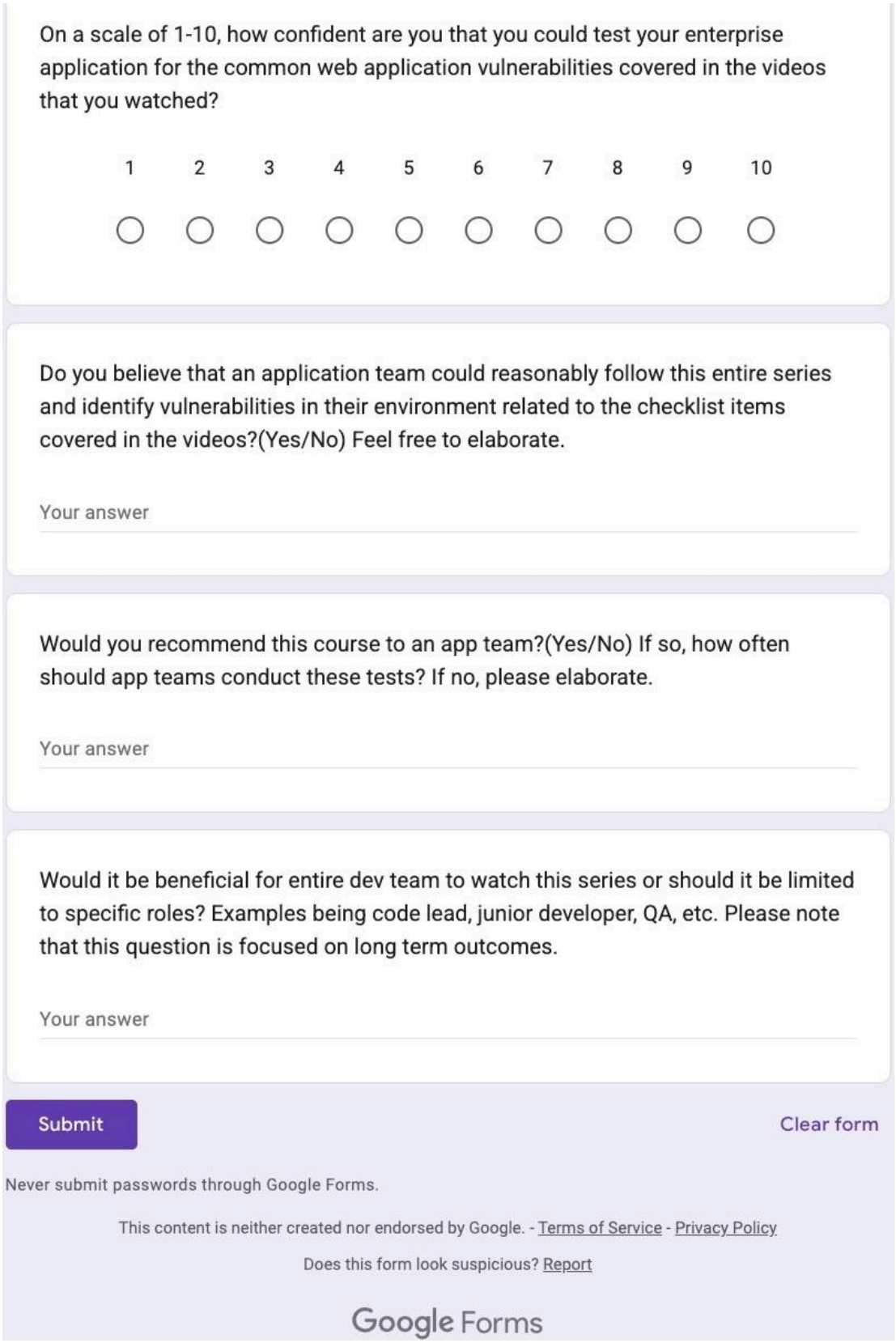
If Yes: How was your experience attempting to follow the videos? Please provide feedback on the pros and cons of the material, explanations, and format.

Your answer

If Yes: Were you able to identify any vulnerabilities or misconfigurations in the application you tested?(Yes/No) If so, what were they?

Your answer

Appendix C Figure 4: Post-Training Survey Cont.



Appendix C Figure 5: Post-Training Survey Cont.