

# Verification and Validation Report: SFWRENG 4G06

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# 1 Revision History

Date	Version	Notes
April 3, 2023	1.1	Updated test cases to reflect VnV Plan changes. Fixed grammatical and styling issues. Added next steps.
March 6, 2023	1.0	Initial Version

## 2 Symbols, Abbreviations and Acronyms

Symbol	Description
Data Structures and Algorithms	A topic of study for Computer Scientists.
CodeChamp	The system being built and tested.
Angular	A web framework for building web applications.
API	Abbreviation for Application Program Interface.
DSA	Abbreviation for Data Structures and Algorithms.
CI	Abbreviation for Continuous Integration.
SRS	Abbreviation for Software Requirements Specification.
MIS	Abbreviation for Module Interface Specification.
MG	Abbreviation for Module Guide.
Mocha	A JavaScript testing framework.
Jasmine	A JavaScript testing framework.
GitHub	A service for software development and version control.
GitHub Actions	A CI system integrated with GitHub.

Table 1: Symbols, Abbreviations and Acronyms

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### 3 Introduction

This document describes the verification & validation effort for the CodeChamp system. Other relevant documentation is listed below:

1. [Validation & Verification Plan](#)
2. [Development Plan](#)
3. [System Requirements Specification](#)
4. [Hazard Analysis](#)
5. [Design Documentation](#)

### 4 Purpose

This document is written to describe the steps taken to verify & validate the requirements and the implementation of the CodeChamp system. Primarily, it describes the functional requirements evaluated in accordance with the Validation & Verification plan. Moreover, it reports the results of the testing regarding non-functional requirements. It also delves deeper into the validation and verification of two non-functional requirements: usability and security, which are of particular importance to the CodeChamp system. Additionally, unit testing done by the testers is summarized, as well as how automated testing tools were leveraged. Finally, the changes due to testing are summarized and justified and the tractability between the requirements, modules and tests are given.

### 5 Functional Requirements Evaluation

The functional requirements evaluation is summarized by Table 2:

Test Case ID	Testing Result
TC-MM-1	Passed, tester pressed the "find a match" button and the correct page shows up.

TC-MM-2	Passed, tester was able to join a existing lobby with the correct lobby code shared by friends.
TC-MM-3	Passed, tester was able to create a lobby using the create button in the home page.
TC-IG-1	Passed, testers were able to complete a match by winning or losing match.
TC-IG-2	Passed, input given was able to compile a solution.
TC-PM-1	Passed, tester was able to add new problems using admin account.
TC-PM-2	Passed, tester was able to modify problems using admin account.
TC-PM-3	Passed, tester was able to delete problems using admin account.
TC-PV-1	Passed, profile was able to display wins and losses.
TC-PV-2	Passed, profile was able to display match history.
TC-LB-1	Passed, tester was able to see data of leaderboard tests.
TC-A-1	Passed, tester was able to login with correct credentials.
TC-A-2	Passed, tester was not able to login with wrong credentials. The system returns an error message.

Table 2: Functional Test Cases and Requirements

## 6 Non-functional Requirements Evaluation

The non-functional requirements evaluation is summarized by Table 3:

Test Case ID	Testing Result
TC-LF-1	Passed after Changes, information below in Usability section <a href="#">6.1</a> .
TC-LF-2	Passed, all screen sizes worked as expected.
TC-P-1	Passed, Chrome Dev Tools showed response time less than the maximum response time when an action was performed.

TC-P-2	Passed, Chrome Dev Tools showed response time less than the maximum compile time when a compilation was performed.
TC-OE-1	Passed, the program was tested on devices on multiple OS(mac, windows) and in combination with browsers(Google Chrome, Firefox and Safari).
TC-S-1	Passed after changes, testers were able to call functions for other users as long as they had their user id and the game id they were currently in. Changes were made to fix this through authentication checking. Further discussed in <a href="#">8</a> .
TC-C-1	Passed, the game did not have any cultural references.
TC-L-1	Passed, the repository was protected by the GNU license.
TC-HS-1	Passed, the game did not have any flashing lights that could cause harm to users.

Table 3: Non-Functional Test Cases and Requirements

## 6.1 Usability

In addition to the non-functional tests for usability, a semi-structured interview was conducted with a total of eight users in the target demographic. To achieve this, a CodeChamp lobby was setup with the users. This included current Computer Science and Software Engineering students, as well as current Software Engineering professionals. After finishing a game, each user was asked several questions. Rough notes from the interviews can be found in the Appendix, under section [12.2](#). The questions, interview structure and results are summarized below:

- From 1 - 10, How easy was the interface to navigate? 1 being un-navigatable, 10 being no issues navigating.

If users answered less than 8, we would follow up and ask for feedback. The result for this question was that all users said the interface was simple and all ratings were 9 or above. Figure [1](#) below summarizes the results for this question:



From 1 - 10, How easy was the interface to navigate? 1 being un-navigable, 10 being no issues navigating.

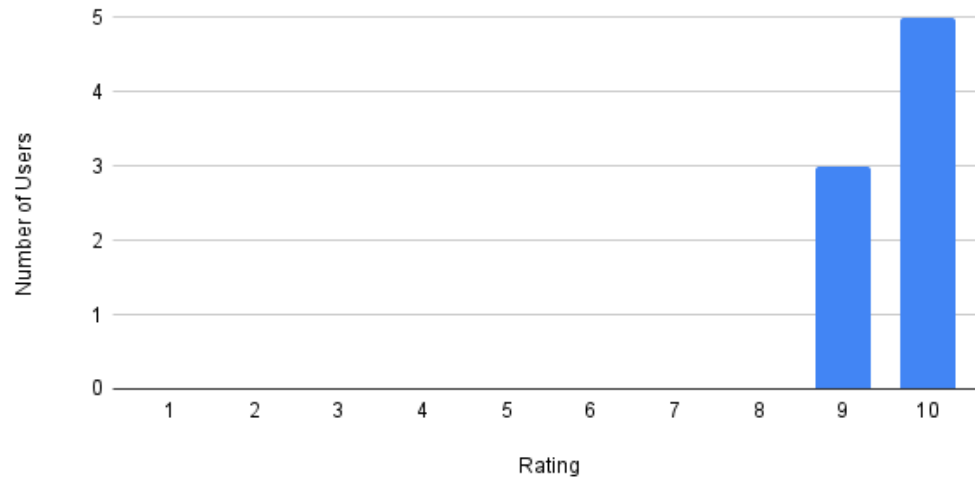


Figure 1: Results for interface navigation usability

- From 1 - 10, How consistent was the visual theming of the website? 1 being not consistent at all, 10 being super consistent.

If users answered less than 8, we would follow up and ask for feedback. The result for this question was that most users rated 7 or above. Users who said 7 and 8 mentioned that the game screen and login screen had a different colour scheme than the rest of the website. Figure 2 below summarizes the results for this question:

From 1 - 10, How consistent were the visual theming of the website?  
1 being not consistent at all, 10 being super consistent.

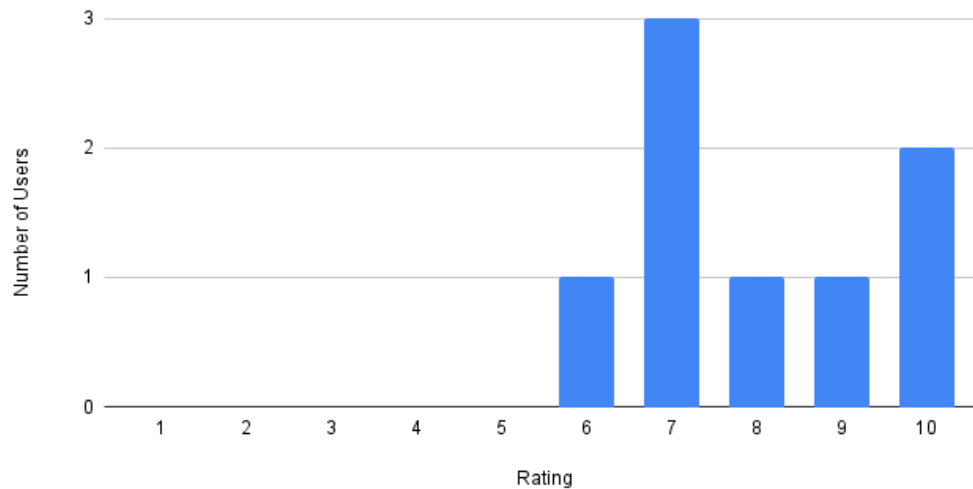


Figure 2: Results for visual theming consistency usability

- For testing whether users wanted the copy code button to copy the whole URL or just the game id. Our team did A/B testing where half the users were tested on copying the URL then trying copying the game id and vice versa for the other group. Our testing found that most players preferred sending the whole URL. Figure 3 below summarizes the results for this question:

### Copy Game ID vs Copy URL User Preference

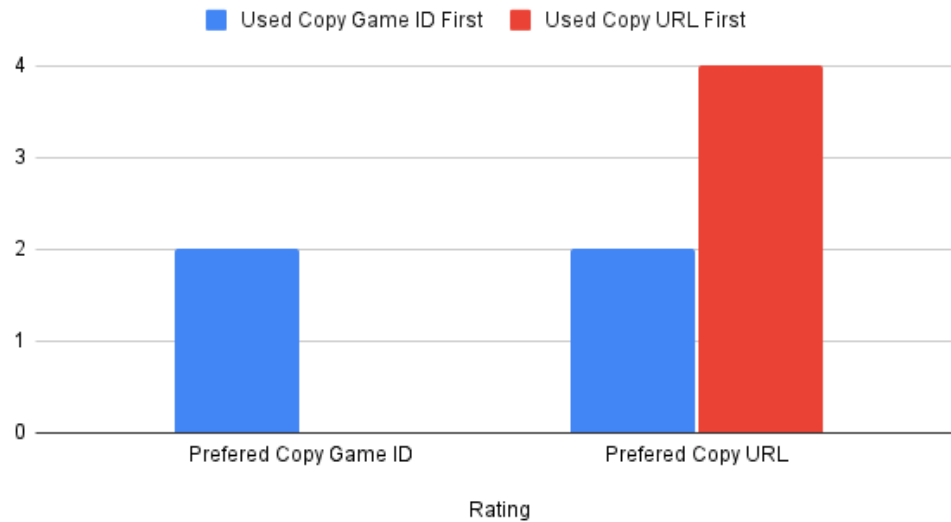


Figure 3: Results for copying URL versus copying game id

- When asked if users felt that any feature was missing from the game. The most common feature missing was stats. When asked about what information the profile page should give. The most common ask was for the difficulty of problems solved as well as calculating their win rate.
- When asked what additional languages they preferred to use. The most common response given was Python. Figure 4 below summarizes the results for this question:

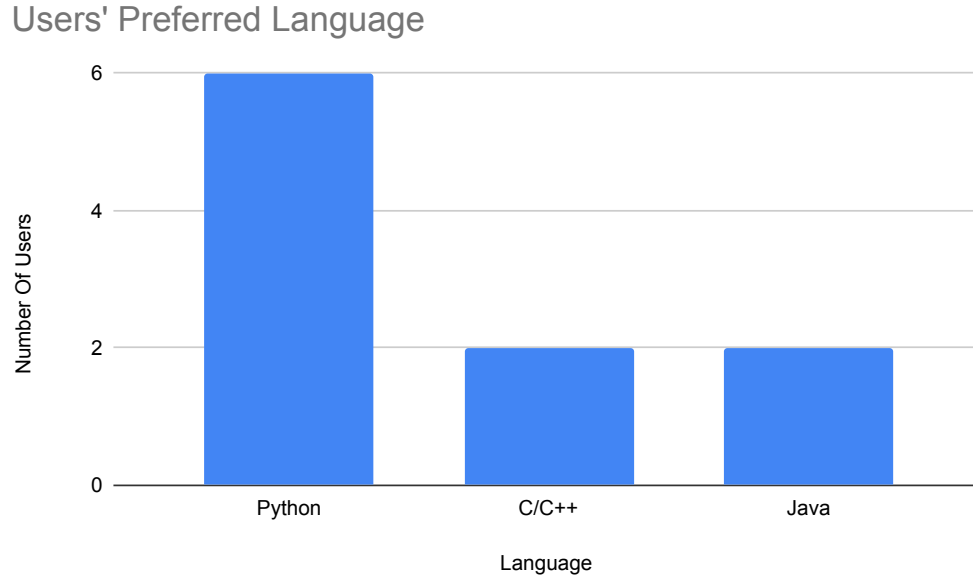


Figure 4: Results for most preferred language to use for data structures and algorithms

## 6.2 Security

A critical part of the CodeChamp system involves compiling and executing user code, which can be potentially destructive to the system's security. To test this, several scripts were written to enact malicious/dangerous submissions and fed into the CodeChamp Judge system. Afterwards, the testers ensured that the system was able to prevent 100% of the scenarios from negatively affecting or compromising the CodeChamp system.

Table 4 below summarizes the scenarios which were considered as part of the security evaluation:

Security cern	Con-	Scenario	Result
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Accessing the CodeChamp server's file system	Code which tries to write a file to the file system was submitted.	No file was written to the CodeChamp file system, as it was only written to the local container which was killed afterwards.
Accessing the CodeChamp server's file system	Code which tries to remove a file from the file system was submitted.	No file was removed from the CodeChamp file system.
Hogging server resources due to non-terminating code.	Code including an infinite loop was submitted to a problem with a 3 second time limit.	The Judge system returned a TLE (Time-Limit Exceeded) code. The container running the code was killed.
Hogging server resources due to unnecessarily large memory usage.	Code which initializes a large array was submitted to a problem with a 64 MegaByte memory limit.	The Judge system returned a MLE (Memory-Limit Exceeded) code. The container running the code was killed.
Potential code Injections, cheating / hacking concerns	Code which makes an HTTP request was submitted.	The Judge system returned a Code Error, which resulted from an unhandled exception due to the failing network call. The container running the code was killed.

Table 4: Security Scenarios Considered for CodeChamp Judge System

## 7 Unit Testing

Unit testing was done for all applicable modules. For back-end modules, Mocha was used as the unit testing framework. For front-end modules, Jasmine was used. Additionally, these tests were automated as described in Section 10. In particular, for back-end testing, all API endpoints were tested.

This covered operations of creating, reading, updating, and deleting data. The data we used to verify these operations were mocked data that was used by a mock database for the purposes of testing. For front-end testing, we tested components for each page. This involved testing the usability and functionality of menus, buttons, interactions, events and other GUI elements visible to the user using a Chrome runner.

## 8 Changes Due to Testing

After receiving feedback from the Rev 0 demo, we changed the mechanism for copying a lobby's unique code. What we initially had was copying the code itself, but we changed the text that would be copied to the URL of the lobby. This way, instead of entering the code to join a lobby, the URL can be used to join the lobby, reducing the number of clicks the user has to go through. This was A/B tested as previously discussed in the usability section, with the majority of users preferring this option.

Feedback from users also initiated the change of statistics that will be shown to the users when viewing their profiles. Initially, we gave information regarding the win, loss, and the questions solved in each game. According to our testing, users would like to know the number of problems of each difficulty they have solved. Now we have the addition of the types of problems solved in terms of difficulty. This allows users to track their success against easy, medium, and hard-level questions. Alongside the total wins and losses for a player, we have added the respective ratio so they do not have to calculate it themselves.

More programming languages are supported to allow individuals with proficiency in different programming languages to compete on the platform. After a survey with the users indicating which languages we should support, Python was voted the highest among other languages like C++, Java, and C. As a result, we have added support for the Python language to be used on the CodeChamp platform. Other languages could be considered later in development but due to time constraints, only the most popular one, Python, was added.

With the user testing for the look and feel non-functional requirement (TC-LF-1) 2 users found the system's lack of consistency in the design. This included the design of the game page as well as the login page. With this feedback, game and login pages were redesigned and implemented to be con-

sistent with the rest of the application.

After user acceptance testing, some users brought up that they were uncomfortable with emails being displayed in the leaderboards. Additionally, this violates the security requirement of storing and displaying only the necessary data (TC-S-2). As this is a private data point of the user, it should not be displayed as it may compromise the users' Google and other accounts associated. Due to this, the email display was changed to the user's username.

The current implementation uses a player's ID as their email. Thus, submissions from users that are not actually involved in a game can be allowed if a malicious user discovers this, and can somehow reverse-engineer or discover the game ID for a particular game. Due to this an authentication middleware is applied to the backend for communication from clients to fulfil the requirement of user authenticity (UC-S-1).

## 9 Next Steps

Usability testing should be conducted with larger user groups in order to ensure that the results are statistically significant. Additionally, it would be beneficial to conduct a longer-term study on the learnability of the system in order to ensure that it succeeds in improving the user's algorithmic skills. This would include a comparison to other existing platforms such as Leetcode and would help the developers understand its upsides and shortcomings in comparison to the currently offered market solutions.

## 10 Automated Testing

GitHub Actions were used to automatically test new pull requests using Mocha and Jasmine, which were used to test the back-end and front-end, respectively. Additionally, linting and formatting rules were written using ESLint and Prettier using the [Airbnb style guide](#) and the [official Angular style guide](#) for reference. The code base was checked against these rules using GitHub actions on every pull request as well.

## 11 Trace to Requirements

Test Case ID	Requirement ID	Requirement Description
TC-MM-1	FR.1	Should join a random match.
TC-MM-2	FR.19	Should join an existing page with a code.
TC-MM-3	FR.18	Should create a match.
TC-IG-1	FR.2, FR.3, FR.4, FR.5, FR.8, FR.9, FR.10	Should complete a match.
TC-IG-2	FR.6, FR.7, FR.15, FR.16, FR.17	Should compile solutions from the input.
TC-PM-1	FR.11, FR.12, FR.16, FR.17	Should be able to add new problems (admin).
TC-PM-2	FR.11, FR.12, FR.16, FR.17	Should be able to modify problems (admin).
TC-PM-3	FR.11, FR.12, FR.16, FR.17	Should be able to delete problems (admin).
TC-PV-1	FR.21	Profile should view win percentage.
TC-PV-2	FR.20, FR.22, FR.23	Profile should view match history.
TC-LB-1	FR.24	Leaderboard view should show the players sorted by their scores.
TC-A-1	FR.13	Users should be able to login
TC-A-2	FR.14	System should error when login credentials are wrong
TC-LF-1	NFR.1, NFR.2, NFR.3	Ease of navigation.
TC-LF-2	NFR.2, NFR.3	Responsive display among devices.
TC-P-1	NFR.4	Performance of user actions.
TC-P-2	NFR.10	Performance of user solution compilation.
TC-OE-1	NFR.6	Should run on any modern browser on any device.



TC-S-1	NFR.7	Only requests from authenticated users should be accepted.
TC-C-1	NFR.10	Content of the system should not contain any cultural references.
TC-L-1	NFR.11	System should be protected by GNU License.

Table 5: Traceability Table for Test Cases and Requirements

## 12 Trace to Modules

Test Case ID	Module ID(s)	Test Case Description
TC-MM-1	HomePage, LobbyPage, LobbyService, WebSocketService, GameHandler	Should join a random match.
TC-MM-2	HomePage, LobbyPage, LobbyService, WebSocketService, GameHandler	Should join an existing page with a code.
TC-MM-3	HomePage, LobbyPage, LobbyService, WebSocketService, GameHandler	Should create a match.
TC-IG-1	GamePage, ProblemsService, SubmissionService, UserService, GameHandler	Should complete a match.
TC-IG-2	GamePage, ProblemsService, SubmissionService, GameHandler	Should compile solutions from input.
TC-PM-1	ProblemsService	Should be able to add new problems (admin).
TC-PM-2	ProblemsService	Should be able to modify problems (admin).
TC-PM-3	ProblemsService	Should be able to delete problems (admin).

TC-PV-1	ProfilePage, UserService	Profile should view win percentage.
TC-PV-2	ProfilePage, UserService	Profile should view match history.
TC-LB-1	LeaderboardPage, UserService	Leaderboard view should show the players sorted by their scores.
TC-A-1	LoginPage, AuthService	Login should successfully login on correct credentials.
TC-A-2	LoginPage, AuthService	Login should show a error message on failed login.
TC-LF-1	All page modules	Ease of navigation.
TC-LF-2	All page modules	Compatibility among devices.
TC-P-1	All modules	Performance of user actions.
TC-P-2	SubmissionService	Performance of user solution compilation.
TC-OE-1	All page modules	Should run on any modern browser on any device.
TC-S-1	LoginPage, AuthService	Only requests from authenticated users should be accepted.
TC-C-1	All page modules	Content of the system should not contain any cultural references.
TC-L-1	N/A	System should be protected by GNU License.
TC-HS-1	All page modules	No flashing lights.

Table 6: Traceability Table for Test Cases and Modules

# Appendix

## 12.1 Reflection

The information in this section will be used to evaluate the team members on the graduate attribute of Reflection. Please answer the following question:

1. In what ways was the Verification and Validation (VnV) Plan different from the activities that were actually conducted for VnV? If there were differences, what changes required the modification in the plan? Why did these changes occur? Would you be able to anticipate these changes in future projects? If there weren't any differences, how was your team able to clearly predict a feasible amount of effort and the right tasks needed to build the evidence that demonstrates the required quality? (It is expected that most teams will have had to deviate from their original VnV Plan.)

The biggest change from the VnV plan was the addition of user acceptance testing. As our platform is user-centric, with the goal of teaching users, it is essential that we measure the users' experience to understand if it fulfills their needs. This involved adding interview questions, as well as reaching out to target demographic members in order to setup a testing session. With the bigger emphasis on usability testing through user acceptance testing, there was less time to spend on automated testing. This resulted in a deviation from the original VnV plan for functional testing, which included automated end-to-end (E2E) tests for the majority of the requirements. While E2E tests are crucial to catching regressions in a constantly evolving system, it was determined to be a sub-optimal use of the team's testing budget at this stage for a multitude of reasons. Primarily, many of the requirements and modules that would be tested using E2E tests are also covered by unit tests. Additionally, the majority of the functional tests were also tested by other users during the user acceptance sessions, as well as by the developers of the platform and the instructors during development and demonstrations. Finally, automating the E2E tests to run using GitHub actions is significantly more time consuming than other types of tests, as it requires to sandbox the entire platform to be run (i.e. the server, client, database, browser). For these reasons, there was enough confidence to modify this section of the VnV plan. In the future, it would be beneficial to consider a broader range of testing techniques from an earlier stage, as the original VnV plan was too focused

on functional testing and thus did not consider other aspects such as the user experience. Therefore, with better scoping, we could have anticipated these changes by analyzing the aspects which the end-user will interact with the most, and dividing the testing budget to cover the most crucial aspects.

## 12.2 Usability Interview Rough Notes

Questions:

1. From 1 - 10, How easy was the interface to navigate? 1 being un-navigable, 10 being no issues navigating.
2. From 1 - 10, How consistent were the visual theming of the website? 1 being not consistent at all, 10 being super consistent.
3. Do you prefer the copy code button to copy the game id or the full url?
4. What language do you prefer to learn data structures and algorithms for?
5. What feature is missing from the website that you would like implemented?

1. User 1 - Man, Third year Computer Science student

- Q1: 10
- Q2: 7. The overall theme looks great, however the game screen looks like a different part of the website.
- Q3: Tested copy game id first. Preferred copying the full url.
- Q4: Python
- Q5: Nothing

2. User 2 - Man, Fourth year Software Engineering student

- Q1: 9
- Q2: 10
- Q3: Tested copy full url first. Preferred copying the full url
- Q4: Java

- Q5: The timer should vary for each problem based on the difficulty. The timer should count faster when people have finished, similar to a racing game. The leaderboard should not display email, only username.
3. User 3 - Man, Fourth year Software Engineering student
    - Q1: 10
    - Q2: 8, Felt dark colors on game page did not match color scheme
    - Q3: Tested copy game id first. Preferred Game ID.
    - Q4: C++
    - Q5: Addition of more stats, wanted win rate. The Leaderboard should not have emails.
  4. User 4 - Man, Industry Junior Software Developer
    - Q1: 9
    - Q2: 9
    - Q3: Tested copy full url first. Preferred copying the full url
    - Q4: Python
    - Q5: Support for more languages. Problem hints.
  5. User 5 - Woman, Fourth year Software Engineering student
    - Q1: 9
    - Q2: 7, half of the game page was light mode and the other was dark mode.
    - Q3: Tested copy full url first. Preferred full url
    - Q4: Python
    - Q5: Performance stats per problem (which percentile is the solution)
  6. User 6 - Woman, Fourth year Software Engineering student
    - Q1: 10
    - Q2: 10

- Q3: Tested copy game id first. Preferred copying the full url
- Q4: Python
- Q5: Detailed game history, ability to see opponents and their ranks or wins

7. User 7 - Man, Fourth year Computer Science student

- Q1: 10
- Q2: 6, the game page does not match the rest of the website.
- Q3: Tested copy game id first. Preferred game id
- Q4: C
- Q5: Ability to have a % of people ready up (voting system) rather one person clicking ready

8. User 8 - Man, Fourth year Computer Science student

- Q1: 10
- Q2: 7
- Q3: Tested copy full url first. Preferred full url
- Q4: Python
- Q5: Profile pages for all players, not just mine. Gives more visibility into the leaderboards.