Cyber Adventure - An Education 2D RPG Game to teach Cybersecurity Concepts

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***Abstract*—In today's digital age, there exists a pressing need to educate students about cybersecurity principles. However, traditional teaching methods can often be inaccessible or tedious. Recognizing this gap, this project, 'Designing a Computer Game to Teach Computer Science Concepts' proposes a novel approach to addressing this educational challenge. It introduces a 2D RPG web-based game which is designed to create an engaging learning environment for students. Beyond just mere entertainment, this game integrates interactive mini-games and puzzles tailored to convey core cybersecurity concepts. These puzzles are carefully crafted to provide players with hands-on experience to face real-world scenarios and challenges in a fun, virtual environment. The aim of the project is not just to educate but to captivate beginners, especially those with minimal prior knowledge in cybersecurity. By transforming passive learning into an active discovery process, this approach has the ability to ignite a passion for cybersecurity in students. Initial user feedback and surveys suggest a promising trend: participants consistently report heightened interest and retention of the subject matter. In conclusion, the project offers a novel solution to a contemporary educational challenge, presenting an instructive tool that makes learning cybersecurity both enjoyable and effective, paving the way for innovative teaching methods in the digital era.**

I. Introduction

Computer Science is the study of computer systems and technologies, including the theory, design, development, and application of computer systems. It involves various branches such as Artificial Intelligence, Machine Learning, etc. However, the main focus of the project is to design a computer game to teach cybersecurity concepts.

Cybersecurity is a major branch of computer science that applies principles and techniques to secure computing systems and networks. It is essential for students to learn and understand cybersecurity fundamentals to protect themselves from potential threats. An innovative way to teach cybersecurity concepts is through computer games. Games have proven to be effective in educating students about cybersecurity, providing an immersive and enjoyable environment for learning. This report explores the development of a computer game designed to teach fundamental cybersecurity principles to students.

A survey suggests that 64 percent of students would not know how to react in a situation where they were under a cyberattack [1]. This is a significant problem as cyberattacks are becoming more prevalent with the rapid advancement of technology. It is crucial for students to have a basic understanding of cybersecurity concepts and be aware of possible threats. While theoretical knowledge is important, research indicates that people often struggle to apply their theoretical knowledge in real-life scenarios [2]. This highlights the importance of practical application and hands-on learning experiences.

Another study conducted by the National Cybersecurity Alliance (NCA) and CybSafe revealed that 62 percent of users lack access to cybersecurity knowledge, and a significant portion relies on the help of friends and family [3]. This indicates a significant gap in cybersecurity awareness among users who are regularly exposed to potential threats online. Therefore, raising awareness about cybersecurity concepts and promoting safe practices is crucial.

The incentive to learn cybersecurity among students is low due to the primarily theoretical nature of available knowledge and training tools. Existing games like CyberStart [4], TryHackMe [5], and Hack the Box [6] can appear intimidating and can create an environment that discourages beginners from using them, which is not ideal for an educational game. Additionally, many existing games operate on a membership basis or require purchases to access more engaging sections, further hindering accessibility for newer users. To address these challenges, the project aims to make the game accessible to everyone and beginner-friendly, reaching a broader audience.

The project aims to bridge the gap between fun and learning by utilizing game-based learning. Gamification can effectively teach and reinforce skills that might be forgotten without practical application [7]. Using gamification, can help educate the target audience about fundamental cybersecurity concepts, simulate an engaging and interactive environment, and facilitate learning reinforcement. It goes beyond traditional educational approaches and offer a unique and innovative platform to educate students.

The game follows a 2D Role-Playing Game approach, incorporating maps, levels, and interactive gaming logic to teach cybersecurity concepts. The intermediate deliverables, include completing game levels, designing character sprites, creating maps, and implementing interactive elements. The game consists of a map with a distinct theme and multiple intriguing and puzzling mini-games to teach and reinforce cybersecurity concepts to the end user.

In terms of sustainability, the project had limited consideration due to its intrinsic educational nature. However, the project realized certain domains where it intersects with the broader sustainability goals categorized by the United Nations Sustainable Development Goals (SDGs) [8]. The Sustainability Considerations section provides an in-depth discussion on this topic.

The final product, 'Cyber Adventure', is a 2D RPG web-based game tailored to convey intricate cybersecurity concepts through engaging puzzles and mini-games. This innovative

This project was supervised by Dr.Karsten Lundqvist.

approach has garnered positive feedback, with users demonstrating heightened interest and retention in cybersecurity topics. The game's success emphasizes the potential of gamified learning in modern education.

II. Background Research

This section will cover background information about games,concepts and tools that exist to teach cybersecurity concepts along with the tools and methodology discussion to check which ones are fit for use.

A. Related Concepts

1) Serious Games: Serious games are video games aimed toward problem-solving rather than entertainment. They use the same media as video games aimed at recreational play. However, serious games can help learners gain a good understanding of a specific topic and sustain the acquisition of complex competencies [9].

In terms of cybersecurity, serious games play a significant role in teaching and reinforcing cybersecurity concepts, skills, and best practices. Games can be designed to simulate real-world cybersecurity scenarios and challenges, providing a hands-on and practical learning experience for individuals.

One study investigated whether a serious game that is designed based on the findings of previous studies and best practices can improve participants' scores on theory of planned behavior (TPB) factors. TPB scores help conceptualize serious gaming in the context of cybersecurity as it takes into account not only personal attitudes, but also the influence of peers and perceptions of ability, allowing us to investigate more than just the change in intentions or behavior . They found that a well designed serious game based game can have a positive effect on self-reported TPB scores and user behavior [10].

Another study involved developing a 2D Sherlock-based serious game and focused on studying the effectiveness of the serious games on undergraduate students. The study found the game to be an effective, attractive and fun solution for allowing further engagement with content that students were introduced to during lectures. This research lends additional evidence to the use of serious games in supporting learning about cyber security [11].

Learning from the impact of serious games, the platform melds narrative with core cybersecurity concepts. This design choice fortifies the bridge between theoretical knowledge and its practical, real-world implications.

2) Capture the Flag: When it comes to the gamification of cybersecurity and its concepts, the most popular approach is called Capture the Flag. All the existing solutions discussed above follow this concept. The concept refers to a game mode or challenge where participants compete to find and exploit vulnerabilities, solve puzzles, and complete various tasks in order to capture flags or obtain specific pieces of information.

Introducing technical concepts to students with limited technical background can be a daunting task for educators. However, gamification has emerged as an effective method to engage and motivate students by incorporating elements from popular games into educational modules. In this context, capture the flag (CTF) style competitions have proven to be a successful approach for introducing students to various technical concepts within the standard computer science curriculum [12].

A study that focused on the Learning Obstacles in the Capture The Flag Model, also showed that this concept has been very successful for learning and evaluation and has been deployed with much success in many different environments [13].

Overall, CTFs can help in developing and upgrading practical cybersecurity skills, encouraging critical thinking and fostering a competitive learning environment. These games offer a hands-on experience where players can apply their knowledge, test their abilities, and gain exposure to various cybersecurity concepts and techniques.

Taking inspiration from the CTF model, the game weaves in immersive challenges. To ensure a holistic learning experience, users are exposed to both concepts and hands-on skills in cybersecurity.

B. Related Works

The state of the art for this project is in the form of existing games and learning tools. These were researched and carefully selected to conduct the literature review on to study their benefits and drawbacks.

1) TryHackMe: TryHackMe is a gamified online platform that delivers hands-on cybersecurity training. It provides a variety of virtual environments, referred to as "rooms," in which users can practise and improve their cybersecurity skills [5].

TryHackMe has a user-friendly interface that makes it accessible to both novices and more experienced users. The platform provides a guided learning route that allows users to develop at their own pace while gradually expanding their knowledge and skills. It offers step-by-step instructions and recommendations to help users solve problems, making it an invaluable resource for learning and practising various cybersecurity approaches.

However, the main drawback of this tool is that it relies on the user's self-motivation and dedication levels to facilitate learning. Due to this, some users may find the learning curve steep, especially if they have limited prior knowledge of cybersecurity concepts. Moreover, TryHackMe is heavily textual and at times theoretical, which can cause boredom amongst students.

Reflecting on TryHackMe's strengths, the new game harnesses an intuitive interface, catering to all proficiency levels. Moreover, responding to drawbacks on its theoretical and textual nature, the game has been tailored to be more interactive and visually engaging.

2) CyberStart: CyberStart is a dynamic online game created with students in mind to present and teach cybersecurity fundamentals. It was developed by the SANS Institute, a leading organization in cybersecurity education and training

[4]. The game focuses on teaching cybersecurity fundamentals to college and high school students who have little to no prior experience with cybersecurity.

One of CyberStart's primary features is its interactive nature. It gives students timely feedback and direction so they may learn from their errors and advance their comprehension of cybersecurity principles while also providing resources and hints. CyberStart's gameplay is organised into a series of levels or challenges, each of which focuses on a different cybersecurity topic which encourages critical thinking and problem-solving among students.

CyberStart's major drawback is the course fees associated with games and levels. Although the games can be very fun and intuitive, accessing the majority of the games requires users to pay a lump sum amount which can drive the newer and less passionate users away.

Taking cues from CyberStart's feedback-centric approach, the game offers users engaging and actionable guidance. To address the cost-related critiques, this platform ensures comprehensive content is free and accessible.

3) OverTheWire: OverTheWire offers a variety of wargames designed to help individuals learn and practice cybersecurity skills. It provides a series of challenges and puzzles that require players to solve them using various techniques and tools [14].

The challenges called wargames, on OverTheWire are designed to simulate real-world cybersecurity scenarios, allowing participants to apply their knowledge in a realistic context. Moreover, unlike the majority of other games, OverTheWire offers their services for free, making the game beginner-alluring and accessible.

Due to the fact that the game is free, it lacks a structure and support facilities which can lead to lack of assistance for new users who get stuck on a challenge. The game is beginner-friendly, however, the learning curve increases drastically after a few levels which can prove to be challenging for new users and beginners.

Adapting from OverTheWire's cost-free approach, the game presents users with real-world cybersecurity challenges. Additionally, to address the need for structured learning, the platform offers a clear and progressive learning path.

C. Proposed Solution

To summarize, Building upon the limitations found in existing gamified cybersecurity platforms such as TryHackMe, CyberStart, and OverTheWire, the proposed solution introduces a gamified platform designed to be highly engaging, user-friendly, and economically accessible.

Drawing from the success of serious games in teaching complex concepts, the platform integrates narrative and storytelling to make cybersecurity learning engaging and effective. Through a carefully designed storyline, users are introduced to cybersecurity concepts in a contextual and memorable manner.

Building on the Capture The Flag (CTF) concept, the platform provides a simulated environment where users can engage in real-world cybersecurity scenarios, fostering not only theoretical understanding but also practical skills.

The game leverages advanced gamification techniques to ensure sustained user engagement. Unlike TryHackMe, which is textual and theoretical, this platform provides a more interactive and visually appealing learning environment. Moreover, it addresses the cost barrier associated with CyberStart, allowing users to access content for free.

In contrast to OverTheWire, which lacks structured support for learners, the proposed platform offers a well-structured learning pathway, guiding users through progressively challenging cybersecurity concepts and practices.

To further support the learning journey, the platform incorporates an in-built support system, providing hints and explanations to users when they encounter challenges, ensuring a conducive learning environment that caters to both novices and more experienced individuals.

The proposed solution, therefore, aims to fill the identified gaps in existing solutions, offering a comprehensive, engaging, and novel solution for learning cybersecurity.

D. Tools and Methodology

1) Javascript: For this project, vanilla JavaScript was predominantly utilized. This decision was made keeping in mind key considerations. Firstly, vanilla JavaScript ensured that there were no overheads associated with external libraries, leading to a lightweight and efficient game. It also provided complete control over the game's functionalities, allowing for tailored optimizations and customizations specific to the game's educational objectives. While frameworks can offer pre-built functions and shortcuts, they sometimes come with unnecessary bloat and can introduce complexities not essential for the project. Using vanilla JavaScript also posed challenges, demanding a deeper understanding of the language and careful manual coding to ensure cross-platform compatibility. This choice aligned perfectly with the project's principle of 'Universal Accessibility', as the game was designed to be accessed across various devices without any specific software dependencies. However, for the audio component of the game, Howler.js [15], a lightweight yet powerful audio library was used. It was chosen for its simplicity and effectiveness in handling audio across various devices and browsers, ensuring a consistent auditory experience for users. This was particularly crucial given the educational nature of the game, where clear and reliable audio cues could enhance the learning experience. Howler.js's capabilities meant that while the game's primary logic and mechanics were crafted entirely using vanilla JavaScript, the audio was managed seamlessly, providing an integrated and immersive experience for users. Regarding the decision to bypass traditional game engines, while game engines like Unity or Godot offer robust tool-sets for game development, they often come with complexities and functionalities that were extrinsic to the project's core focus on education. The primary goal was to create a streamlined educational experience without the distractions of intricate game mechanics or heavy visual effects. Moreover, game engines typically demand a steeper learning curve and greater resource commitments. Given the project's specific objectives and the need for a lightweight

and highly compatible solution, vanilla JavaScript emerged as the most fitting choice, ensuring both accessibility and alignment with the project's educational goals.

2) Aseprite: Aseprite served as the primary tool for all visual elements in the game. Starting with basic items, the design process expanded to intricate backgrounds, ensuring a unified visual theme. Characters and objects, essential components of any game, found their design origins in Aseprite. Its intuitive features ensured that these designs seamlessly integrated within the game's environment. When compared to graphic design giants like Photoshop, Aseprite's dedicated pixel art and animation capabilities made it a more suitable choice. While Photoshop offers broad graphic design functionalities, Aseprite's specialization in pixel art and its tailored toolset for 2D game design provided a more efficient and streamlined workflow for the project's needs. Animations, crucial for infusing life into a game, were crafted using Aseprite's sprite sheet capabilities, facilitating smooth movement of characters and objects. The game's map, the foundation for in-game exploration and interaction, was also crafted within this tool. The grid overlay feature in Aseprite proved invaluable for accurate alignment and design precision, guaranteeing visual consistency throughout the game. In essence, every visual aspect, from static backgrounds to animated entities, was realized through the capabilities of Aseprite.

E. Methods

1) Agile: The Agile methodology was chosen for this project due to its adaptability and emphasis on continuous improvement. Given the dynamic nature of the project's requirements, a flexible approach was vital. Agile allowed for the segmentation of the project into distinct phases, known as sprints and milestones. This structure ensured that any changes or new insights could be rapidly integrated, maintaining the project's relevance and alignment with its objectives. Another crucial advantage of Agile was its inherent feedback loops. Regular reviews with the project supervisor and user-testing were conducted, ensuring that the project consistently met and adapted to the evolving needs and expectations. Throughout the project's development, various different changes were required to be made following the advice of the project supervisor and the results of the user-testing. Due to this, the scope of the project changed in various ways and the agile approach allowed for smooth adaptability to these changes [16]. Compared to more rigid methodologies, like the waterfall model or Kanban, Agile provided the necessary fluidity and iterative approach, making it the optimal choice for ensuring the project's success and timely completion.

III. Design

A. Map Design

The primary objective of the map design within this game is to create a lively, inviting environment where players can seamlessly transition from beginners to proficient learners of cybersecurity concepts. The journey begins in a friendly town, leading to a university on the verge of a robot takeover. The narrative-driven design aims to intrigue players, guiding them through a series of mini-games, each unlocking a part of the larger mission to save the university.

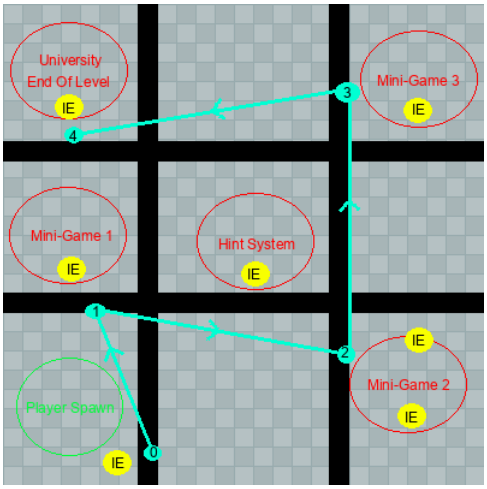

Fig. 1. Overview of the Map Design

1) Design Choices: The map has 40x40 grids with each grid being 16 pixels. In crafting the map, a distinct topography was conceptualized to mirror the progression of cybersecurity learning. Starting at the map's bottom left(Stage 0), players are informed by an NPC about the overarching missions. They are then directed towards three mini-games(Stages 1,2,3), each representing a different facet of cybersecurity, and upon completion, they earn flags necessary to confront the robotic gatekeeper barring the university(Stage 4). The scale of the map is crafted to promote exploration while ensuring players remain focused on the learning objectives. The aesthetics of a friendly town are employed to make the cybersecurity learning journey less daunting and more engaging. The interactive elements are pivotal; key locations like mini-game areas, the hint-providing monument, and the dynamic and informative NPCs are intricately designed to offer contextual learning experiences.

Several considerations were factored into the map design to ensure an optimal user experience. Firstly, The game's world is initially divided into 9 distinct regions. 6 regions of the 9 were used to facilitate the gameplay to the users. This segregation aids in organizing the game's content and guiding players through a progressive learning curve. Moreover, most of the map space was used, reducing the 'dead spacing' in the map, which has the potential to make the map 'smarter' and 'more player friendly' [17]. However, a small amount of space was deliberately left for potential mini-game additions or useful features if required in the future.

The interactive NPCs were crucial in providing guidance and context, aiding understanding of the cybersecurity concepts embedded within each mini-game. Additionally, a consistent design language across the different regions of the map was maintained to ensure a cohesive narrative and learning experience.

2) Considerations: Initially, the map dimensions of 16x16 grids were considered, making the map more of a 'room' than a 'town', where each small room would have one dedicated mini-game and the users would have to clear it to progress to the next level. However, upon deliberation, it was reckoned that this format might feel too constrained and linear, possibly hindering the explorative and interactive essence vital for an immersive learning experience.

The chosen theme of a friendly town leading to a university under threat was a compelling narrative that aligned with the educational goal of teaching cybersecurity concepts. This theme not only engages players but also provides a conducive environment for learning, making it an integral part of the design choice.

B. Character Design

The character design in the game serves as a critical component for player engagement and education in cybersecurity concepts. Characters are designed to be visually appealing, relatable, and instrumental in guiding players through the game's cybersecurity narrative. They are the player's companions in the journey towards understanding cybersecurity concepts in a friendly and engaging manner.

1) Design Choices: The character sizes in the game are 16x16 pixels. This was a deliberate design decision which aligned with the game's 2D aesthetic and technical constraints. This dimension offers a balance between detail and performance, ensuring that characters are visually recognizable and expressive while maintaining a consistent performance across different platforms. The sprite sheets with walking animations add a layer of dynamism and realism to character movement, making the gameplay more engaging and visually appealing. The diversity in characters, both male and female, with a friendly and adorable appearance, reinforces the game's inviting and inclusive atmosphere. This aesthetic choice aims to lower the intimidation barrier often associated with cybersecurity, providing a more approachable and enjoyable learning experience[?].

Fig. 2. Pixel Art Design of a Game Character

2) Considerations: Other sprite dimensions and character aesthetics were considered during the design phase as 32x32 and 64x64 sized character assets. However, the chosen 16x16 sprite assets were deemed to provide the right balance between visual clarity, performance, and the desired friendly aesthetic. The 16x16 sprite assets also offer optimized performance, ensuring smooth animations and interactions without overburdening the browser resources. Moreover, walking animations were favored over static sprites to enhance the game's interactive and realistic feel, contributing to a more engaging player experience. This also helped add another layer of dynamic interactions to the game which made it more intuitive.

C. Game Assets Design

1) Design Choices: The design of game assets is pivotal in creating a visually appealing and thematic gaming environment. A diverse range of dimensions were employed for different game assets to cater to their respective roles within the game's visual narrative. Characters were designed with 16x16 dimensions, aligning with the retro aesthetic of the game, while other assets like buildings, trees, and various environmental elements utilize larger dimensions to emphasize their prominence and detail within the game world. The chosen assets resonate well with the friendly and retro-styled theme of the game, contributing to the overall inviting and nostalgic ambiance.

For the audio aspect of the game, the Howler.js library was utilized instead of an in-house audio solution. Howler.js is a reputable and efficient library for handling web audio, and leveraging it allows for a more reliable audio experience within the game. This choice not only enhances the audio quality but also speeds up the development process, as it leverages a well-tested library known for its performance and ease of use.

2) Considerations: The selection of dimensions for different game assets was made with consideration to the game's aesthetic, performance, and the significance of each asset within the game environment. The 16x16 dimensions for characters align with the retro aesthetic, while larger dimensions for other assets provide the necessary visual distinction and detail. This diversified dimension approach ensures that each asset fits well within the game's thematic setting while serving its intended function.

The choice of utilizing Howler.js for audio processing over developing an in-house audio solution was driven by the desire for a reliable, efficient, and well-supported audio handling system. The use of a well recognised library ensures a smoother audio experience, mitigates potential issues that might arise from an in-house solution and removes the need for users to download audio resources to enhance the lightweight gaming experience.

D. Hint System Design

1) Design Choices: The hint system in the game is envisioned as a welcoming and interactive aid for players, designed to provide varying levels of assistance based on player choice. It is named the 'CodeWhisper Monument'. Upon accessing the CodeWhisper Monument, players are first prompted to select which chest (1, 2, or 3) they seek assistance with. Following this, they are asked to choose the degree of help needed: small, big, massive, or the solution. Based on their selection, the system then presents a fun riddle aimed at nudging them closer to solving the challenge at hand. This tiered approach to

delivering hints allows for a tailored assistance level, catering to different player aptitudes and preferences.

The interface is user-friendly, featuring back and exit buttons at all times, providing players with the ease of exiting or back-tracking in the hint system. The central location of the hint monument in the town ensures its visibility and accessibility from most locations, making it a convenient and noticeable feature for players as they navigate through the game.

2) Considerations: A primary consideration in designing the hint system was the balance between providing adequate assistance and encouraging self-driven problem solving. The tiered hint approach addresses this by offering varying levels of help, allowing players to choose how much assistance they need. The interactive and playful riddle format was chosen to keep the hint process engaging and enjoyable, rather than merely transactional.

The central placement of the hint system was deemed optimal for visibility and accessibility, yet other locations were considered initially. However, positioning it centrally ensures that it is equi-distant from most game locations, making it a convenient resource for players.

Additionally, the user interface of the hint system was designed to be intuitive and non-intrusive, with clear exit and back options. This design choice facilitates smooth navigation within the hint system, enhancing the overall user experience. The narrative-driven hint delivery, via riddles, was favored over straightforward hints to add a layer of engagement and fun, making the learning process more interactive and less of a chore.

E. GUI Design

1) Design Choices: The GUI (Graphical User Interface) design in this game is crafted to create an intuitive and immersive gaming experience. A significant feature is the game container, which, although expansive, employs a camera mechanism that follows the player as they traverse through the game environment. The camera movement is engineered through mathematical calculations, as seen in the draw method provided, ensuring a smooth transition as players explore different areas. This design choice aligns with common practices in 2D RPG games where camera movement enhances the player's exploration experience while maintaining focus on the player's character.

Interaction within the game is streamlined to be straightforward and minimalistic, requiring user input mainly for engaging with NPCs, accessing hints, and unlocking chests. This design minimizes cognitive load on the player, allowing them to focus more on the game's narrative and cybersecurity learning aspects.

A unique aspect of the GUI design is the cool reveal text mechanism employed to display text in the game. Through the RevealingText class, text is unveiled in a manner that adds a dramatic effect, enhancing user engagement and attention.

2) Considerations: A primary consideration in designing the GUI was ensuring a balance between user engagement and simplicity. The chosen design facilitates easy navigation and interaction while keeping the user immersed in the game's narrative. The camera-follow mechanism was favored over a fixed camera system to encourage exploration and provide a more dynamic view of the game environment. Similarly, the reveal text mechanism was chosen to add an element of surprise and engagement as opposed to displaying static text, which could be less engaging. These design choices were influenced by the aim to create an interactive and engaging learning environment within the game.

The GUI design was also influenced by the need to optimize system performance and ensure that the game runs smoothly across different platforms. The mathematical calculations used in the camera movement, and the efficient coding practices employed in the RevealingText class, contribute to optimized performance while delivering a rich user experience.

F. Coding Technique Design

1) Design Choices: The game's architecture is rooted in an object-oriented approach, aiming for a modular, scalable, and maintainable design. This approach allows for clear hierarchical relationships, promoting reuse of properties and methods across game components. The game's composition of multiple cohesive units or components ensures a clear separation of concerns, with each component encapsulating its unique state and behavior.

To achieve a dynamic and reactive game environment, an event-driven programming approach was chosen. This allows the game to respond promptly to specific user inputs and game events. Real-time feedback to players is of paramount importance, and as such, a dedicated system for handling animations was deemed a critical design choice. The animation system would ensure fluid transitions and visually appealing feedback.

Lastly, state management was envisioned as a cornerstone of the game's design. This would ensure game continuity and offer a seamless experience for players, providing an efficient means to track and manage the player's progress and state.

2) Considerations: The game's design was influenced by the objective of striking a balance between complexity and usability. A component-based design was deemed optimal for modularity, ensuring each game component can be developed, tested, and debugged independently. The event-driven approach was seen as the bridge to interactivity, allowing the game to mirror the dynamic nature of user inputs. Furthermore, the choice of implementing a dedicated system for animations was driven by the goal of rich visual feedback, while state management was seen as a pillar for game continuity.

IV. Sustainability Considerations

Due to the nature of the educational game, it does not inherently require extensive sustainability considerations, especially when compared to other sectors like electronics or mechanics. However, even within this scope, making informed decisions

can further promote sustainability, albeit on a smaller scale. The following analysis outlines how this project has integrated certain sustainable practices, aligning with some of the United Nations Sustainable Development Goals (SDGs) [8].

A. Environmental Sustainability - Aligned with SDG 12: Responsible Consumption and Production

The choice of a pixel-art aesthetic and 2D graphics significantly reduces the processing power required compared to high-resolution 3D graphics. This design choice contributes to lower energy consumption during both development and gameplay, which is coherent with responsible consumption and production principles.

B. Social Sustainability - Aligned with SDG 4: Quality Education

The game serves as a means of educating individuals on cybersecurity concepts, contributing to the broader goal of quality education. By providing educational resources for free, the game fosters a level of awareness and knowledge that is crucial for navigating the digital world safely, thus aligning with the goal of quality education outlined in SDG 4.

C. Economic Sustainability

Economic sustainability wasn't a primary focus during the development of this game as it was designed to be a free and accessible educational resource. The project's primary aim is to provide a platform for learning and awareness rather than economic growth or profitability, which deviates from the traditional economic sustainability considerations. While the direct economic benefits might not be substantial, the potential for reducing cybercrime through education could contribute to broader economic stability by minimizing financial losses associated with cyber threats.

D. Technical Sustainability - Aligned with SDG 9: Industry, Innovation, and Infrastructure

The game's modular and scalable design allows for potential expansions or adaptations, ensuring its longevity and relevance over time. Moreover, the project identified and sought to fill a gap in the market for an educational, 2D game on cybersecurity, showcasing a level of innovation that aligns with the industrial innovation aspect of SDG 9.

Through careful design and implementation decisions, the project demonstrates a blend of sustainability considerations, striving to contribute positively towards the broader Sustainable Development Goals outlined by the United Nations. This thorough approach not only enhances the game's appeal but also underscores the project's commitment to fostering a sustainable digital landscape.

V. Implementation

A. Map Implementation

The foundational step in the map implementation was the creation of a 40x40 grid system, with each grid cell spanning 16 pixels, as laid out in the design blueprint. This grid system served as the canvas upon which game objects, buildings, and other imagery were carefully placed. The placement of these elements was done to create a lively, inviting environment that engages players as they navigate through the game.

A crucial part of ensuring a coherent gameplay experience was the construction of walls for buildings, fences, and other boundary elements within the map. A custom Python script was developed for this purpose. This script not only facilitated the construction of walls but also ensured that players remain within the designated game container, thereby preventing any unwanted access to unauthorized locations and eliminating potential edge cases.

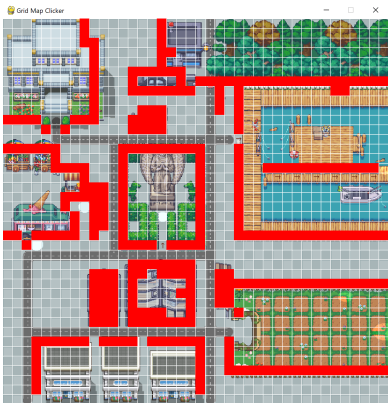

Fig. 3. Wall Creation using custom tile editor

The theme of the map is crafted around a narrative where the player embodies a cybersecurity whiz tasked with obtaining flags using their skills, to gain entry into a university building guarded by a robot and halt a robot takeover of the university. To accomplish this, players need to navigate through three functional mini-games embedded within the map, each teaching a different cybersecurity concept or technique.These mini games are the main method of delivering the game's educational content.

Fig. 4. Map - Level 1

1) Mini-Game 1: Caesar Cipher: The first mini-game aimed to introduce players to the concept of Caesar Cipher, a popular text cipher technique. Players encounter an NPC who communicates in Caesar Cipher, uttering what initially appears as gibberish but is actually logical sentences encoded using this cipher. The objective for the players is to decipher these sentences to uncover a key. This key unlocks a chest, granting players the first flag essential for progressing in the game. Players could either copy the text and decipher it using an online tool or employ logical thinking to ascertain the cipher shift based on the shortest path to the chest from the NPC.

Fig. 5. Mini-game 1 Implementation

2) Mini-Game 2: Pig Pen Cipher: The second mini-game delved into the Pig Pen Cipher, a well-known picture cipher. In this scenario, players find themselves in a magical garden with an NPC who directs them to a wisdom tree. Upon interaction with this tree, a transformation occurs on the map, with flowers rearranging themselves to form a pattern representing the Pig Pen Cipher. Deciphering this pattern reveals the key needed to unlock a chest and obtain the second flag, progressing the narrative further.

Fig. 6. Mini-game 2 Implementation

3) Mini-Game 3: Phishing Awareness: The third mini-game was crafted to enlighten players on Phishing, a prevalent social engineering technique. An NPC provides players with a set of lock picking tools, which are essential for unlocking the third chest without a key. However, to reach the chest, players are required to accurately answer six phishing-related questions. A consecutive correct answer streak is needed to access the chest; otherwise, players need to start over. Successful completion grants players the third flag.

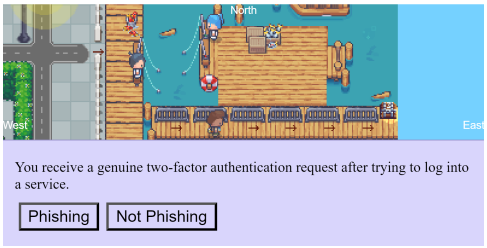

Fig. 7. Mini-game 3 Implementation

Once all three mini-games are completed and the flags are collected, the narrative progresses with the guard blocking the university entrance disappearing. This allows players to enter the university building, moving them further along in their cybersecurity learning journey. The flags are essential for this progression, and without them, the guard remains at his post, barring the players' entry. The hint monument, centrally located on the map, serves as a resource for players to obtain hints for each chest related to the mini-games, ensuring guidance is available whenever needed.

This careful and precise implementation of the map design ensures a seamless transition from start to finish, as players navigate through an engaging narrative filled with interactive and educational challenges.

B. Character Implementation

1) Sprite Creation and Sourcing: The implementation of character design was carried out to adhere to the 2D aesthetic and technical constraints specified in the design section. A consistent character size of 16x16 pixels was employed for all characters, which was achieved pixel by pixel using Aseprite. This decision ensured that the characters were visually recognizable, expressive, and performed consistently across different platforms. Besides crafting characters from scratch, some character sprites were also sourced from external sources, who are acknowledged for their contributions.

2) Animation Development: The animation of characters was a critical aspect of making the gameplay engaging and visually appealing. To accomplish the animations, sprite sheets were created with a layout of 4x4 sprites on each sheet. Each row in these sprite sheets represented a different walking direction, enabling a range of movements for the characters.

Fig. 8. Character Animation Walking Sprite Sheet

The Sprite class played a pivotal role in handling the character animations. Within this class, a method named updateAnimationProgress was defined to manage the progress through the frames of the current animation. This method ensured that the animation frames were cycled through in a smooth and consistent manner, creating a continuous animation loop as the game runs.

Moreover, the draw method in this class helped render the character sprites on the canvas. It calculated the position where the sprite should be drawn, based on the position of the game object associated with the sprite and the camera person. This method then rendered the shadow and the current frame of the sprite at the calculated position, further enhancing the visual appeal of character movement.

The setAnimation method within the Sprite class allowed for updating the current animation, which in turn, facilitated the transition between different animations, such as moving from an idle state to a walking state, based on the character's interactions within the game.

These methods, combined with the structured layout of the sprite sheets, established a system that efficiently cycled through sprite animations to depict character movement in a dynamic and realistic manner. By managing the animation frames and rendering the sprites on the canvas, a layer of dynamism and realism was added to character movement, making the gameplay more engaging and visually appealing. Through this setup, the characters in the game were brought to life, moving in various directions based on player interactions and game events, thus enriching the overall gaming experience.

The integration of walking animations, as opposed to static sprites, enriched the game's interactive and realistic feel. By cycling through sprite animations, characters in the game exhibit movement, enhancing the player experience. This dynamic interaction added another layer of engagement, making the game more intuitive and visually appealing.

C. Game Assets Implementation

1) Asset Creation and Animation: The game assets were implemented with varying dimensions to adhere to the visual aesthetics of the game as outlined in the design phase. A plethora of game assets including buildings, trees, and other environmental elements were created to enrich the game environment. The animations for various assets like billboards, fishes, and bubbles were designed to continuously cycle through their animation frames, unlike the situational character animations which are triggered by character movements.

Fig. 9. BillBoard Animation Sprite Sheet

An example of how asset animations were implemented can be observed in the BillBoard class. This class extends GameObject and utilizes a Sprite object to manage the animation frames. An animationInterval of 200 milliseconds was set to dictate the speed at which the frames are cycled. The startAnimation method was defined to initiate the animation loop, which cycles through the animation frames at the specified interval, thus creating a continuous animation effect. This method leverages setInterval to update the currentAnimationFrame and setAnimation method of the Sprite object to update the current animation frame being displayed. This mechanism enables the continuous animation of game assets, enhancing the visual appeal of the game environment.

2) Interactions: The interaction between players, game objects, and NPCs (Non-Player Characters) is an integral part of the gameplay. To ensure an intuitive and enjoyable interaction experience, specific conditions were set for interactions. For instance, NPC interactions were designed to occur only when the player and the NPC face each other. This was achieved through the checkForActionCutscene method which checks the positioning and facing direction of the player relative to the NPC, and triggers a cutscene if the conditions are met.

Fig. 10. NPC Interactions

Similarly, interactions based on the player stepping on certain grids were managed through the checkForFootstepCutscene method. This method checks the player's position against predefined cutscene trigger positions and initiates a cutscene if a match is found. This mechanism facilitated the triggering of events based on player positioning, adding a layer of engagement to the gameplay.

3) Player States and Scenario-Driven Interactions: In crafting a more immersive and responsive gaming environment, player states were introduced to track the progress of the player as they navigate through the game. These states are represented through story flags, which are updated based on the player's achievements and interactions within the game. A prime example of this is the 'Chest1Unlocked' story flag, which becomes activated once the player successfully unlocks the first chest in the game.

The 'Chest1Unlocked' story flag serves as a milestone indicator, reflecting the player's advancement in the game. This flag, once activated, influences subsequent interactions within the game, especially interactions with NPCs. For instance, before unlocking the first chest, interacting with a certain NPC might yield hints or encouragements to unlock the chest. However, once the 'Chest1Unlocked' flag is set, interacting with the same NPC post this achievement will yield a different response - perhaps congratulating the player and providing hints or encouragement for the next milestone.

This dynamic interaction mechanism, driven by player states, adds a layer of depth to the gameplay. It makes the game environment feel more alive and responsive to

the player's actions, creating a more realistic and engaging gaming experience. The scenario-oriented interactions, guided by story flags, enrich the narrative of the game, making the player's journey more coherent and rewarding.

4) Audio: The audio aspect of the game was enriched using the Howler.js library as planned in the design phase. Various sound effects were integrated into the game to correspond with different events. For instance, uplifting sound effects were played upon successful chest unlocking, while a denying sound effect was played upon unsuccessful attempts. Additionally, a background sound was added to create a more immersive gaming experience. The use of Howler.js facilitated a smooth audio implementation, enriching the overall gaming ambiance and user experience.

D. Hint System Implementation

Following the design, the implementation of the hint system was carried out to establish a supportive gameplay environment. This system serves as a hint guide for players, helping them navigate through the challenges of the mini-games. The hints are arranged in a way to provide graded assistance based on the level of help the player desires, allowing them to choose the extent of guidance they receive.

Upon approaching the CodeWhisper Monument, players are welcomed and asked which chest they need help with. This interactive approach categorizes the hints based on the mini-games associated with each chest. Once a chest is selected, the player is further provided with a choice regarding the level of hint they want: 'Small', 'Big', 'Massive', or direct 'Solution'. This structured approach facilitates a tailored hint provision, catering to the different needs and preferences of players.

Fig. 11. Code Whisper Monument

The design of the hint system makes use of a gradual guidance model. Under the 'Small' hint category, players receive subtle nudges towards the solution. If they require more assistance, the 'Big' hint category provides clearer clues. For players struggling significantly, the 'Massive' hint section provides overt guidance. And lastly, the 'Solution' category provides a direct solution to the puzzle.

For instance, in Chest 1 related to Caesar Cipher, a 'Small' hint nudges players towards a potential solution through a narrative around Dr.Caeser, while the 'Big' hint suggests taking the 'Shortest Path' from Ms.Tina to the chest. The 'Massive' hint further reinforces the 'Shortest Path' hint, and the 'Solution' option gives players a translator tool to decipher Ms.Tina's ciphered speech.

Each hint is wrapped in an engaging narrative that not only provides assistance but also enriches the game's story environment. The conversations with the CodeWhisper Monument are designed to be both informative and engaging, adding an enjoyable aspect to the hint system.

The hints are delivered through a series of text messages within the game, providing an interactive dialogue experience. Depending on the choice made by the player, the hint system dynamically adapts to provide the relevant level of assistance.

The hint system plays a crucial role in enhancing the player's learning experience, especially with the cybersecurity concepts embedded within the mini-games. By offering a range of hints, players can choose the level of challenge they are comfortable with, thus promoting a self-paced learning environment. Moreover, the narrative-driven hints add a layer of storytelling that enhances the gameplay experience, making the learning process enjoyable and engaging.

E. GUI Implementation

The GUI implementation in the game is crafted to enhance player engagement and create an intuitive interface for player interactions. The aesthetic choices for the GUI were inspired by a retro gaming theme, evident from the pixelated graphics and the color scheme used throughout the interface.

The game employs a simplistic yet functional GUI, allowing players to navigate and interact with ease. The main GUI elements include a points display, directional labels for movement, text messages for player instructions or feedback, and an input panel for entering passwords at certain stages in the game.

A global CSS file defines the styling parameters for the entire game, ensuring a consistent and thematic appearance. The color palette, borders, and fonts are defined here, setting a retro and inviting ambiance for the players.

During gameplay, players receive text messages that provide instructions or narrative elements. These messages appear in a designated area at the bottom of the screen, ensuring they are easily noticeable without being intrusive. For certain interactions like unlocking chests, players are prompted to enter passwords. An input panel slides up from the bottom, allowing players to type in or paste the necessary keys.

The game's control scheme is designed to be intuitive. The DirectionInput class captures keyboard inputs for controlling character movement. Players can use either the arrow keys or the WASD keys for movement, making the control scheme flexible and user-friendly. The game also ensures that interactions with NPCs and other game elements are straightforward. When engaging with NPCs or certain objects, text messages provide the necessary feedback or further instructions to the player. This minimalist approach keeps the gameplay focused and enjoyable.

The game container sets the stage for all the action. It's defined with specific dimensions and scaling factors to ensure consistency across different screen sizes. This encapsulated environment houses all the game elements, contributing to a neatly organized game layout.

F. Coding Technique Implementation

1) Class Relationships and Hierarchies: The game's implementation hinges on the object-oriented design as planned. The Person class, for instance, extends the foundational GameObject class, showcasing a clear hierarchical relationship. This relationship allows the Person class to inherit properties and methods from GameObject, ensuring a modular design where each class retains its specific responsibility.

2) Event Handling: The game's dynamism is brought to life through its event-driven programming approach. Using functions such as utils.emitEvent, custom events from the OverWorldEvent class can be dispatched, allowing various game components to respond. This mechanism fosters an interactive environment, allowing the game to adapt and react to specific situations and user inputs in real-time.

3) Animation Management: The game's appeal is further enhanced through its animation management system. The Sprite class, for instance, offers methods such as setAnimation and updateAnimationProgress. These methods provide a foundation for the game's animations, ensuring smooth transitions and visually enriching feedback corresponding to user actions.

4) State Tracking: State management is efficiently handled through the PlayerState class. This class serves as the bedrock for tracking the player's progress and state in the game. By managing the state separately, the game ensures a seamless experience for players, allowing for easy save, load, and manipulation of game progress.

5) Component Initialization: The game's modular components are brought to life through the init.js file. This script is responsible for initializing the game, ensuring that all components, from Overworld to PlayerState, are set up correctly and in the right order. This modular approach ensures that each component is initialized independently, promoting a structured yet flexible architecture.

In conclusion, the game's architecture and coding techniques have been carefully implemented to offer an engaging, educational, and user-friendly experience. The blend of coding techniques and design choices ensures a harmonious balance between game mechanics and the educational content.

VI. Evaluation

A. User Testing

User testing was essential in the development of the game. It guided the project by evaluating the game's usability, educational aspects, and overall user experience. In a game designed to teach cybersecurity concepts, user testing helped identify areas of challenge and confusion, ensuring clear and intuitive gameplay. Additionally, it provided insights into the educational effectiveness of the game's content and helped create a more immersive and enjoyable experience for players.

B. User Testing Methodology

The user testing methodology followed an iterative and user-centric approach, inspired by Jakob Nielsen's principles [18]. It involved two rounds of testing with small groups of users, each consisting of five participants. This approach uncovered usability issues early in development, aligned with the user-led design process, and ensured that user feedback guided decisions. While iterative development affected project timelines, the benefits of user-centric design far outweighed the delays, as it led to improved usability, educational content, and overall user experience.

User testing was assessed through a questionnaire presented to participants. This questionnaire integrated both multiple-choice items and open-ended inquiries, addressing diverse facets of the game. These responses were vital in defining the performance criteria for evaluating the game. Specific performance criteria were set for each round of user testing, tailored to their contextual significance. Additionally, users were prompted to rate the game's overall usability on a scale of 1 to 10, gauging the entire experience.

C. Performance Metrics for the First Round of User Testing

1) Engagement Metrics: These metrics check the extent to which the game captivates users' attention and maintains their interest throughout the experience. It helps in understanding if the game is engaging and enjoyable.

2) Learning and Educational Metrics: This set of metrics evaluates the educational value of the game. It measures whether users' understanding of cybersecurity concepts improved after playing the game and if they would prefer it as a learning tool.

3) Game Mechanics Metrics: Game mechanics metrics explore how intuitive the game controls and mechanics are. It also assesses the balance of difficulty in the mini-games.

4) Visual and Audio Design Metrics: These metrics examine the quality of the game's graphics and visual design, as well as the impact of audio and sound effects on the overall gaming experience.

5) Narrative and Storytelling Metrics: Narrative and storytelling metrics assess how engaging and informative the game's storyline is. It also evaluates if the narrative aids in understanding cybersecurity concepts.

6) Overall Experience Metrics: Overall experience metrics provide a holistic view of user satisfaction with the game. They encompass all aspects of the game's design and functionality.

7) Feedback and Suggestions Metrics: These metrics capture users' feedback and suggestions, which are invaluable for making improvements to the game. It highlights areas that need refinement or enhancement.

D. Results of the First Round of User testing

TABLE I
RESULTS OF THE FIRST ROUND OF USER TESTING

Metric	Result
Engagement Level	5/5
Users Who Found Objectives Clear	4/5
Users Who Felt Educated in Cybersecurity	4/5
Users Who Found Controls Intuitive	3/5
Users Who Rated Graphics Positively	5/5
Users Who Found Audio Enhancing	4/5
Users Who Found Storyline Engaging	3/5
Overall User Satisfaction	4/5
Overall Usability Score	7.2/10

1) Engagement Metrics: The game appears to be engaging, with all 5 users indicating they felt engaged while playing.

2) Learning and Educational Metrics: The educational aspect of the game seems to be effective. 4 users felt their understanding of cybersecurity concepts had improved after playing the game. Interestingly, when given a choice between the game format and traditional teaching methods, all 5 users expressed a preference for the game.

3) Game Mechanics Metrics: When it comes to game mechanics, there's a mix of feedback. 3 users found the game controls and mechanics intuitive, suggesting ease of use. However, the difficulty levels of mini-games varied in users' perceptions. Mini-game 2 stood out as particularly challenging for many.

4) Visual and Audio Design Metrics: The game's visual and audio design was a highlight. All participants rated the graphics positively, and 4 out of 5 felt the audio enhanced their playing experience.

5) Narrative and Storytelling Metrics: The narrative components were well-received. 3 users found the game's storyline engaging, and the same number felt that the narrative helped make the cybersecurity concepts clearer.

6) Overall Experience Metrics: In general, the game seems to have left a positive impression. On the usability front, the game received an average rating of 7.2 out of 10, suggesting a positive user overall experience. A majority of users, specifically 4 out of 5, found the objectives of the game clear, indicating a well-defined purpose and direction. The positive feedback suggests a high likelihood of recommendation.

7) Feedback and Suggestions Metrics: Users provided a wealth of feedback and suggestions. Common themes emerged around the need for clarity in objectives and game progression. Many also felt there should be greater cohesiveness between mini-games and suggested improved hints or cues for direction.

E. Changes Made after the first round results

Following the initial round of user testing and the valuable insights it provided, several significant improvements were implemented to the game. The results of the user tests indicated many flaws in the game that had to be addressed. Due to this, the development timelines had to be pushed to accommodate for the changes to be made.

The primary focus was on enhancing clarity throughout the game, particularly concerning objectives and game progression. Variations in the perceived difficulty of mini-games were addressed to achieve a more balanced and enjoyable gameplay experience for all users. Some mini-games were designed to be easier such as Mini-game 2. This was done by providing better information and context surrounding the mini-game. In Mini-game 3, the number of interactive tiles that asked phishing or not questions were also reduced to reduce its tedious nature. However, Mini-game 1 remained the same as most users were able to decipher this mini game with not too much difficulty.

Efforts were made to improve cohesion between mini-games, ensuring smoother transitions and a more immersive gameplay flow. This was done by making the directions of where to head next more obvious, making the objectives of the game more clear and progression smoother. The NPCs and game object interactions had a major role to play in order to accomplish this. Enhanced hints and cues were implemented to assist users in navigating the game world and understanding objectives more intuitively. The CodeWhisper Monument's hints were altered to provide more valuable and clearer hints.

Leveraging the strengths of the game, such as its engaging narrative, visuals, and educational value, remained a top priority. Further rounds of usability testing were conducted to evaluate the impact of these changes, solidifying the dedication to creating a valuable and enjoyable tool for cybersecurity education.

F. Performance Metrics for the Second Round of User Testing

The performance metrics for the second round of testing diverged from the first round, primarily due to the game's intrinsic educational focus. As the game focuses on teaching cybersecurity concepts, user familiarity with the game necessitated adjustments in the evaluation criteria for the subsequent testing phases. Among these metrics, the usability score stood out as pivotal, offering insights into the game's overall experience enhancement across the two testing rounds. Below are the refined performance metrics for this round.

1) Overall Experience Metrics: These metrics measure the improvement in user usability and experience with the updated version of the game. They capture the general sentiment about the overall gameplay, helping to identify if the changes made are aligned with user expectations and preferences.

2) Mini-games Feedback Metrics: This set of metrics specifically evaluates user feedback on the mini-games. Given that mini-games are a central component of the gameplay, understanding their perceived difficulty, clarity, and enjoyability is crucial for continuous refinement.

3) Game Flow and Transitions Metrics: These metrics focus on the seamlessness of transitioning between different parts of the game. A smooth flow is essential to prevent users from feeling disoriented or lost, ensuring a cohesive and immersive gameplay experience.

4) Overall Feedback Metrics: These metrics measure the broad feedback provided by users on various aspects of the game. It's a comprehensive metric that highlights the areas that have improved, areas that need further refinement, and the overall recommendation rate of the game.

G. Results of the Second Round of User testing

TABLE II
RESULTS OF THE SECOND ROUND OF USER TESTING

Metric	Result
Users Who Noticed Improvements in Mini-game 2	5/5
Users Who Found Transitions Smoother	4/5
Users Who Found NPCs Interactions Helpful	4/5
Users Who Found Hints Improved	4/5
Recommendation Rate for Cybersecurity Education	5/5
Overall User Satisfaction	5/5
Overall Usability Score	9.2/10

1) Overall Experience Metrics: All five users indicated that the overall experience of the game improved in the updated version. The average usability rating given to the updated game compared to the previous version was 9.2 out of 10. This suggests that the game updates were well-received by the majority of users.

2) Mini-games Feedback Metrics: For the mini-games, the feedback was overwhelmingly positive. All users noticed changes in Mini-game 2, with the majority indicating that these changes made the game easier and more enjoyable. Similarly, the majority of users found the modifications in Mini-game 3 helpful in reducing its previously tedious nature. The clarity and helpfulness of hints, especially from the CodeWhisper Monument, were cited as improved by four out of five users.

3) Game Flow and Transitions Metrics: The game's flow and transitions between mini-games saw significant improvements, as indicated by the feedback. Four out of five users found the transitions smoother in the updated version. NPCs and game object interactions were also highlighted as more helpful by three out of the five users, showcasing an enhanced directive experience.

4) Overall Feedback Metrics: The feedback provided a holistic view of user satisfaction with the game. The most significant improvements, as cited by users, included clearer objectives, improved hints, and smoother game transitions. While the game has seen considerable enhancement, a couple of users still highlighted areas that could be further refined. However, the consensus was highly positive, with all users indicating that they would recommend the updated version for cybersecurity education.

H. Challenges and Future Work

1) Scope Reduction and Timeline Adjustments: The iterative nature of user testing brought to light numerous flaws in the game design, which necessitated significant alterations. Adapting to these feedback-driven changes had a domino effect on the project's timelines. While this is a common occurrence in the realm of game development, especially during initial user testing phases, it posed a significant challenge.

The introduction of Agile methodologies allowed for dynamic adjustments to the development timeline. Regular consultations with the project supervisor reinforced the project's scope, ensuring alignment with the revised objectives.

While the original plan aimed to have three levels, the extensive time required to design and craft these levels meant that only one could be completed within the adjusted timeframe. Lack of prior experience in game development further compounded this challenge, resulting in additional delays.

Given more time or resources, the development of the remaining two levels could be pursued. Additionally, collaboration with experienced game developers might expedite the process and provide insights into efficient design and implementation techniques.

2) Deviation from Target Audience for User Testing: The game underwent substantial design evolution since its inception. As the implementation and scope of the game morphed, development was protracted, which subsequently delayed the formulation of evaluation methods. By the time the evaluation approach was finalized, obtaining ethics approval for testing on the intended target audience - beginners or first-year cybersecurity students - became unfeasible. As a workaround, the Human Ethics Application procured by ECS permitted testing on 4th-year engineering students. Although diverse backgrounds were chosen to simulate the personas of first-year students, this proxy method doesn't equate to testing the actual target demographic. This deviation could potentially affect the accuracy and relevance of the feedback.

Future iterations of the game should prioritize obtaining the necessary ethics approvals in advance to facilitate testing with the actual target audience. This would ensure feedback is directly relevant and more representative of the intended user base.

3) Vanilla JavaScript vs. Game Engine: Opting to use vanilla JavaScript over a dedicated game engine was a conscious decision, driven by various benefits such as finer control, customization, and avoiding overheads of engines. However, this choice came with its set of limitations.

Using vanilla JavaScript, while offering granular control, can increase the complexity of game development. Game engines typically provide built-in functionalities, tools, and optimizations, which can streamline the development process. In the absence of such features, building the game from scratch can be more labor-intensive and time-consuming.

Game engines are generally optimized for performance, ensuring smooth gameplay across different devices and platforms. When using vanilla JavaScript, achieving a similar level of optimization requires additional effort and expertise.

Considering the scalability challenges posed by vanilla JavaScript, future iterations could explore migrating to a lightweight game engine, especially if the game's scope expands or requires integration of advanced features. This would simplify development while maintaining performance benchmarks.

4) Non-Replayable Nature of the Game: One inherent limitation of the game is its non-replayable design. Given that its primary purpose is to instruct and familiarize players with cybersecurity concepts, once the content is consumed and understood, there's limited incentive for players to revisit the game. This contrasts with many games in the market that offer dynamic content or multiple endings to entice repeated playthroughs.

While the non-replayable nature can be seen as a limitation, it's essential to recognize the game's primary objective. The game is designed to serve as an engaging introduction to cybersecurity for novices. Its core aim is to educate, and in that regard, it succeeds. Players are provided with a foundational understanding of key concepts in an interactive manner, making the learning experience memorable.

To address the non-replayability challenge, future versions of the game could introduce modular content updates, ensuring that as the field of cybersecurity evolves, the game remains relevant. Dynamic quizzes or puzzles, randomized on each playthrough, could also be integrated, providing players with fresh challenges and ensuring sustained engagement.

VII. Conclusion

In the rapidly changing digital environment, the need for cybersecurity education has become crucial. To meet this demand, 'Cyber Adventure', a groundbreaking 2D RPG web game, was developed, seamlessly combining entertainment with educational value. This game, consisting of carefully designed interactive puzzles and mini-games, implemented using efficient tools and techniques which not only helps educate the masses about cybersecurity concepts but also stands out in terms of engagement and efficacy compared to traditional teaching methods.

Feedback from users emphasizes the game's capacity to ignite curiosity and reinforce retention of concepts, signaling a transformative direction for contemporary educational tools. The favorable user feedback of the game indicates that gamified learning can make intricate subjects both accessible and enjoyable, potentially reshaping perceptions and strategies in digital-age education.

Future prospects include broadening the game's curriculum to encompass more advanced cybersecurity concepts, migrating the game to use a light weight game engine, testing on target audience and increasing the levels and themes in the game. Ongoing user feedback and iterative design adjustments can help maintain and enhance the game's relevance and efficacy for many years.

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