A Serious Game Designed to Teach Computer Science Students About the Domain Name System

Xuanxuan Du

Master of Science
Design Informatics
School of Informatics
University of Edinburgh
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Abstract

The Domain Name System (DNS) plays a fundamental role in computer networks, making it relatively easy for people to access websites. However, the principles behind it are often difficult to understand and thus challenging for students to learn. This project's main goal is to design and build a serious game, which will help computer science students grasp the various kinds of attacks that might occur during the DNS lookup process and its basic concepts.

Serious games are thought to increase students' interest in the subject and their learning efficiency during instruction. This project combines the basics of DNS with a serious game to help the audience understand the learning objectives at three distinct levels. My implementation method was based on an initial prototype design. Interviews that followed provided feedback so the game flow, interface, gameplay and presentation could be optimised. Phaser was then used to develop a web game. The pre- and post-game tests led to the conclusion that the game would assist participants in achieving the learning objectives and would meet the System Usability Scale's criteria.

Acknowledgements

I would like to show my deepest gratitude to my supervisor, Dr Kami Vaniea, who has provided me with valuable guidance in every stage of the project.

I would also like to thank all the participants in this project, whose advice has been invaluable to me.

Last but not least, I would also like to thank my family and friends for their constant support and companionship.

Declaration

I declare that this thesis was composed by myself, that the work contained herein is my own except where explicitly stated otherwise in the text, and that this work has not been submitted for any other degree or professional qualification except as specified.

(*Xuanxuan Du*)

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Chapter 1

Introduction

Computer science is a popular field of study, with an increasing number of students choosing to study it at universities. Computer communication and networking is an important course in computer science. It introduces basic networking concepts, such as protocol, network architecture, reference models, layering, etc. [1]. Courses such as this, which are relatively abstract, focus more on explaining theory and protocols. Moreover, the content of such theory-centred science is often too rigid to hold the interest of young students [17]. This, coupled with the fact that lecturer-led seminars or video-based courses are still the predominant modes of teaching, makes it challenging for students to concentrate on the content for an extended period.

1.1 DNS and Serious Games

The Domain Name System (DNS) is critical in computer networks, making it relatively simple for individuals to access websites. DNS is a distributed database that maps domain names and internet protocol (IP) addresses to one another; hence, it makes it easier for users to connect to the internet without having to remember a string of IPs that machines can read directly. To access Google, for example, a user simply types 'google.com' into their browser's address, instead of its IP address (74.125.224.72). DNS usually goes unnoticed as a silent service provider, but its name becomes known when there is a network security threat caused by DNS issues. To illustrate, there was an instance when the New York Times appeared to be down, but this was due to a DNS attack [8]. What happened to the news site can be rather difficult for people to grasp unless they are aware of how the DNS works and how the protocol is set up to ensure accuracy and stability, both of which can be threatened by attackers. The DNS can also

be disrupted by a non-malicious attack, such as a prolonged power outage in the data centre where the server is located, a natural disaster affecting the area, fire or other issues. Understanding how the DNS works can aid in determining general network problems [3].

Although there are many DNS explanations available on the internet, most of them are limited to text and video formats. For university students studying computer science, DNS explanations are usually covered in computer communication and networking courses. However, while the DNS is explained in detail by lecturers in the classroom, scientific concepts in textbooks might be difficult for students to understand, and, consequently, apply [17]. To make the DNS more engaging for students and help them absorb its underlying principles more easily, serious games can be used as an educational tool to teach complex topics. Serious games are games that do not primarily aim to entertain but instead have an educational purpose. It is an emerging discipline that combines learning design and games to enhance students' learning experiences by incorporating educational needs into the functionality of games [22]. Previous research has also experimented with computer security and serious games, with topics mostly in the areas of firewall management [25], programming education [23] and computer security education [19]. However, serious games on DNS are quite limited.

1.2 Research Goals and Process

This project's primary purpose is to design and build a serious game to help computer science students understand the DNS lookup process's basic principles and the different kinds of attacks that could happen. The other objectives of this project are the following:

- Help students in reaching the knowledge and comprehension levels of Bloom's taxonomy [14].
- Produce a usable and engaging game for students.

The game was built based on a prototype design, which was then iterated through interviews with five student participants, an expert and a focus group to obtain feedback, thereby optimising the game flow, interface, gameplay and expression. A web game was then created based on the iterated prototype. Finally, the game was evaluated to determine whether it met the learning objectives and whether it was a usable system. The DNS is a complex protocol with many elements. As I learned about it, it became

clear that teaching all aspects of the DNS was too much for a single game to cover, with the given design time frame. After discussing with my supervisor, I found that it would be more feasible to introduce several types of DNS attacks to beginners. Eventually, the goal changed to helping Computer Science students understand the basic principles of the DNS lookup process and the various types of attacks that can occur along the way. I built this game using Phaser, a game engine. Due to time constraints, I have only implemented a few of the game's levels, but enough to get a sense of the whole game. This serious game's ultimate purpose is to be used as a teaching aid to assist students in reaching the knowledge and comprehension levels of Bloom's taxonomy [14], i.e. to be able to recall and explain facts and basic concepts.

At the end of the project, I administered a pre- and post-game questionnaire to assess whether the game helped the five participants achieve their learning objectives. The pre-game questionnaire collected the participants' basic information. The five respondents had different backgrounds, with only one having previous knowledge of the DNS and computer networks. The results showed that the game aided them in reaching the comprehension level of Bloom's taxonomy, thus understanding the DNS search process and several types of attacks.

For the game interface's usability, I employed the System Usability Scale (SUS) by Brooke [15] and asked the five participants to rate the game. Based on their given scores and the description of the SUS scores by Bangor et. al [13], the game attained a good level of usability.

1.3 Paper Structure

Chapter 2 reviews the literature on the DNS and serious games, as well as their development and applications.

Chapter 3 describes the first prototype design phase in detail, from the initial ideas and sketches to the feedback collection phase, which included interviews with students and experts.

Chapter 4 details the prototype iterations based on student and expert feedback in the first stage. It also includes the focus group discussions with Technology Usability Lab in Privacy and Security (TULIPS) [7] research team members to determine the game's conclusive version.

Chapter 5 shows the game's implementation phase, which includes the selection of a development platform, the application of version control and the game's final layout.

Chapter 6 presents the game's final evaluation, which includes an assessment of the user's knowledge before and after playing the game and an evaluation of the game's usability.

Chapter 7 concludes the thesis, identifies its limitations and reflects on its future.

Chapter 2

Literature Review

2.1 DNS

In the late 1960s, the US Defence Advanced Research Projects Agency (DARPA) began funding an experimental computer network, the Advanced Research Projects Agency's Network (ARPANET), to link the country's major research departments [21].

The system, developed by Bolt, Beranek and Newman, was a packet-switching system that allowed different hosts to interact with each other by exchanging data over the network. When ARPANET was first built, only a few hundred hosts it as a small community. Each host in the community had its own numerical address; ARPANET used these strings of numbers to connect them to each other using the network control protocol. Moreover, for ease of communication, each host was given its own text name. The mapping between these text names and their corresponding numeric addresses is recorded in a simple text file called 'hosts.txt'. This denotes that only a hosts.txt file is needed to contain the name and address resolution for each host connected to the ARPANET. This file is maintained by the Stanford Research Institute's (SRI) Network Information Centre (NIC) and is distributed by a single host, the SRI-NIC [24].

The Internet was launched in 1983, and its growth has been unstoppable. With the increasing network traffic caused by the update process, each new host means not only an additional line in the hosts.txt file but also the need for other hosts to be added. Other hosts must also be updated via the SRI-NIC. However, the use of hosts.txt files at this point presents some problems [10].

- Overload: When the transmission control protocol/internet protocol (TCP/IP) was used, the number of networks began to proliferate. It was therefore impractical to rely on hosts.txt to record the mapping between hostnames and numeric

addresses.

- Duplicate names: When looking for mappings, there will be conflicts if two hosts have the same name. As the number of hosts grows and the NIC lacks administrative authority over hostnames, the problem of duplicate names will worsen.

- Update lag: As the network expands at a rapid rate, it becomes increasingly difficult to maintain consistency. For example, suppose a user wants to access host A, and by the time the hosts.txt file found its numerical address, the user now wants to access host B. This traditional approach is no longer practical for today's Internet.

Considering the problems outlined above, Paul Mockapetris developed the DNS under the auspices of DARPA, a distributed database for mapping domain names and IP addresses to each other, making it easier for users to access the internet without having to remember a string of IPs that machines can read directly. To access Google, for example, a user simply types 'google.com' into the browser's address bar, rather than its given IP address –74.125.224.72.

2.2 Serious Games

As digital media technologies become more prevalent in people's lives, the use of games to support learning is an inevitable trend. In many previous studies, serious games have been shown to have strong pedagogical potential. In an experiment with 44 students aged 15 to 16, Yang [29] found that digital game-based learning had a positive effect on student learning while enhancing the classroom atmosphere. Moreover, Arnab et al. [11] experimented with four different groups of young people on the use of serious games to support the teaching and learning objectives of relationship and sex education and demonstrated that serious games can have a favourable influence in the classroom.

Serious Games, as a highly useful teaching tool, require a proper design; designers must find a balance [20] between gameplay, game elements, learning objectives and educational principles. Arnab et al.'s Learning Mechanics-Game Mechanics (LM-GM) [12] paradigm enables the mapping of learning elements to game elements. As shown in Fig. 2.1, it can be used as a design framework for diverse types of serious

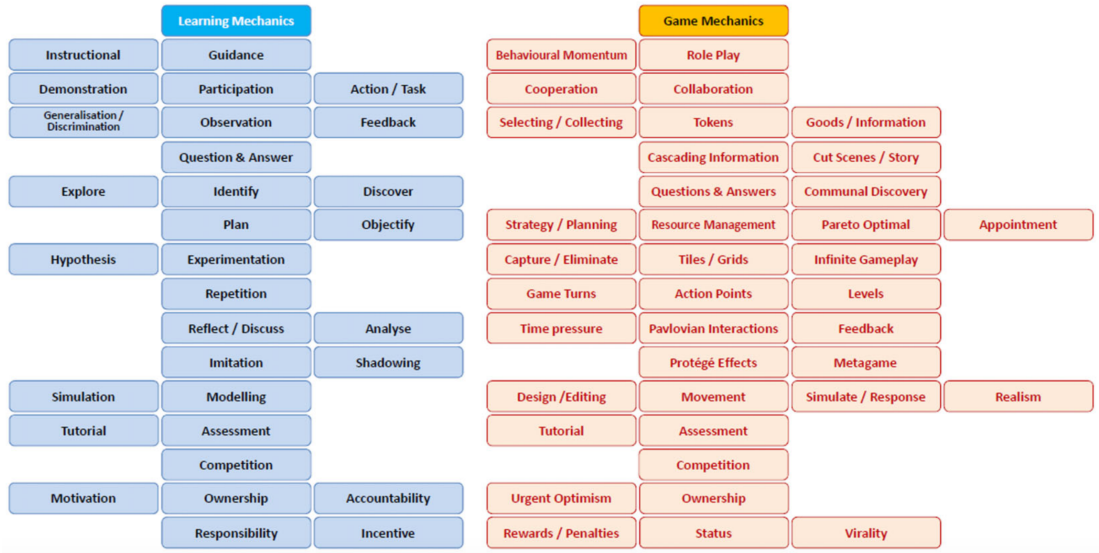


Figure 2.1: Learning and game mechanics are used as the bases to construct the LM-GM map for a game, taken from [12]

games, mapping game elements to educational objectives clearly and concisely. The model allows the designer to describe the game elements and pedagogical aims of serious games in a table. The model's nodes are the product of research into various educational theories (e.g. constructivism, behaviourism) and game theories (e.g. game mechanics and dynamics). This mechanism has contributed significantly to the application of serious games in a range of fields.

2.2.1 Existing Security Games

According to previous research, in the field of network security games, many serious games concerning firewalls already exist but only a few of them are about the DNS. Two extant firewall educational games are described below.

Permission Impossible

This game was designed and built by Sibylle Sehl [25] to teach beginners how to use firewalls to manage incoming and outgoing traffic based on the tool iptables (Fig. 2.2). Sehl modified the game design based on data gathered from interviews and questionnaires before implementing the game with Unity. The game consists of ten levels, each of which introduces a different concept and provides fewer hints as the game progresses.

GAP

Despite decades of research on internet security, users still choose to set passwords

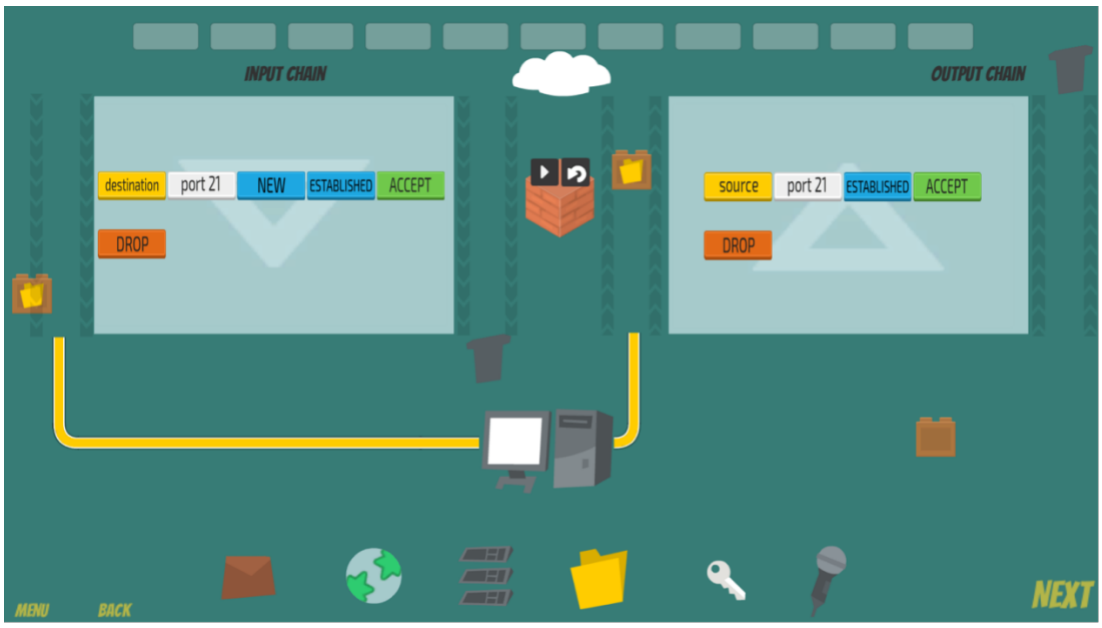


Figure 2.2: Permission Impossible Level Layout [25].

that can be easily guessed. In this context, Tupsamudre et al. [27] built a web-based casual game with the goal of educating users about the various negative effects of password security through serious gaming (Fig. 2.3). This project evaluated its impact through a comparative user study with 119 participants, and the results showed that those who played the game were better able to recognize insecure password features than those who did not.

What.Hack: Learn Phishing Email Defence the Fun Way

Humans are progressively becoming the weakest link in the security pipeline as information security solutions grow more sophisticated and dependable. For this reason, Wen et al. [28] introduce the game What.Hack to educate information security and defense methods for social engineering threats (Fig. 2.4). The objectives are (1) teach players how to safely handle URLs, attachments, and social media, and (2) provide a compelling storey on how social engineering assaults may lead to security vulnerabilities.

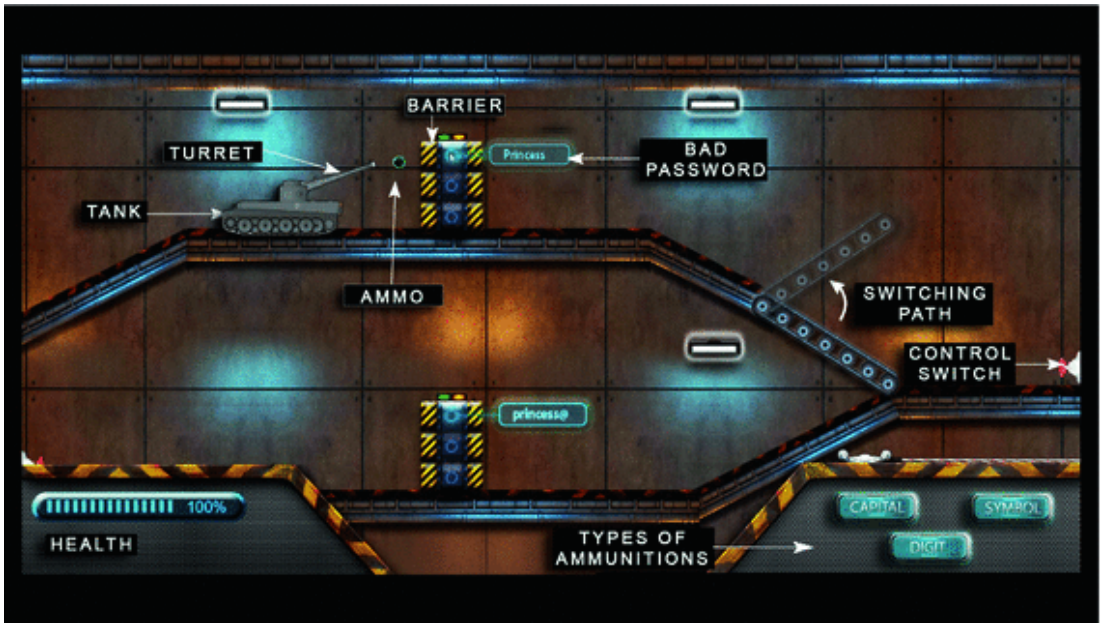


Figure 2.3: GAP Layout [27].

Figure 2.4: What.Hack Layout [28].

Chapter 3

First Design Phase

This chapter describes the initial design of the game prototype and the collection of feedback. By following the Double Diamond model proposed by the British Design Council in 2005 [18], the overall design process of the game was thus defined. I started by designing the game levels based on the LM-GM model, then sketched and built the prototype, and then collected user feedback through interviews with five student participants and an expert.

3.1 The Overall Design Process

The overall design of this project applies the Double Diamond model (Fig. 3.1), proposed by the British Design Council in 2005 [18], which divides the process into four stages:

- Discover: Study the problem in depth and really understand it, not assume it. In this project, I have found that for university students studying computer science, theory-centred content such as DNS is often too rigid to hold the interest of young students [17]. This, coupled with the fact that lecturer-led seminars or video-based courses are still the predominant modes of teaching, makes it challenging for students to concentrate on the content for an extended period.
- Define: Identifying key issues. In this project, a teaching aid that both engages students and teaches them about DNS is needed.
- Develop: Propose solutions on defined problems and discuss them with other people. In this project, the initial idea was to create a serious game to help computer students learn all the knowledge of DNS that should be covered in

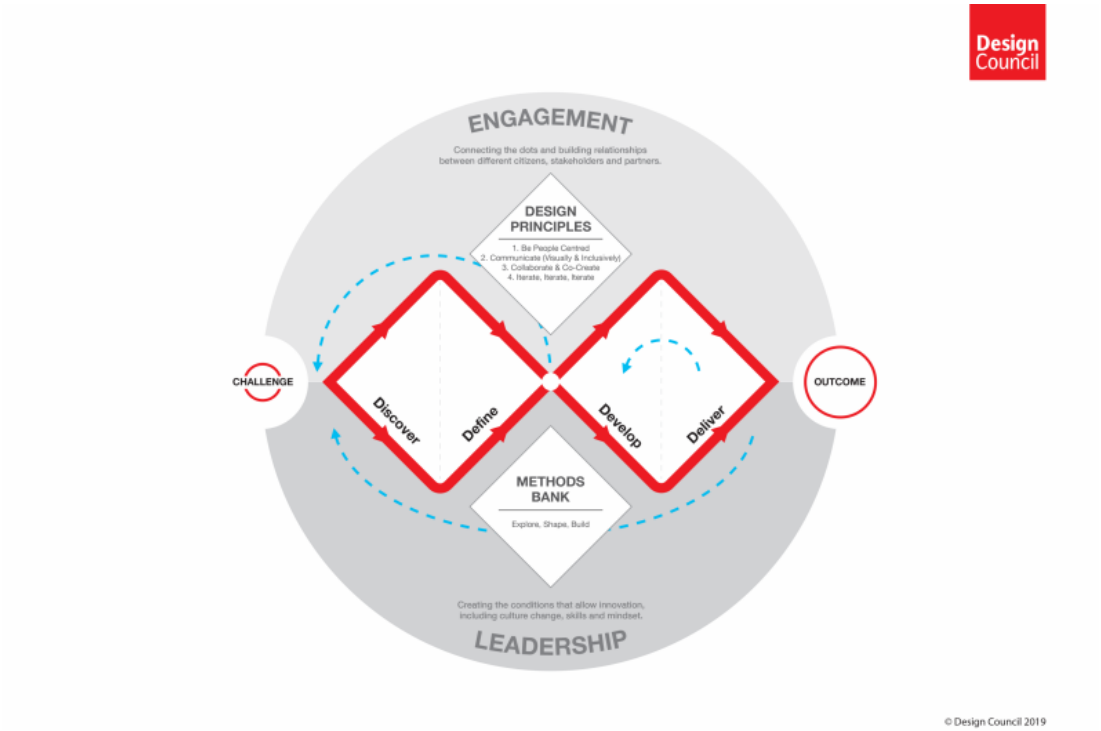


Figure 3.1: Double Diamond Model [2].

the Computer Communication and Networking course. As I learned about it, it became clear that teaching all aspects of the DNS was too much for a single game to cover, with the given design time frame. After discussing with my supervisor, the solution changed to helping Computer Science students understand the basic principles of the DNS lookup process and the various types of attacks that can occur along the way.

- Deliver: Small phases of testing to discard unworkable solutions while improving those that would work. This project was iterated through interviews with five student participants, an expert and a focus group to obtain feedback, thereby rejecting the inappropriate idea and optimising the appropriate ones.

3.2 Prototype Design

I used a standard approach to designing my prototype starting with setting the design goal and then moving on to design the story line, following by game level design and drawing the sketches, finally build the prototype mock-ups.

3.2.1 Design Goal

I intend for the game to be very immersive, to be able to really walks the players through the DNS look-up process, allowing them to learn the process from a first-person perspective.

The game should be a user-friendly system that is accessible to a general audience and easy to play for people with no experience of computer networking. It should also be fully designed in terms of interface interaction, and should clearly provide interaction clues for the player.I also wanted the game to be enjoyable and desirable to the player, and appealing enough to the player.

Finally, the ideal goal of the game is the player can reach the knowledge and comprehension levels of Bloom's taxonomy in learning.

3.2.2 Story Line

To bring in the player's first-person perspective, I have created the following story as an introduction.

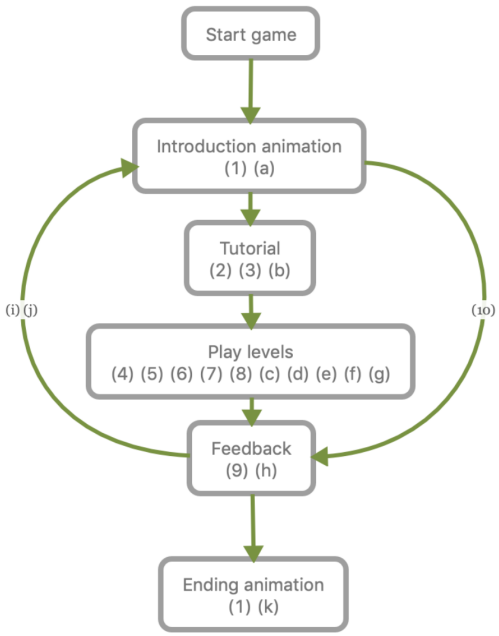
The main character, a man, sits at his computer at work. After working all morning, he wearily glances at his watch (11:25) and realises it is almost time for a break. He then opens his browser and navigates to www.example.com. After typing the Uniform Resource Locator (URL) in the address bar, he presses the Enter key. At that instant, a bright light erupted from the screen, impeding his vision. While panicking, he hears the browser talking to the operating system. Browser: 'Hey, do you have the IP address of www.example.com?'

Operating System: 'No...but I will ask our Local Name Server to find it for you.'

The operating system's animated image then informs the man that he is the Local Name Server. The system also explains its function before leading the man to the game's main task, which is to find the website's IP address by progressing through three levels.

Once the main character has passed all three levels and found the IP address, the game is finished. The man steps away from the computer and returns to his seat. He has no idea how much time has passed because he has just been through so much. His watch, however, indicated that it was only 11:26. Finally, he considers what has just occurred, remarking that it felt like a dream.

This story can matched the consistency of immersive, it helps players more easily put themselves in the shoes of the game characters and learn the knowledge mentioned



Game mechanic	Learning mechanic
1) Cut scene/Story	a) Instructional
2) Tutorial	b) Tutorial/Guidance
3) cascading information	c) Discovery
4) Simulate/response	d) Imitation
5) Time pressure	e) Simulation
6) Levels	f) Incentive
7) Movement	g) Competition
8) Capture/elimination	h) Feedback
9) Feedback	i) Reflection
10) Behavioural momentum	j) Repetition
	k) Discuss

Figure 3.2: Game mappings using LM-GM-based analysis.

in the process.

3.2.3 Game Level Design

The game is organised into three levels, each of which corresponds to a distinct stage in the DNS lookup process and includes a simulation of a specific DNS attack as a challenge. Tab. 3.1 describes each game stage's objectives, gameplay, challenges, learning outcomes and initial mapping to game mechanics. The three levels of the game are mini games with different play styles. The reason for this is to give the students more varied play styles, so that they can have anticipation for the next level and thus increase the appeal of the game. The type of attacks (challenges in the game) are selected because they are the most common DNS attacks and they are mostly mentioned in the Computer Communication and Networking lectures.

Along with the level design, I used the LM-GM model to integrate the game elements and learning objectives so that each of the latter has its mapped game mechanics (Fig. 3.2). Any numerical and alphabetical sequences in the flowchart can be found in the table below, along with their corresponding game and learning mechanics.

Tab. 3.2 presents the LM-GM analysis of this game. It details each game mechanic, along with its corresponding learning mechanism and implementation in the game.

Stage/Level	Objective	Gameplay	Challenge	Learning outcomes	Game mechanic
Introduction	Background storytelling	N/A	N/A	Understand the player character and the basics required to play the game.	Cut scene/Story, tutorial
Level 1	Win the game to find the Root Name Server	Bricks breaker game	Simulation of man-in-the-middle attack.	Understand the first stage in DNS look-up process and the man-in-the-middle attack.	Simulate/ response, time pressure, tutorial, capture/ elimination, movement, cut scenes/ story, behavioural momentum
Level 2	Win the game to find the Top-Level Domain Name Server	Platform game	Simulation of DNS poisoning attack.	Understand the second stage in DNS look-up process and the DNS poisoning attack.	
Level 3	Win the game to find the Authoritative Name Server	Maze game	Simulation of the Distributed Denial of Service (DDOS) attack.	Understand the third stage in DNS look-up process and the DDOS attack.	
Ending	Summarising	N/A	N/A	Enhance the knowledge from the levels.	Cut scene/Story

Table 3.1: Description of the objectives, gameplay, challenges, learning outcomes, and initial mapping to game mechanics in each game stage.

Game mechanic	Implementation	Learning mechanic	Description
Cut scene/Story	Use pre-rendered videos to explain the background story and basic information.	Instructional	The introduction and ending animation are used for introducing and summarising.
Tutorial, cascading information	Use tutorial to guide player how to play the game.	Tutorial/Guidance	Player is guided by text guide or graphics scenes at the beginning of the levels.
Simulate/response	Use simulation of the attacks to show the damage.	Imitation, simulation	The simulation of the attacks will be shown after losing the corresponding level.
Time pressure	To enhance activity, engagement.	Incentive, Competition	Countdown in each level.
Behavioural momentum, levels	Advanced technology of financial computing.	Repetition, reflection	Know the working principle of it.
Movement, capture/elimination	Navigate player to find the right place.	Discovery	Player needs to interact with the game to win the level, it can make the game more engaging.
Feedback	To present the result of the levels.	Feedback, Reflection, Discuss	After winning or losing the game, there will be simulating animation as feedback.

Table 3.2: The game's LM-GM analysis.

3.2.4 Sketches

In the early stages of the project, I sketched some designs on my iPad using the Notability app to illustrate a few ideas before formalising the game's content. It was similar to brainstorming in that I captured thoughts as they arise and considered their feasibility.

For example, while designing the first level, I made a sketch similar to Fig. 3.3 to indicate that the level has a bricks breaker game. While avoiding the monsters, the player must control a pad so that the ball may break the bricks that are blocking the root name server. If the player hits a monster, the game will simulate a man-in-the-middle attack and then ends.

3.2.5 Mock-Ups

After finishing the sketches, I chose to use MockingBot, a prototyping software that allows for easy sharing and engagement with interactive and dynamic prototypes, resulting in high-fidelity ones [9]. It not only has a wide range of tools for creating attractive designs and interactions, but it also ensures that participants may try out the prototypes more easily and realistically in the later feedback-gathering stages. Fig. 3.4 and Fig. 3.5 show examples of the prototype for the first level.

3.3 Feedback Collection

To promptly acquire user input on the game so that it could be iterated further, I invited and interviewed three students from the University of Edinburgh and a DNS research expert. They gave me advice after testing out the prototype.

3.3.1 Interview with Students

3.3.1.1 Participants

The three respondents have different backgrounds and are currently completing a master's degree at the University of Edinburgh.

- Participant A is an MSc student from the school of informatics. He has extensive programming and computer science knowledge and thus gave me professional advice on the game's DNS information.

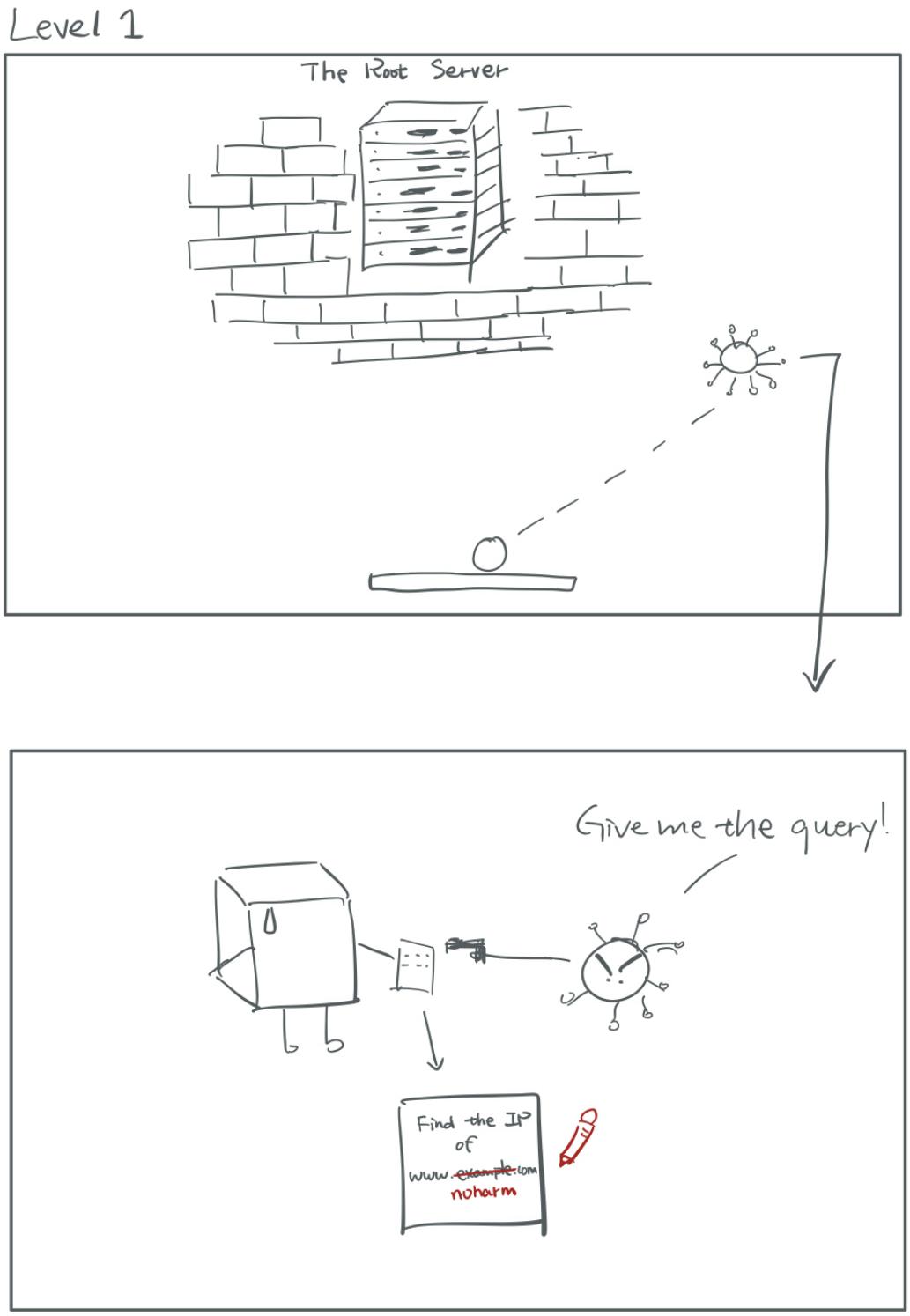


Figure 3.3: Level 1 sketches.

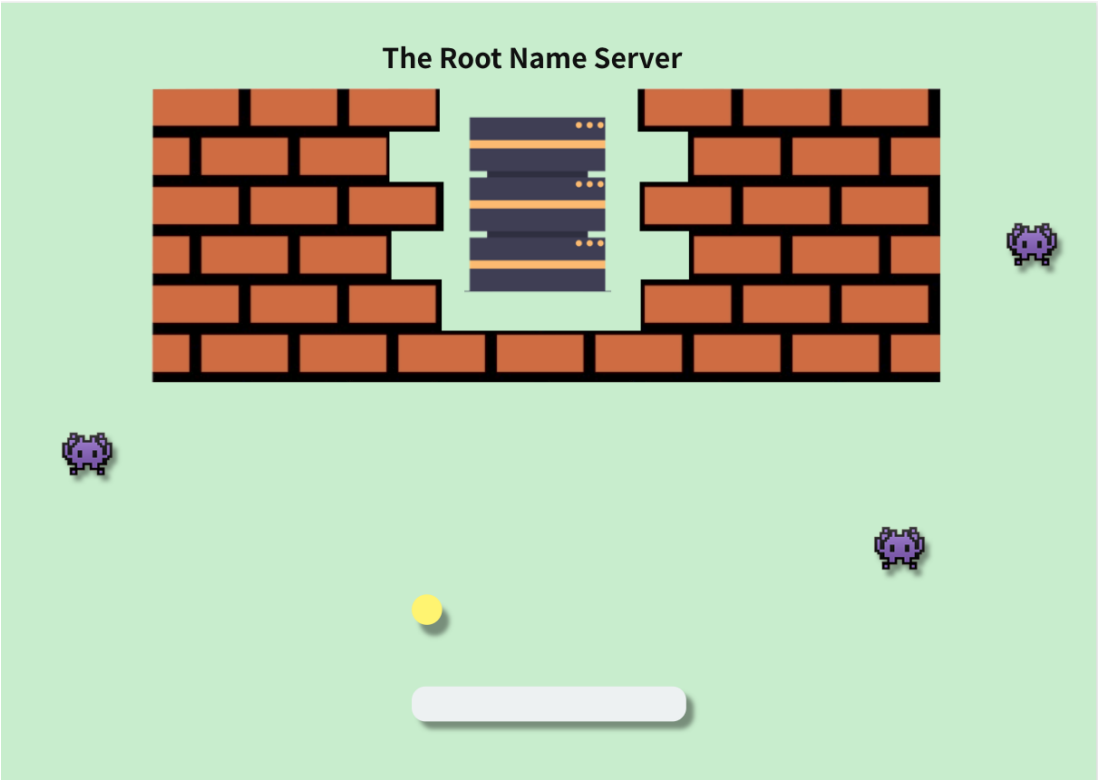


Figure 3.4: Prototype of Level 1.

Figure 3.5: Prototype of Level 1.

- Participant B is an MA student studying design informatics. She is highly knowledgeable in user interface and human-computer interaction aspects. Hence, she gave feedback on interface and interaction design.
- Participant C is an MSc student studying linguistics who knows little about computer networking. She offered input from a beginner's perspective, which could make the game more user-friendly to those who do not know the DNS.

3.3.1.2 Interview Procedure

The interviews with the three students took place in the common area of their respective flats to create the most convenient and comfortable environment for them. First, I handed each participant an information sheet (see Appendix A.1) and requested permission to make audio and video recordings. Before testing out the prototype, I asked them for some basic information, then explained the general gameplay and how the prototype would work. Afterwards, I started filming their screens and hands as they manipulated the computer. At the end of the experiment, I inquired about their experience, the learning content and whether they had any comments on parts not subjected to questioning. The complete interview script can be found in Appendix B.1.

3.3.2 Interview with an Expert

The expert interviews were an immensely powerful tool for this project, providing me with invaluable advice on game design, common problems, technical vulnerabilities, etc. The expert's advice was far more specialised than that of the student participants and gave deeper insights into specific technical issues.

Following an introduction from my supervisor, I was put in touch with Expert D, a professor in the School of Informatics at the University of Edinburgh, who has a distinguished career in web architecture, markup languages, cognitive science foundations and more.

After contacting Expert D via email, we agreed on a time and format for the interview. Due to the impact of COVID-19, we decided to conduct the interview online, using Microsoft Teams. Before the interview, I prepared a semi-structured script (see Appendix **??**) to follow the expected direction.

On the day of the interview, I presented the expert with the participant information sheet (see Appendix A.1) and asked if making an audio and video recording was possible. After receiving permission, I used the record option in Microsoft Teams, capturing

any key from the interview and aiding my recall. I began by briefly introducing myself and my project and inform how I would like him to advise me about my game. Then I presented my game prototype via screen sharing. After the demonstration, I questioned Expert D using the prepared interview script. As it was a semi-structured interview, he had greater freedom to elaborate on his ideas for the proposal.

3.4 Results

3.4.1 Student Participant Feedback

Before the participants tested the prototype, some basic questions were asked: how well they thought they knew about computer networking, their current level of knowledge on DNS and their views on educational games.

Though Participant A had taken a computer communication and networking course as an undergraduate and had some knowledge of DNS, he could not recall the specifics. He often plays video games in his leisure time but has not tried many educational ones. He believes that 'games can be a good educational medium, and the variety of expressions can provide a better presentation of the educational content'. He used terms such as 'profound', 'engaging', 'interesting' and 'expressive' to describe what he would like to see in an educational game.

Participant B did not know much about computer networking. Though she had heard about DNS in some courses, she did not understand its principles. She occasionally plays video games and has tried educational ones. According to her, educational games help the player better grasp the lesson and prompts critical thinking during gameplay. The current issue with them is that they can quickly get boring because many require users to repetitively perform the same action. Thus, the interaction is not innovative. She used the words 'playable', 'interesting', 'rewarding', and 'social' to describe her expectations for educational games.

Participant C had never heard of DNS. She occasionally played video games and had tried educational games that taught English many years ago. She found educational games to be 'very interesting and more engaging than the traditional way of learning about knowledge'. She uses adjectives such as simple, meaningful, accessible and lightweight to describe what she expects from an educational game.

After trying the game, Participant A felt that the connection between the gameplay and the content in the levels was weak, making it difficult for the player to experience

the DNS search process and the distinct types of attacks during the game.

Participant B found some of the terminology difficult to understand and several sentences explaining the learning content were not unclear. If the player wins on the first try, they will not be able to view the explanation for the attacks as it is only presented when the game is over. She suggested that after winning, a few dialogues can be added to convey the explanation.

Due to their vast number, Participant C felt that, while many of the abbreviations came with full terminologies when they first appeared, they were easy to forget and difficult to distinguish from one another when the player encountered them later.

3.4.2 Expert Participant Feedback

Expert D shared specialised input after witnessing the prototype presentation. He noted that, in the introductory animation, the content of the dialogue between the characters should be clearer. For example, the sentence 'You should start with The Root Name Server' should ideally end with the phrase 'at xxxx IP address'. This game must make people understand that it is not their fault if they experience DNS attacks and that the probability of such attacks occurring in real life is quite low. The game is an exaggeration of the facts; it does not imply that individuals should stop using the internet. He also suggested that a connection be formed between the levels – during the second level's pre-game tutorial. For instance, when the mouse hovers over the Root Name Server's image, an effect could be added – a phrase indicating the IP address given in the first level would appear. He also proposed that I provide a more detailed explanation of the attack after the game was over, making it easier for the player to grasp the attacker's actions. Furthermore, he recommended that another level be created if there is still time to do so. A fourth level could be an introduction to restrictive firewalls in some countries. In the game, it is assumed that a country has a restrictive firewall. Its network cannot access certain websites because any DNS requests made within this country are only redirected to its other routes. Based on this context, an additional level could give students some insight into the virtual private network (VPN) and restrictive firewalls. He said that 'instead of going into detail, you just have to say if your network situation means that you cannot access the full root servers, then you may need to do your lookup via a VPN. You need to install that VPN before you leave home.'

3.5 Conclusions

Overall, the three student participants each provided highly practical feedback on the links between gameplay and content, the logic of the game's flow and whether it is a beginner-friendly game. The expert participant shared numerous and detailed advice in terms of technical expertise, teaching content and level setting.

Some notable comments are as follows:

- The connection between the gameplay and the level's teaching was weak.
- Some of the terminologies were difficult to understand. A few of the sentences used to explain the learning content were unclear.
- After winning the game, the rationale for the attack is no longer visible.
- There were far too many abbreviations, making them forgettable.
- The dialogue between characters should be more explicit in explaining the content.
- The information on DNS redirection could be used to create a new game level.

Chapter 4

Second Design Phase

Following the user evaluation of the first design, many suggestions for improvement were obtained. This section details the first prototype design's iterations based on the student and expert participants' input. Moreover, I participated in a discussion with the TULIPS group at the University of Edinburgh and solicited feedback from its members on the second version's completed design.

4.1 Prototype Iteration

After considering the suggestions of both student and expert participants, I made the following changes to the prototype design.

1. Some sentences explaining the lectures' contents were enhanced to make them more comprehensible to beginners (Fig. 4.1).

2. Full terminologies of abbreviated technical terms were added as hints to help strengthen beginners' recall (Fig. 4.2).

3. The first level's bricks breaker game was changed to a dodge game, with the monster serving as a metaphor for a malicious middleman. The player controls the Local Name Server to evade the monster's (middleman) attacks and successfully gain access to the Root Name Server (Fig. 4.3).

4. Level 3's gameplay was changed from a maze game to a catch game, with magnifying glasses representing lookup requests and monsters signifying Distributed Denial of Service (DDOS) attacks. Players must open the port if the magnifier falls in and close it if the monster falls in within the stipulated time (Fig. 4.4).

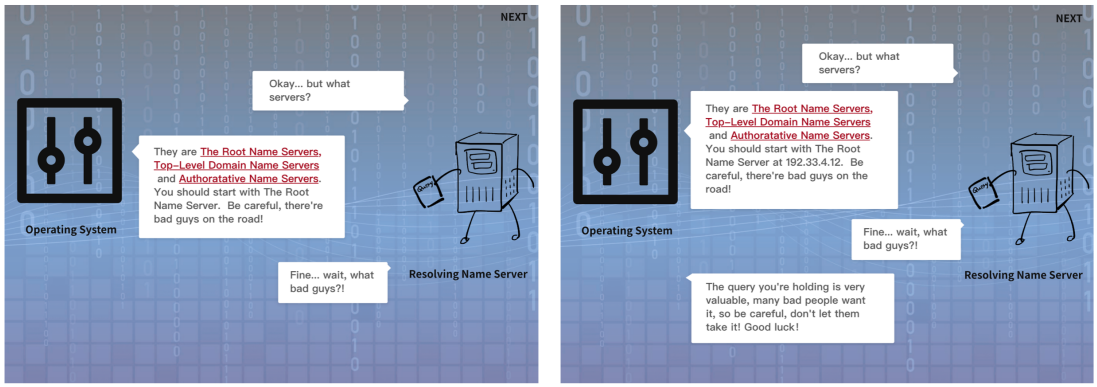


Figure 4.1: Original (left) and revised (right) explanations in the introduction animation.

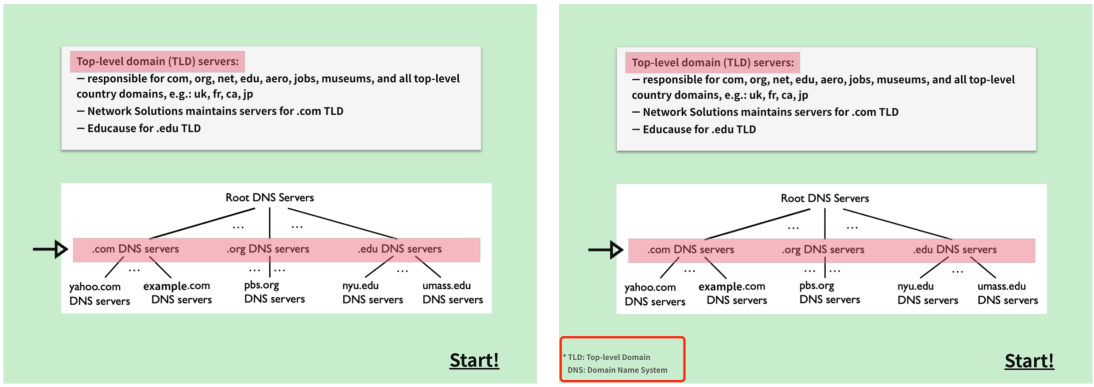


Figure 4.2: Original pre-game tutorial interface (left) and revised interface with full terminology hints (right).

5. At each level's pre-game tutorial stage, the player can view the IP address obtained from the previous level by hovering the cursor over the corresponding server image, gaining a better understanding of the context (Fig. 4.5).

6. A page has been added to clarify that the game exaggerates DNS attacks (Fig. 4.6).

4.2 Focus Group

The Technology Usability Lab in Privacy and Security (TULIPS) brings together a diverse set of students and researchers interested in understanding and improving the usability of security and privacy technologies. The members have extensive human-computer interaction experience, and have lots of experience giving feedback. They regularly giving advise to MSc and undergraduate students, some of them have a lot

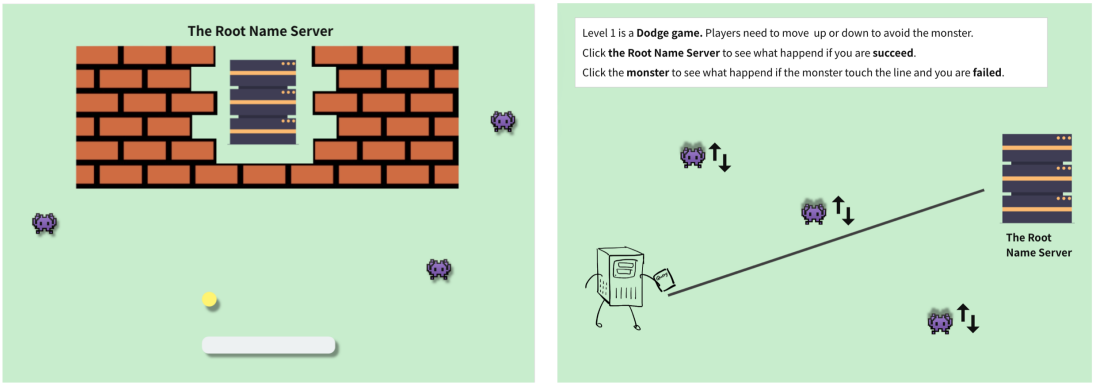


Figure 4.3: The first level's bricks breaker game (left) was changed to a dodge game (right).

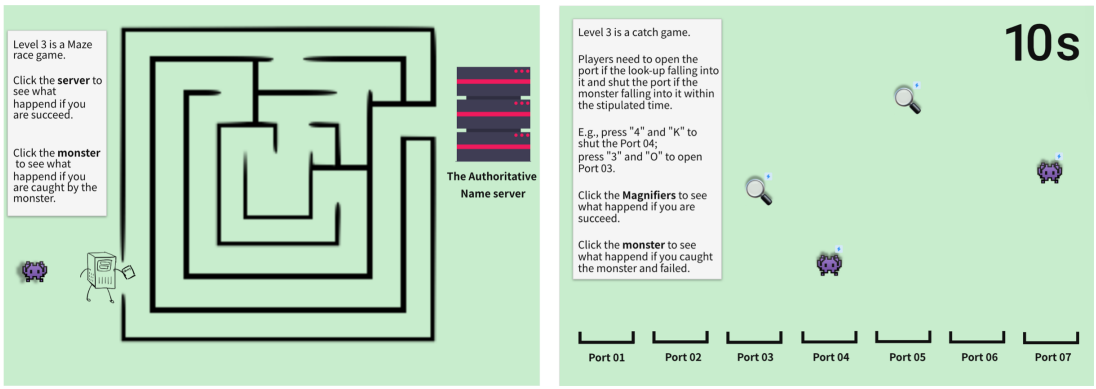


Figure 4.4: Modified level 3's gameplay from a maze game (left) to a catch game (right).

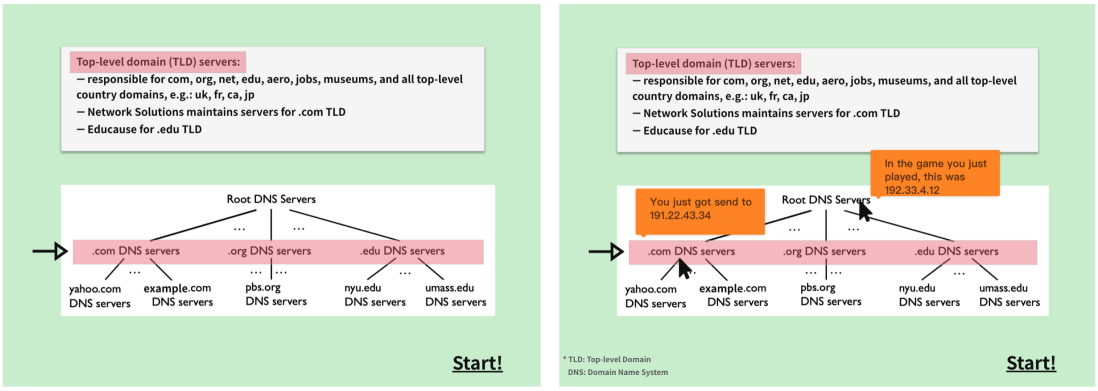


Figure 4.5: Original pre-game tutorial interface (left) and altered interface with IP address obtained from the previous level (right).

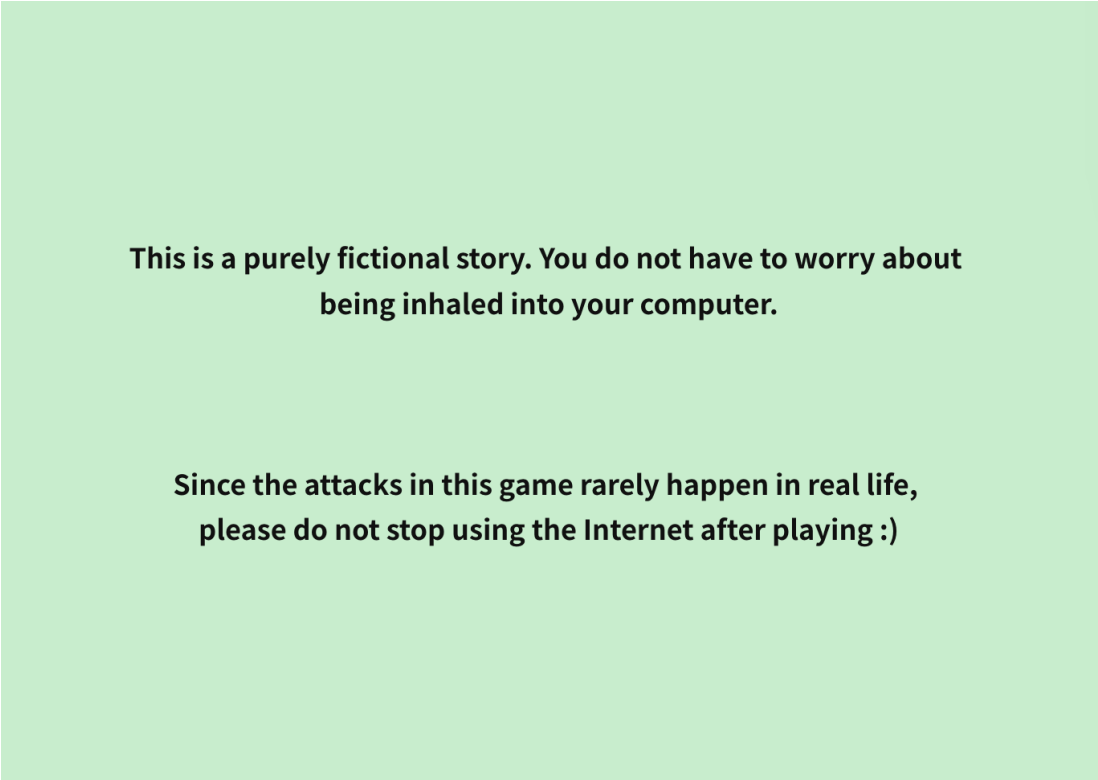


Figure 4.6: A statement page has been added for clarification.

educational game experience. They provided me with professional advice on a wider range of aspects which helped me a lot with my project.

4.2.1 Aims

To evaluate whether the modified game prototype would meet the preferences of most users and fulfil the stated learning objectives, I participated in a TULIPS group discussion and invited its researchers to hear a demonstration of my project and provide feedback.

4.2.2 Method

The TULIPS meeting occurs weekly. My supervisor sent an email to its members a week before my presentation, introducing my project and informing everyone that the following week's meeting would be running an informal focus group for my project. Due to the COVID-19 pandemic, the meeting was conducted online using Microsoft Teams. I started by introducing myself to the group, showing the participant information sheet and requesting permission to record audio and video. Once allowed, I

activated the record function and began sharing my screen, discussing my game prototype. After the presentation, several group members offered me valuable advice.

4.2.3 Result

This section explains the game iterations following the student and expert participants' feedback on the first version, as well as the focus group's evaluation and suggestions.

In the focus group, the researchers were extremely supportive of my project, giving positive comments. At the same time, one of the researchers shared that DDOS attacks were not particularly relevant to the game's theme as they do not only happen during DNS lookups. It was suggested that these could be replaced by, for example, the fast flux attack. Though this was an excellent input, the ensuing discussion led the group to realise that a DDOS attack was an example mentioned in the school's computer communication and networking course. Therefore, they ultimately recommended that I keep the DDOS attack and use the fast flux attack as a challenge if there was an opportunity to extend it to more levels in the future.

4.3 Conclusion

This chapter describes the seven main optimisations made to the prototype based on the feedback from the user interviews during the first design phase. After the focus group with the TULIPS group, the members had a very positive comment on this project.

The iterative design caused a lot potentially good changes, I therefore think when I do the evaluation it will be fine. However, when doing the evaluation, I need to make sure I look out for issues about the understanding of terminology and explanations in the game by players with no experience of computer networking.

Chapter 5

Game Implementation

5.1 Chosen Platform

I researched various game engines before starting development and settled on Phaser, a free and open source HTML5 game framework that supports WebGL and Canvas rendering and has most of the features needed to develop a web game [6]. I wanted to create a two-dimensional (2D) web game, and Phaser specialises in 2D games, which aligns with the goals of my project. In addition, many tutorials and examples can be found on Phaser's official website and on other video sites, which was highly beneficial for my game development.

5.2 Version Control

In software development, it is particularly useful and common to use a version control system to store and rebuild past versions of program source code, which can be especially important in collaborative projects. For this project, I used Git, a distributed version control system [26] that can be used on most development platforms. Also, Git facilitates software revisions by providing each developer with a full private copy of the software repository as well as numerous methods for managing modifications within its context.Github [4] is an online website which allows user to manage source code using Git. I have used Git via Github in previous projects, so I am relatively familiar with its use.

5.3 Problems and Solutions

In the process of implementing the first level of the game I encountered some problems, some in technical terms and some in design terms, but in the end I figured out ways to solve them all.

In my original prototype, I designed the game to allow the player to control the main character by using the keyboard arrow keys to avoid the monsters in the interface and eventually reach the Root Name Server, but in the actual code development, I found that instead of having four arrow keys to control the main character, it would be easier for most users to use the cursor to control the character's movement. This is more convenient for most users and gives more flexibility in controlling the character.

When setting the movement of the monsters, the idea during the prototyping stage was to have a few monsters moving in a random straight line across the interface and bouncing back when they hit the boundary. However, during the development process I realised that this would make it difficult for the user to win the game if the speed of the monsters' movement was set at a high level, and if the speed was low, the game would become unchallenging. Therefore, I changed the movement of the monsters to follow the cursor, but added a delay to the movement so that the monsters can follow the main character. The player needs to plan a good route or they will be caught by the monsters.

5.4 Game Layout

For the game's background colour, I chose light green since Clarke and Costall's research [16] stated that green, blue and purple usually make individuals feel comfortable, relaxed and calm, helping them reduce their anxiety levels. In this game, I wanted the players to be relaxed and entertained to relieve the stress of learning.

Due to time constraints during game development, it became impractical to implement all three levels of the design prototype. Therefore, I only implemented the introduction animation and the first level, simulated the man-in-the-middle attack and completed the conversations after winning and losing. The finished section included a complete story and level. Since the two remaining levels are similarly structured to the first level, the users watched a game demonstration to establish its viability.

Fig. 5.1 shows a screenshot of the first level, in which the player can direct the Local Name Server's path by moving the mouse to avoid the monsters in the middle

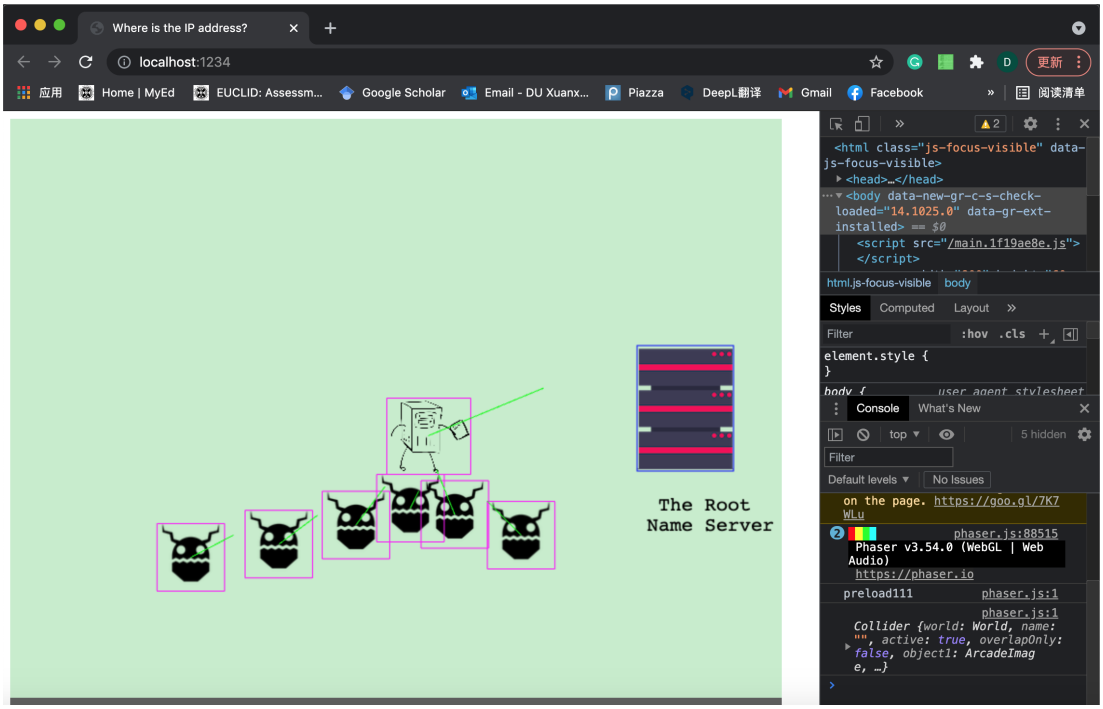


Figure 5.1: Screenshot of the developed Level 1.

and reach the Root Name Server.

Chapter 6

Discussion and Evaluation

This chapter establishes that the game was modified based on feedback, which includes an assessment of the user's knowledge before and after playing the game and an evaluation of the game's. The assessment of the learning objectives took the form of a pre-/post-game questionnaire, with questions designed in reference to Benjamin Bloom's taxonomy of learning created in 1956 [14]. For the game interface's usability, I employed Brooke's System Usability Scale (SUS) [15] and invited participants to rate the game.

6.1 Evaluation Questionnaire Design

6.1.1 Pre-Game Questionnaire

The pre-game questionnaire focused on the participants' current knowledge of computer networking and DNS, intending to compare their responses to the post-game questionnaire and more easily analysing the learning outcomes. A total of five participants took part in the evaluation of the game. Tab. 6.1 depicts some of their basic background information. Only P5 had taken the computer communication and networking course, whereas most of the respondents had not. Accordingly, those who had not studied computer networking and DNS systematically selected the 'never heard of it' or 'heard of it but don't know what it is' options when answering the question 'What do you know about computer networking?' Though P5 answered with 'know the working principle of it', he might not remember the specifics since he had taken the course three years ago.

Participant	Program	Taken Computer Communication and Networking?	Knowledge on computer networking?	Knowledge on DNS?	Frequency of playing video games
P1	Environmental protection and management	No	Heard of it but don't know what it is.	Never heard of it	Rarely
P2	Sociology and global change	No	Never heard of it	Never heard of it	Sometimes
P3	Lingguistics	No	Never heard of it	Never heard of it	Rarely
P4	Design Informatics	No	Heard of it but don't know what it is.	Heard of it but don't know what it is.	Rarely
P5	Advanced technology of financial computing	Yes	Know the working principle of it	Know the working principle of it	Often

Table 6.1: Participants' background information.

6.1.2 Post-Game Questionnaire

Bloom's taxonomy, which divides cognitive learning into six levels: knowledge, comprehension, application, analysis, synthesis and evaluation, was used in the construction of the post-game questionnaire [14]. The project aims to get beginners interested in the DNS and teach them some basic concepts. It was expected that, after playing the game, users would at least reach the knowledge stage and possibly progress to the comprehension or application level. Therefore, I divided the questionnaire into four sections: overall perception, knowledge, comprehension and application to assess whether the game could meet the learning objectives. In the overall perception section, I developed three questions: how fun the game was, how easy it was to play and how much the participants would recommend the game to anyone who needs to learn computer communication and networking. Knowledge is the lowest level in Bloom's taxonomy. At this stage, students should be able to recall the information they have learned and complete the following key verbs: list, recite, outline, define, name, match, quote [14]. I designed four questions to correspond to this section: choose the correct DNS full name, list at least one kind of DNS attack and DNS server and select the correct server in the diagram.

Comprehension follows the knowledge level, in which students should be able to understand, explain and summarise what they have learned in their own words and be able to perform the following key verbs: describe, explain, paraphrase, restate, give original examples of, summarise, contrast, interpret and discuss [14]. At this level, I created three assessment questions: describe the DNS lookup process, explain one of the DNS attacks and differentiate between DNS servers.

The succeeding level is the application stage, in which students should be able to use their knowledge flexibly and accomplish the following key verbs: calculate, predict, apply, solve, illustrate, use, demonstrate, determine, model, perform and present. At this level, I designed five assessment questions: how to prevent DNS attacks, what it means to build your own DNS, how to solve DNS-related computer problems and determine the reason for some DNS issues.

6.2 System Usability Scale

Five participants took part in the evaluation of the game's usability. I analyzed their responses by using Bangor et. al's [13] SUS score description (see Fig. 6.1) and Nathan

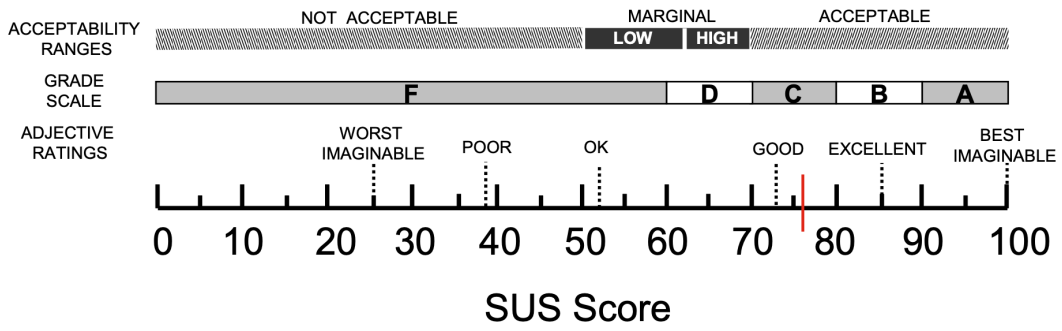


Figure 6.1: Comparison of average SUS scores to adjective ratings, acceptability scores and school grading scales, taken from [13]. The red line indicates the score achieved by the game in this project.

Participant	SUS	Gender	Age
P1	77.5	Female	25
P2	80	Female	23
P3	70	Female	23
P4	75	Gender	22
P5	77.5	Gender	24

Table 6.2: Each participant's SUS score and background information.

Thomas's SUS score calculation [5]. The game resulted in an average score of 76 (see Tab. 6.2), which is considered a *good* usability level [13].

6.3 Evaluation Result

Tab. 6.3 depicts participants' responses to the overall perception section of the post-game questionnaire. All of them thought the game was enjoyable and would recommend it to potential DNS learners they know. Regarding the game's ease of use, all participants found it fairly or somewhat easy. One respondent found it quite easy because he had taken a course on computer communication and networking. In terms of how much they would recommend the game to those who need to learn the content, four participants scored 4 and one scored 5, indicating that the game was well-received by them.

Regarding the knowledge section, all participants answered the questionnaire well and met the project's expectations. First, all of them accurately identified the full

Participant	Program	Rate the game according to how fun it is (1-5).	How easy was the game to play?	Rate the recommendation (1-5).
P1	Environmental protection and management	4	Fairly Easy	4
P2	Sociology and global change	4	Somewhat Easy	4
P3	Lingguistics	5	Somewhat Easy	5
P4	Design Informatics	4	Fairly Easy	5
P5	Advanced technology of financial computing	3	Fairly Easy	4

Table 6.3: Each participant's overall perception answers.

name of the DNS, even though three participants initially had no prior DNS knowledge before taking part in the evaluation game. Each remembered at least one DNS attack, with P2 recalling the names of two DNS attacks despite having never heard of DNS before, exceeding my expectations. Furthermore, participants were able to remember at least one DNS server name in the memory test, with P1 and P2 remembering two. All participants correctly answered the question about choosing a server based on hints in the game's screenshots, demonstrating that this project can help players reach the knowledge level of Bloom's taxonomy.

Although participants were less confident in their answers at the comprehension level than at the knowledge level, they were still able to give relatively correct responses to some questions. Participants were able to explain the general concept of the DNS lookup process but forgot the specific names of some of the DNS servers. When asked to briefly describe any of the DNS attacks, the participants were able to do so rather accurately. Notably, apart from P5, who detailed all three attacks, the other four participants chose to discuss the DNS poisoning and the DDOS attacks, with no one describing the man-in-the-middle attack. I believe this is because the man-in-the-middle attack appeared on the first level and was not as impressive as the latter two attacks. The third question asked participants if they could distinguish between the functions of different DNS servers, and all five participants chose yes. While many of the recruited participants did not have a computer science background, they nevertheless reached the comprehension level through the game's assistance. In comparison, students with computer science knowledge could certainly achieve their learning goals.

Except for P5, who had prior DNS knowledge and gave vague responses to some of the questions at the final application level, none of the remaining four participants could answer any of the questions. This was consistent with the project's initial expectation that the application level would require an extremely high level of knowledge and understanding. Since the project was designed to help beginners understand the DNS fundamentals, it was assumed that the players would be unable to reach this level.

Chapter 7

Conclusion

In conclusion, the game designed for this project fulfils its objective: it can be used as a teaching aid to help computer science students learn the basics of DNS and reach the knowledge and comprehension levels of Bloom's taxonomy. In terms of usability, the game also achieved a good level rating based on the SUS. Additionally, players who thought that the game would be a useful educational tool strongly recommended it.

7.1 Overview

The project started with the intention of creating a serious game that would support the DNS content taught in the university's computer communication and networking course. After conducting research and consulting with my supervisor, I realised that it would be impossible to entirely include the vast amount of DNS-related information in the game due to a limited time frame (one summer). Thus, the game's goal was then narrowed to helping computer science students learn the basics of the DNS lookup process and the different types of attacks they might encounter.

I conceived a preliminary storyline and level design for the game before creating the first version of the interactive-supported prototype, which was based on the LM-GM model's mapping of game elements and learning objectives. I then conducted interviews with three student participants and an expert to gather feedback on the initial version, thereby adjusting the game design. Moreover, through a focus group, TULIPS team members commented on my project, which helped determine the final version of the game. Some of their input could also be used as references for future work. The game was then developed based on the final prototype. Due to time constraints, the whole game could not be fully produced. Therefore, I only developed the introduction

animation and the first level of the game; the rest of the project could be completed by future researchers. At the end of the project, I invited five participants to evaluate the game's learning effect using a pre- and post-game questionnaire format and assess its usability via the System Usability Scale.

7.2 Achieved Result and Limitations

According to the evaluation results, the game achieved its stated objectives and served as an effective teaching aid for computer science students to learn about the DNS lookup process and the associated different types of attacks. The game was also assessed as a good system in terms of usability.

However, during the evaluation process, some participants were unable to remember the specific names of some servers, and some concepts may not have been thoroughly understood. Furthermore, only five participants were included for game evaluation in this project. A larger sample size would be required for a more advanced assessment and study of the game. This project's game development only covered the introduction animation and the first level. Hence, there is still more work needed and a lot of room for improvement in the game's level design and teaching content.

7.3 Future Work

Future work will probably focus on four areas: completion of the unfinished game parts, interface embellishment, expansion of the teaching content and optimisation of the game mechanics.

Due to time limitations, the game has only been partially implemented in the design draft, with the remainder to be completed in the future by researchers interested in this game.

The aesthetics of the game's interface elements left much to be desired and can be improved in the future by professional designers or art students. The game currently only covers a small portion of DNS-related information included in the university's computer communication and networking course and does not offer students a complete picture of what they should be learning. Extending the material by adding more levels should be done in the future, as Expert D suggested during his interview. In addition, the TULIPS members in the focus group recommended that the fast flux attack could be added as another challenge in the game if the levels are expanded in the

future.

When a game is won, the game presently only displays a congratulatory screen but with no full reward mechanism. A complete reward structure could further engage the user if more levels were introduced in the future. In addition, the explanatory sentences in the game need to be stated clearly so that students can understand them more easily.

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Appendix A

Participant Information Sheet

A.1 Phase 1

Participant Information Sheet

Project title:	A Video Game that Helps Computer Science Students Learn about the Domain Name System
Principal investigator:	Kami Vaniea
Researcher collecting data:	Xuanxuan Du
Funder (if applicable):	The University of Edinburgh

This study was certified according to the Informatics Research Ethics Process, RT number 2019/67374. Please take time to read the following information carefully. You should keep this page for your records.

Who are the researchers?

The research is being conducted by Xuanxuan Du who is a Masters student at the University of Edinburgh and her supervisor Dr Kami Vaniea.

What is the purpose of the study?

The purpose of this project is to help beginners to understand the basic principles of the Domain Name System (DNS) and help them achieve higher marks in their Computer Communications and Networks courses using a serious video game. This study is used to collect the feedback of a game prototype for further improvement.

Why have I been asked to take part?

You have been asked to take part because you are a University student in Informatics. This study is used for improving the interface, gameplay and process of the game, basic knowledge of computer networks is needed for participating the study.

Do I have to take part?

No – participation in this study is entirely up to you. You can withdraw from the study at any time, without giving a reason. Your rights will not be affected. If you wish to withdraw, contact the PI. We will stop using your data in any publications or presentations submitted after you have withdrawn consent. However, we will keep copies of your original consent, and of your withdrawal request.

The University of Edinburgh is a Data Controller for the information you provide. You have the right to access information held about you. Your right of access can be exercised in accordance Data Protection Law. You also have other rights including rights of correction, erasure and objection. For more details, including the right to lodge a complaint with the Information Commissioner's Office, please visit www.ico.org.uk. Questions, comments and requests about your personal data can also be sent to the University Data Protection Officer at dpo@ed.ac.uk.
For general information about how we use your data, go to: edin.ac/privacy-research

Who can I contact?

If you have any further questions about the study, please contact the lead researcher, Xuanxuan Du on s2017973@ed.ac.uk.
If you wish to make a complaint about the study, please contact inf-ethics@inf.ed.ac.uk. When you contact us, please provide the study title and detail the nature of your complaint.

Updated information.

If the research project changes in any way, an updated Participant Information Sheet will be made available on http://web.inf.ed.ac.uk/infweb/research/study-updates.

Consent

By proceeding with the study, I agree to all of the following statements:

- I have read and understood the above information.
- I understand that my participation is voluntary, and I can withdraw at any time.
- I consent to my anonymised data being used in academic publications and presentations.
- I allow my data to be used in future ethically approved research.

  [Button here named "I agree" or "take me to the survey"]

A.2 Phase 2

Participant Information Sheet

Project title:	A Video Game that Helps Computer Science Students Learn about the Domain Name System
Principal investigator:	Kami Vaniea
Researcher collecting data:	Xuanxuan Du
Funder (if applicable):	The University of Edinburgh

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The research is being conducted by Xuanxuan Du who is a Masters student at the University of Edinburgh and her supervisor Dr Kami Vaniea.

What is the purpose of the study?

The purpose of this project is to help beginners to understand the basic principles of the Domain Name System (DNS) and help them achieve higher marks in their Computer Communications and Networks courses using a serious video game. This study is used to collect the usability and knowledge-acquisition feedback of a game for evaluation.

Why have I been asked to take part?

You have been asked to take part because you are a University student. This study is used for evaluating an educational game which is intended to be a teaching aid in universities.

Do I have to take part?

No – participation in this study is entirely up to you. You can withdraw from the study at any time, without giving a reason. Your rights will not be affected. If you wish to withdraw, contact the PI. We will stop using your data in any publications or presentations submitted after you have withdrawn consent. However, we will keep copies of your original consent, and of your withdrawal request.

The University of Edinburgh is a Data Controller for the information you provide. You have the right to access information held about you. Your right of access can be exercised in accordance Data Protection Law. You also have other rights including rights of correction, erasure and objection. For more details, including the right to lodge a complaint with the Information Commissioner's Office, please visit www.ico.org.uk. Questions, comments and requests about your personal data can also be sent to the University Data Protection Officer at dpo@ed.ac.uk.
For general information about how we use your data, go to: edin.ac/privacy-research

Who can I contact?

If you have any further questions about the study, please contact the lead researcher, Xuanxuan Du on s2017973@ed.ac.uk.
If you wish to make a complaint about the study, please contact inf-ethics@inf.ed.ac.uk. When you contact us, please provide the study title and detail the nature of your complaint.

Updated information.

If the research project changes in any way, an updated Participant Information Sheet will be made available on http://web.inf.ed.ac.uk/infweb/research/study-updates.

Consent

By proceeding with the study, I agree to all of the following statements:

- I have read and understood the above information.
- I understand that my participation is voluntary, and I can withdraw at any time.
- I consent to my anonymised data being used in academic publications and presentations.
- I allow my data to be used in future ethically approved research.

  [Button here named "I agree" or "take me to the survey"]

Appendix B

Interview Documents

B.1 Students Interview Script

Opening remarks:

Hi, my name is Xuanxuan and I am writing my dissertation on educational games for the Domain Name System (DNS), trying to understand the issues that can arise in educational games. I would also be interested to know your opinions on my game prototype at this stage. Your contribution to my dissertation research has been extremely valuable to me and I would therefore like to ask your permission to make audio, video and photographic recordings. (switches recorder on)

Please be assured that this is purely for data collection purposes and that your data will be treated confidentially. The data will be referred to by a unique participant number rather than by name. If at any time you feel uncomfortable, just let me know and you can stop participating at any time.

Pre-game session:

At first, I will ask you some basic questions before you try the prototype:

1. What do you study now?
2. What would you say about your current level of knowledge of computer networking?
3. Have you heard about Domain Name System (DNS)? What do you know about DNS?
4. Do you play video games?
5. Have you tried educational video games?

6. What do you think about educational video games?

7. Please use 4 words to describe an educational video game in your expectation.

Gameplay explanation:

Thank you for answering these questions. I am going to explain the general gameplay of this game, this is a prototype of an educational game which try to explain DNS to potential networking students, the game is started with an animation, then there will be three levels, after winning all the levels, there will be an ending animation.

Now please try the game prototype. In the meantime, you can ask me questions when confusing, please be noted again, your questions will be recorded.

// The participants trying the prototype.

Post-game session:

After participants have tried it, ask them these questions:

Experience

1. What do you think about the interface of the game you played?

2. What do you think about the interaction of the game you played?

3. Which parts of the game did you enjoy the most?

4. Which parts of the game did you enjoy the least?

5. What do you think the way of imparting knowledge?

6. In your opinion, how effective was it to use a game to teach about DNS?

7. Did the game flow make sense to you?

Learning result

1. Please describe a few components of DNS.

2. Please describe a few types of attack.

3. Please name or describe one new thing you learned from this game.

Problems

1. Is there anything you found confusing?

2. Do you have any advise about the gameplay?

3. Is there anything else that you think should be included in the game?

Concluding remarks

Thank you very much for your contribution in my research and share your insights with me, have a good day. (switches recorder off)

B.2 Expert Interview Script

Hi, my name is Xuanxuan and I am writing my dissertation on an educational game for the Domain Name System (DNS), trying to understand the issues that can arise in educational games and the vulnerabilities that I may face. I would also be interested to know what aspects of DNS you think should be taught better and your thoughts on my game prototype at this stage. Your contribution to my dissertation research has been extremely valuable to me and I would therefore like to ask your permission to make audio, video and photographic recordings. Please be assured that this is purely for data collection purposes and that your data will be treated confidentially.

First, I am going to show you the prototype of the game, it's going to take about 10 minutes.

[Show the prototype]

Questions:

1. How do you like the storyline in this game?
2. Do you think that the game contains enough knowledge for students to have a general understanding of DNS?
3. How do you think the resolving name server performed as the main character of the mini games? Does that make sense?
4. Is there anything wrong about the servers or attacks in this game?
5. What do you think of the conversations? Do you think the explanations should be more detailed?
6. Are there any other elements that you think would be important but the game haven't included?

I think this brings us to the end of the interview. Do you have any remaining questions or remarks?

Well then, thank you very much for your contribution in our research and taking the time out of your busy day to talk to me and share your insights with me.

Appendix C

Evaluation Documents

C.1 Pre-game Questionnaire

Pre-game questionnaire

1. What is the program you are doing now?

   _____

2. How often do you play video games?
   - ☐ Never
   - ☐ Rarely (1-2 times a week)
   - ☐ Sometimes (3-4 times a week)
   - ☐ Often (Daily once or twice)
   - ☐ Always (Multiple times a day)

3. Have you ever taken a course of Computer Communication and Networking before?
   - ☐ Yes
   - ☐ Some courses include some of it
   - ☐ No

4. What do you know about computer networking?
   - ☐ Never heard of it.
   - ☐ Heard of it but don't know what it is.
   - ☐ Only know basic knowledge of it.
   - ☐ Know the working principle of it.
   - ☐ Have sufficient knowledge of it.

5. Do you know how the web page you want to view appears in your browser?
   - ☐ Yes
   - ☐ Not exactly
   - ☐ No

6. What do you know about Domain Name System?
   - ☐ Never heard of it.
   - ☐ Heard of it but don't know what it is.
   - ☐ Only know basic knowledge of it.
   - ☐ Know the working principle of it.
   - ☐ Have sufficient knowledge of it.

C.2 Post-game Questionnaire

Post-game questionnaire

1. How fun do you think the game you just played?

Very boring				Very entertaining
1	2	3	4	5

2. How easy do you think the game was to play?

Not easy				Very easy
1	2	3	4	5

3. How much would you recommend this game to a potential DNS learner you know?

Not recommended				Very recommended
1	2	3	4	5

Knowledge:

4. Please tick the right full name of DNS.
   - ☐ Distribute Network System
   - ☐ Domain Name System
   - ☐ Domain Network System

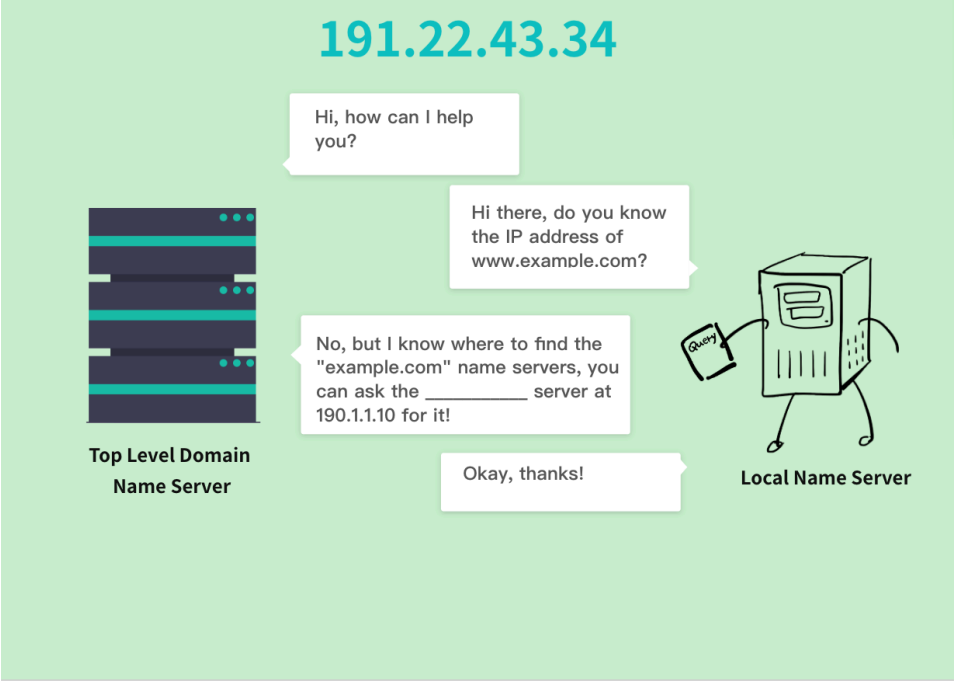
5. Please list at least 1 kinds of DNS attacks that you remembered.

   _____

6. Please list at least 1 kinds of DNS servers that you remembered.

   _____

7. Please fill the blank in the image.



Comprehension:

8. Please describe the DNS look-up process with an example.

_____

_____

_____

9. Can you briefly explain one of the DNS attacks?

_____

_____

_____

10. Can you distinguish between the functions of different DNS servers?
    - ☐ Yes
    - ☐ No

Apply:

11. Do you know how to prevent the DNS attacks? (strongly agree — dis)
    - ☐ Yes
    - ☐ Not really
    - ☐ No

12. Do you know the meaning of building your own DNS?
    - ☐ Yes
    - ☐ Not really
    - ☐ No

13. Do you know how to solve computer problems relate to DNS?
    - ☐ Yes
    - ☐ Not really
    - ☐ No

14. Can you determine the reason of some DNS problems?
    - ☐ Yes
    - ☐ Not really
    - ☐ No

C.3 System Usability Scale Survey

Feedback Survey

Please check the box that reflects your immediate response to each statement. Don't think too long about each statement. Make sure you respond to every statement. If you don't know how to respond, simply check box "3."

	Strongly disagree				Strongly agree
1. I think that I would like to use this product frequently.	1	2	3	4	5
2. I found the product unnecessarily complex.	1	2	3	4	5
3. I thought the product was easy to use.	1	2	3	4	5
4. I think that I would need the support of a technical person to be able to use this product.	1	2	3	4	5
5. I found the various functions in the product were well integrated.	1	2	3	4	5
6. I thought there was too much inconsistency in this product.	1	2	3	4	5
7. I imagine that most people would learn to use this product very quickly.	1	2	3	4	5
8. I found the product very awkward to use.	1	2	3	4	5
9. I felt very confident using the product.	1	2	3	4	5
10. I needed to learn a lot of things before I could get going with this product	1	2	3	4	5

11. What is your gender?
    - ☐ Female
    - ☐ Male
    - ☐ Other
    - ☐ Prefer not to say

12. How old are you? I am _____ years old.