Universiteit Leiden

# Master Computer Science

Engaging Female Learners: A Game-Based Approach to Teaching Data Structures and Algorithms


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# Contents

**Abstract**

The persistent gender disparity within the field of computer science has prompted the exploration of novel educational strategies aimed at increasing female participation. One such approach involves the use of serious games designed with gender-specific content to engage and educate female students effectively. In this paper, we explored the design and impact of an educational game specifically designed for female players, aimed at teaching fundamental concepts of data structures and algorithms. Recognizing the gender disparity in computer science, the game integrates romantic elements commonly found in otome games to engage and motivate female learners. The study evaluates the game's effectiveness through a survey distributed among 30 female participants aged 16 to 20, assessing changes in their knowledge, interest in computer science, and perceptions of the game's usefulness and ease of use.

The results indicate that the game successfully enhanced participants' understanding of data structures and algorithms, with improvements in quiz scores from pre- to post-gameplay. The incorporation of romantic elements proved effective in increasing engagement, making the learning process enjoyable and stimulating an interest in further exploring computer science. This study demonstrates the potential of using gender-specific serious games to engage and educate underrepresented groups in fields like computer science.

**Key Words:** serious game, data structure, otome game, computer science education, female-oriented

# 1 Introduction

With the increasing importance of computer science and programming skills in modern society, traditional teaching methods are faced with the challenge of how to effectively engage and stimulate students' interests. Gamified learning and educational games, as an innovative educational approach, are gradually gaining attention from educators and researchers, making complex topics more accessible and enjoyable. It's important to clarify the distinction between gamification and game-based learning at this juncture: gamification involves the use of game elements in non-game contexts, primarily to enhance user engagement, motivation, and participation in activities that are not traditionally game-like. In contrast, game-based learning involves designing actual games with the primary purpose of learning, where the content and learning objectives are integrated into the gameplay [5]. By embedding computer science knowledge into an interactive and fun game environment, gamified learning can not only increase students' engagement and motivation but also help them better understand and apply what they have learned. Additionally, introducing romantic elements into educational games could represent an intriguing and novel direction to explore, potentially enriching engagement and appealing particularly to certain audiences.

Despite the growing popularity of game-based learning [31], there is a notable scarcity of educational games focused on teaching data structures and algorithms. These are foundational topics in computer science, crucial for problem-solving and efficient coding practices.

Another intuition is that the gender disparity in computer science is stark. Men significantly outnumber women in both academic and professional settings within the field. According to the World Economic Forum's Global Gender Gap Report 2023 [13], women represented only 26% of the computing workforce globally. This disparity is even more pronounced in areas like software development and systems architecture. The underrepresentation of women in computer science is partly because of historical and societal factors. Traditionally, computer science has been perceived as a masculine domain [28], a notion that dates back to the early days of computing. During the mid-20th century, the computing field was more balanced, with many women contributing significantly to programming and systems development. However, as the field professionalized and gained prestige, it became male-dominated. The societal stereotype that aligns computing with masculinity has been perpetuated by media portrayals and cultural norms, discouraging many women from pursuing careers in this area [35]. This stereotype has created a feedback loop where the lack of visible female role models in computing further discourages young women from entering the field.

While most computer science education, including game-based learning, is designed to be gender-neutral, there is evidence suggesting that gender-specific environments can be particularly beneficial for women [2]. A teaching tool that is designed specifically for women's interests can motivate them to learn computer knowledge more than gender-neutral teaching materials. Creating a supportive and inclusive learning environment can help mitigate the intimidation and isolation that many women feel in male-dominated settings.

Moreover, Otome Games, a genre of story-based video games primarily targeted at females, showcases the effective use of romantic elements to captivate and engage female players [26]. Otome, meaning "maiden" in Japanese, revolves around navigating romantic relationships with various characters, often combining intricate storylines with player-driven choices that influence the narrative's outcome. These games are distinguished by their deep emotional engagement and complex character development, making them particularly appealing to a female audience. By using the narrative depth and emotional connections formed in Otome Games, educational games can similarly utilize these elements to foster engagement and enhance learning experiences. Incorporating romance into educational content, particularly in fields traditionally perceived as male-dominated, may introduce a novel approach to reducing gender disparities. It provides a familiar and engaging context for female players, helping to dismantle stereotypes and build confidence in their abilities.

In response to these challenges, we have designed a game specifically targeted at female players with romantic elements. This game aims to teach some fundamental concepts of algorithms and data structures through a narrative-driven, interactive experience. By embedding educational content within a game that

was specifically designed for female players by including romantic elements, we hope to pique female players' interest and confidence in computer science. The game introduces players to key computer science concepts through a series of challenges. Each challenge focuses on a specific topic, such as binary search, stack, or Huffman Coding. Players must apply these concepts to solve puzzles and progress through the game. The educational objectives are integrated into the gameplay, making learning both natural and entertaining. To assess the effectiveness of the game, as well as the impact of romantic elements in education, it was published with a survey. This survey was designed to evaluate changes in players' knowledge of the concepts covered and their interest in the field of computer science before and after using the tool. The survey and the game were distributed on social media platforms, targeting women players aged 16 to 18. The feedback collected helps refine the game and provides insights into its impact on encouraging females to consider careers in computer science.

# 2 Background

## 2.1 Game-Based Learning in Computer Science

The concept of using games for educational purposes dates back to the early 20th century, but it wasn't until the advent of digital computers that game-based learning truly began to take shape [22]. The first instructional software appeared in the 1960s and 1970s, thanks to the capabilities of mainframe computers. These early educational games were mostly text-based and designed to teach fundamental maths and reasoning skills.

The 1980s saw significant advancements in personal computing, leading to the rapid growth of educational games. These games combined entertainment with educational content, aiming to make learning more enjoyable for children. Notable examples include *The Oregon Trail* [14], which taught students about American history and resource management, and *Math Blaster!* [3] which focused on improving arithmetic skills. During this period, the potential for using games to teach computer science concepts started to be recognized. Simple programming environments like LOGO [36] allowed students to control a turtle-shaped robot, providing an early form of learning programming through play.

As personal computers and the internet became more widely available in the 1990s, educational technology grew in importance. Educational software became more sophisticated, with improved graphics and interactive elements. This era saw the introduction of games that aimed to teach more complex computer science concepts. One of the pioneering efforts was *Robot Odyssey* [32], a game that taught players about programming and circuit design through puzzle-solving. Another significant development was the introduction of the programming language *Scratch* [33] by MIT in the late 1990s. Scratch used a game-like interface to teach young students the basics of programming through interactive storytelling and game creation.

The emergence of serious games—games designed for a primary purpose other than pure entertainment—was a sign of the development of more sophisticated games aimed at teaching specific skills and knowledge areas [27], including computer science. Serious game is not the same as gamification. The latter refers to the application of game-design elements in non-game contexts to enhance user engagement and motivation [5]. It typically incorporates elements like points, badges, and leaderboards into traditional business processes or educational activities to incentivize participation and engagement. On the other hand, serious games are fully developed games designed for purposes beyond entertainment, such as education, training, or health improvement. These games provide immersive experiences with complete storylines and interactive gameplay tailored to specific learning or training objectives. Games like *LightBot* [37] and *CodeMonkey* [24] were designed to teach programming logic and problem-solving skills through engaging puzzles. Additionally, the rise of online platforms and communities, such as Code.org and Khan Academy, began to offer gamified coding exercises, making computer science education more accessible and appealing to a broader audience.

Driven by advancements in technology, game-based learning became more mainstream, increased research into educational methodologies and a growing recognition of the importance of computer science education. The development of mobile apps and the proliferation of tablets and smartphones provided new opportunities for interactive and portable learning experiences. Games like *Minecraft: Education*

*Edition* and *Roblox* allowed students to learn programming and engineering principles within a popular and familiar gaming environment. A lot of schools have started incorporating game-based learning into their curricula as a result of the growing popularity of this approach to education. It is further aided by the growth of massive open online courses (MOOCs) and platforms like Coursera and Udacity, which frequently include gamified components to increase participation and motivation.

The field of game-based learning in computer science has been enhanced by the emergence of a number of platforms and games in recent years. These tools cover a wide range of learners, from beginners to advanced students, and cover various aspects of computer science, including programming, cybersecurity, and algorithmic thinking. *Human Resource Machine* [8] is a puzzle game that teaches programming concepts through a series of increasingly complex tasks. Players must automate office tasks by writing simple programs in a visual, assembly-like language. This game helps players develop problem-solving skills and a deeper understanding of how computers execute instructions, making it an excellent tool for introducing programming logic and computational thinking. *While True: Learn()* [30] is a game that simulates the work of a machine learning specialist. Players must create and train neural networks to solve various problems, such as image recognition and natural language processing. The game provides a hands-on introduction to machine learning concepts and techniques, allowing players to experiment with different algorithms and see the impact of their choices in real time. *Quadrilateral Cowboy* [15] on the other hand is a unique game that combines elements of cyberpunk aesthetics and puzzle-solving with programming challenges. Players assume the role of a hacker in the 1980s, equipped with a hacking deck that allows them to infiltrate buildings, disable security systems, and complete various heists. The game requires players to write and execute code in a pseudo-programming language to manipulate the environment and achieve objectives.

The field of game-based learning in computer science has been in a state of continuous growth and innovation. This approach has proven effective in engaging students and making complex concepts more accessible. However, most of these educational games tend to focus on teaching programming logic and computational thinking through the use of simplified, pseudo-programming languages, which has led to a somewhat homogeneous landscape in educational game design within the field of computer science. students might not be exposed to the broader applications of computer science in solving real-world problems. Despite the effectiveness of these games in teaching programming basics, there is a notable gap when it comes to topics such as algorithms and data structures. These topics are essential for understanding how to write efficient code and solve complex problems, yet they are rarely the focus of educational games.

## 2.2 Game-Based Learning in Data Structure and Algorithm

Algorithms and data structures are fundamental components of computer science curricula. They are critical for efficient problem-solving. Knowledge of these topics is essential for writing optimized code and crucial for real-world applications. Given their importance, introducing these concepts early in a student's education can spark interest and provide a strong foundation for further studies in computer science. Games specifically designed to teach algorithms and data structures have great potential for making these complex topics more accessible and engaging. One example is the work *The Stack Game* [11] presented in 2018 which was focused on the stack data structure. The game involved tasks and puzzles that required players to use stack operations (push, pop, peek) to achieve specific goals. This hands-on approach helped students visualize and understand how stacks operate. It showed positive results in terms of student engagement and understanding. By actively involving students in the learning process, the game made the abstract concept of stacks more concrete and understandable. Feedback from students indicated that the game was both enjoyable and educational, helping to simplify the core concept of data structures. The success of the stack teaching game suggests that similar approaches could be effectively applied to other data structures and algorithms.

*Binary Dungeon* [16] is another educational game that focuses on teaching binary trees, a fundamental data structure in computer science. Binary trees are hierarchical structures with a root node and two children, each of which can also have children. In this game, Players construct their own dungeon maps where each room serves as a node in a binary tree structure. They need to arrange rooms to optimize paths, balancing complexity and efficiency. The objective is to find a magical torch hidden within the dungeon, with limited time before it fades. This encourages players to understand and apply binary tree principles practically, using traversal strategies akin to search algorithms to navigate the dungeon and


Figure 1: The game system of *The Stack Game*

achieve their goals. It not only serves as an educational tool for teaching the concepts of binary trees but also stands out due to its well-crafted game design elements. The game enhances learning by incorporating a 3D interface, compelling narrative, and satisfying gameplay mechanics, which all contribute to a deeper sense of immersion for the player.

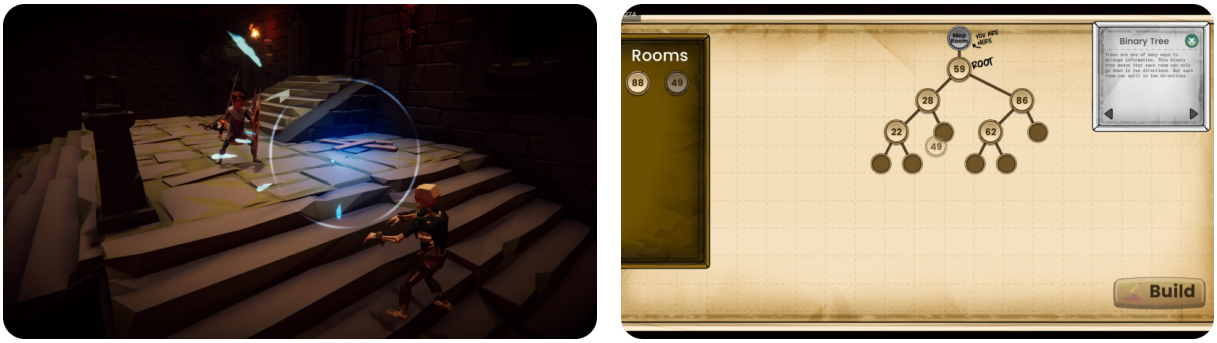


Figure 2: The game system of *Binary Dungeon*

We can observe that the above two games focus only on a single point of knowledge (stack or tree). Developing a complete game around a single educational concept can be resource-intensive, involving significant investments in time, money, and creative energy. Considering the complexity and depth required to create engaging game environments, such a focused approach might not be the most economical or practical use of resources. While initial engagement might be high due to the interactive learning environment, the long-term appeal of these games could disappear once the specific concept is mastered. This could reduce the game's usage and decrease its overall educational impact. Scaling a single-concept game to cover more comprehensive content can be challenging without overhauling the entire game structure. This may need additional development processes, increasing costs and complicating the delivery of updated educational content.

Integrating educational content into gameplay without disrupting the game's flow and engagement level is a major challenge. The game must educate without becoming too instructional or diverting from its entertainment value. When authors want to focus on gameplay and entertainment, they will inevitably sacrifice a certain amount of education. An example of the opposite would be The Forest of Data Structure [12].

The game presents a comprehensive introduction to essential topics within data structures, covering a wide array of fundamental concepts such as arrays, graphs, sorting algorithms, search techniques, and so on. This broad scope covers the core components necessary for a solid understanding of data structures integral to computer science education. However, despite the educational richness, the game's production appears to have been constrained. The graphics and user interface are somewhat rudimentary, which


Figure 3: The game system of *The Forest of Data Structure*

might detract from the user experience. Moreover, the game's complexity and perhaps its intuitive design elements are not as polished, making it somewhat inaccessible for beginners. This lack of refinement could potentially hinder the learning process, as players may find it challenging to engage with the content effectively.

All the serious games mentioned above did not claim to target a certain group when they were made and released. This approach aims to provide an inclusive learning environment that does not favor or disadvantage any gender. However, this well-intentioned strategy of gender neutrality may inadvertently overlook the unique challenges and barriers that specific genders, particularly females, face in the field of computer science. Gender neutrality may not fully address or accommodate the specific needs and preferences of female learners, who are significantly underrepresented in computer science. As the field evolves, it will be important to balance the benefits of gender-neutral designs with the potential advantages of more targeted educational tools. This approach can help ensure that all learners, regardless of gender, have the tools and opportunities they need to succeed.

## 2.3 Game-Based Learning Environment for Female

The educational games *Build a House* and *Rosie the Fashionista* were designed to specifically study the impact of gender-specific educational environments [2]. Both games have the same teaching model, using pseudocode to impart programming logic, yet they have distinctly different game backgrounds—one focused on fashion and dressing, while the other on house building. Without discussing whether the social phenomenon of "girls prefer dress-up games" is the result of artificial cultivation based on stereotypes, the former can be regarded as a learning environment created specifically for women, while the latter is gender-neutral. The reasons for such a phenomenon are still inconclusive. An experiment regarding to rhesus monkey suggests that it is the effect of innate hormones [21]. Yet another paper suggests that this is a trait that individuals acquire through social learning [25]. In any case, the game-comparison study employs this existing observable social phenomenon to state that the girls' engagement levels were significantly higher with *Rosie the Fashionista* compared to *Build a House*. The authors attributed this difference to the gender identity resonance that the fashion-themed game evoked. Such identity resonance can be influenced by various factors, including the portrayal of same-gender characters in textbooks and other educational materials [18]. The findings suggest that gender identity plays a substantial role in educational engagement and can be effectively addressed by designing learning tools that align with the interests and cultural identities of the learners. This is particularly important in fields where there is a significant gender imbalance. Another study [7] shows that by simply changing the stereotype of computer science, women can be easily intrigued. All of the results challenge the effectiveness of purely gender-neutral educational approaches, especially in fields where one gender has historically dominated. While gender neutrality is intended to promote an inclusive learning environment, it may accidentally overlook the needs and interests of disadvantaged groups, thus making the disparities worse. Until the gender ratio in a given field equalizes, it makes more sense for gender equality to adopt minority-specific teaching models as a means of transition and equalization. By engaging underrepresented groups through specifically designed educational content that resonates with their experiences and interests, educators can enhance interest and retention in fields where these groups have been historically marginalized.

Exactly what kind of elements should be included in a game to attract female players and give them a reason to spend a certain amount of learning cost to participate in the game is what we are going to discuss next.

## 2.4 Preference of Female Players

The preferences and gaming behaviors of female players have been a significant topic in video game research. Studies showed that the preference of women towards video games was more sensitive to the richness of meaningful dialogue and character interactions than to competitive elements [20]. Many female gamers are drawn to games that offer rich narratives and the opportunity to establish and develop relationships within the game world. Games that feature complex characters and dynamic interpersonal interactions tend to hold more appeal, as they provide a more immersive and emotionally engaging experience. Also, dialogue that is well-written and meaningful can significantly enhance the gaming experience for female players [20]. Such dialogue helps deepen the understanding of the game's narrative and characters, making the experience more personal and relatable. In addition, on average, female gamers may prefer cooperative or solo gaming experiences over competitive ones. Competitive aspects, especially those that emphasize aggression or direct confrontation, are generally less appealing. Games like *Life is Strange* and *The Sims* series are examples that have resonated well with women, largely due to their strong emphasis on narrative, character development, and personal choice. These games let players explore relationships and make decisions with real effects within the game, appealing to their desire for depth in storytelling and interaction.

Designing games featuring female protagonists can be an effective method for creating diversity and meeting female players' interests. Female players often find games with female protagonists more relatable. Seeing characters that resemble themselves or share similar experiences can enhance their engagement and investment in the game. Studies [1] showed that role-playing games are the females' favorite type of game. Role-playing makes players feel the responsibility to complete the game's tasks. This connection is particularly strong in narrative-driven games, where character development and personal growth are central to the story.

Understanding and integrating emotional and social interactions within video games is crucial [29]. These elements contribute significantly to how immersive and appealing a game can be for female players, impacting their overall gaming experience and satisfaction. A typical category of games related to emotional interaction is Otome Games, which has a significant proportion of the games currently being developed for female players. Otome games are a categorical distinction specifically designed for female players, focusing primarily on romance and interpersonal relationships by allowing players to interact or flirt with non-player characters [26]. For example, *Mystic Messenger* [6] is a well-known female-oriented visual novel mobile game. The game focuses on romantic interactions with the game's virtual characters in the form of a simulated chat software interface, which in turn drives the storyline. In 2023, otome games accounted for nearly 75% of the Chinese gaming market's overall revenue [19]. This statistic not only underscores the significant presence of Otome Games within female-oriented gaming but also highlights their considerable economic impact on the gaming industry. Romantic elements in Otome games have a sizable appeal to female players.

The possibility of integration of such elements into an educational game raises the question of whether they can positively influence female players. In the current landscape of educational games, there is a noticeable gap in offerings that focus on computer science topics, such as data structures, specifically designed for female learners. Moreover, educational games developed with a gender-specific approach are rare. Addressing this gap, the development of a computer education game specific for female players could meet an unfulfilled need in the market. Considering the current market dynamics, where such educational tools are scarce, and gender-specific educational products are even less common, there is a unique opportunity. Utilizing romantic elements to attract female players could significantly enhance engagement and retention, thereby making learning more effective and enjoyable. While it is important to acknowledge the potential criticism of reinforcing stereotypes by associating romance with female-oriented games, the primary intent here is not to perpetuate these norms but rather to explore the engagement strategies that resonate with the target demographic. This approach is based on market trends and the recognized preferences within potential user groups, not on a presupposed gender bias.


Figure 4: *Mystic Messenger*

A relevant example that illustrates the potential of integrating such elements is the educational game *Seekl*. *Seekl* [34] is an educational game designed to teach SQL, the language used for managing and manipulating databases. In this game, players find themselves inadvertently entering a server created by a group of characters posing as hackers. The gameplay involves interacting with these NPC hackers while solving a series of puzzles using SQL queries. The game uniquely combines educational content with an engaging narrative and character-driven storytelling. Many female players have shown great interest in this game. This success can be attributed to its immersive gameplay, character design, and interactive storyline designed to enhance learning and retain interest.


Figure 5: The game system of *SeekL*

The game introduces SQL concepts progressively, allowing players to apply what they've learned directly to solve problems that progress the story. This practical application helps in cementing the knowledge more effectively than traditional, non-interactive teaching methods. The visual presentation of the game, especially its high-quality character designs, plays a crucial role in attracting and retaining the player's attention. This visual appeal is particularly significant in maintaining engagement throughout the learning process. Understanding that some players may have no prior programming experience, it includes a detailed instruction manual. This manual helps to ensure that all players, regardless of their previous exposure to programming, can advance through the game without undue frustration.

*Seekl* exemplifies how educational games can effectively attract and engage female players by integrating educational content with compelling storytelling and high-quality game design. The game's success highlights the importance of creating inclusive, supportive, and engaging educational tools in technology fields.

Based on this understanding, we designed a serious game that integrates romantic elements with the knowledge of data structures and algorithms. By embedding love stories into the educational framework, we aim to assess how these romantic elements influence female players' engagement and learning experi-

ences.

### 2.5 The Technology Acceptance Model

To understand and predict how players come to accept and use this new type of educational method, we used the Technology Acceptance Model [9]. It is a theoretical framework that has been widely used to assess the acceptance of users toward new technologies. TAM posits that two primary factors influence a user's decision to adopt and use a new technology:

- **Perceived Usefulness (PU):** This is defined as the degree to which a person believes that using a particular system would enhance their job performance [10]. Perceived usefulness is a critical factor because users are more likely to adopt a technology if they believe it will improve their efficiency or productivity.
- **Perceived Ease of Use (PEU):** This refers to the degree to which a person believes that using a particular system would be free from effort [10]. Even if a technology is perceived as useful, it will not be adopted if it is too difficult to use. Therefore, perceived ease of use plays a crucial role in technology acceptance.

These two factors influence the user's attitude toward using the technology, which subsequently affects their behavioral intention to use the technology. The behavioral intention then leads to the actual system use. In the context of educational games, TAM can be applied to assess how students perceive the usefulness and ease of use of a learning game. By measuring these perceptions, educators can understand whether students are likely to embrace such technologies as part of their learning process.

## 3 Methodology

### 3.1 Participants

To evaluate the effectiveness of the game, We need a group of participants aged 16-20. This age group was chosen because they are in high school or early college, at a critical time when they are likely to be newly exposed to and learning basic computer science. Their learning experiences may have included some basic programming courses, but not complex concepts. At the same time, females in this age group usually show a higher interest and acceptance of novel educational approaches, such as game-based learning. In addition, the core elements of otome games (e.g. romantic plots and role-playing) are usually able to attract this group and stimulate their learning motivation. Participants mostly began to pay attention to the game early in its development and showed a keen interest in participating in the experiment. Therefore, they are not only a potential audience for this experiment, but also a target population for learning data structures.

we recruited 30 participants who met the age and gender criteria.

### 3.2 Procedure

The experiment was conducted entirely online. To recruit participants, we began by creating personal accounts on various social media platforms early in the game's development. We used this account to post development logs and updates about the game, which helped attract followers interested in the project. From these followers, we recruited 30 participants who fit the criteria. All participants were invited to join our Discord group, where they received detailed instructions on how the experiment would proceed. Specifically, they were informed about the study's objectives, the steps they would need to follow, and the timeline for each phase of the experiment. The necessary materials provided to them included the game installation files, a guide on how to install and run the game, and access to an online survey. The survey link, which was shared after everyone had joined the group, marked the starting point of the experiment.

The first page of the survey was an informed consent form, where participants had to acknowledge and agree to participate in the study. Only after all participants clicked to agree did the experiment officially begin. The participants were first asked to complete a set of 10 questions on data structures and algorithms. These questions were multiple-choice, each with five possible answers. The pre-test took approximately 10 minutes to complete. Once all participants had finished the pre-test, we shared the game installation package in the group, marking the start of the gameplay phase. On average, partici-

pants spent around 30 minutes playing the game. After completing the game, participants were asked to return to the survey to proceed with the post-test. The post-test took about 15 minutes to complete and included the exact same 10 questions in the pre-test and additional questions aimed at evaluating the educational impact of the game, as well as participants' overall experience and enjoyment. After the questionnaire, each participant posted their feelings and thoughts about the experiment in the group.

### 3.3 Measurements

The survey was structured into three key components: pre-test, post-test, and background information and motivation. This design aimed to quantify the educational impact of the game on participants' knowledge and attitudes towards computer science concepts.

- **Pre-test:** The pre-test consisted of 10 multiple-choice questions focused on basic data structures and algorithm concepts. Each question contains five options, including "I don't know". The purpose was to establish a baseline understanding of these topics among participants before they engaged with the game. Questions covered topics such as stacks, queues, and binary trees, etc.
- **Post-Test:** This assessment included the same questions as the pre-test, allowing for a direct comparison of knowledge before and after the game intervention.
- **Background information and motivation:** The final set of 25 questions were designed to gather detailed insights into the participants' backgrounds, motivations, and experiences. This section included:
  - **Personal Information:** 5 questions to collect demographic data, such as age, educational background, gender, nationality, and major.
  - **Perceived Usefulness:** 6 questions (each rated on a 10-point Likert scale, where 1 indicates "Strongly Disagree" and 10 indicates "Strongly Agree") aimed at assessing the perceived usefulness of the educational game. Example questions included:
    - "Do you find the game to be a useful tool for learning data structures?"
    - "Does the game enhance your learning efficiency?"
    - "Has the game motivated you to explore computer science further?"
  - **Perceived Ease of Use:** 3 questions (also rated on a 10-point Likert scale) focused on how easy the participants found the game to use, the level of attention it demanded, and their confidence in overcoming any obstacles within the game. Example questions included:
    - "How easy did you find the game to navigate?"
    - "The game require significant effort or attention to use."
    - "How confident were you in overcoming challenges within the game?"
  - **Additional Questions:** The remaining questions included a mix of formats:
    - **Scored Questions (out of 10):** These assessed specific aspects like prior interest in computer science and how confidence in solving data structure problems changed after gameplay. For instance:
      - "On a scale of 1 to 10, how interested were you in computer science before playing the game?"
      - "How much did your confidence in solving data structure problems increase after completing the game?"
    - **Multiple Choice Questions:** These explored participants' previous experience with similar serious games and their preferred learning methods. For example:
      - "What is your preferred method of learning new concepts?"
      - a) Online Videos
      - b) Online Courses
      - c) Offline Courses

- d) Books
- e) Practice Programs

* **Open-Ended Questions:** These allowed participants to express their thoughts in more detail. For example:
  - "Is there anything else you'd like to say to us? Or are there any other comments or suggestions you would like to make?"

This detailed approach ensured a comprehensive understanding of the participants' backgrounds, their interaction with the game, and the educational impact of the game itself.

## 3.4 Game Design

### 3.4.1 Storyline and Setting

To better incorporate educational concepts into the game, we designed a detailed story background for the game *Convinience Store 31*. The game is set in an area that has fallen into chaos after an accident. Because of this event, all characters, except the player, have turned into non-human entities. The player takes on the role of an employee working in a convenience store in this area. The content of the game is shown from the player character's first point of view throughout. At the beginning of the game, the player's memory is lost, and the full story is revealed gradually as the game progresses. The goal is to complete various daily tasks, earn enough money to buy the key to the escape route, and then leave the area.

### 3.4.2 Educational Components

Each mini-game is linked to a specific algorithm concept. For example, when handling transactions at the checkout, players must use stack and queue structures to arrange items in the correct order. When each new mini-game is introduced, the game explains the relevant concepts. Players are guided step-by-step through the process, ensuring they understand how to apply the knowledge within the game. Successfully completing these tasks earns coins that can be used to buy the key needed for a happy ending in the game. As players engage in increasing interactions with the customer characters, they will unlock new dialogue content and acquire additional snippets of knowledge.

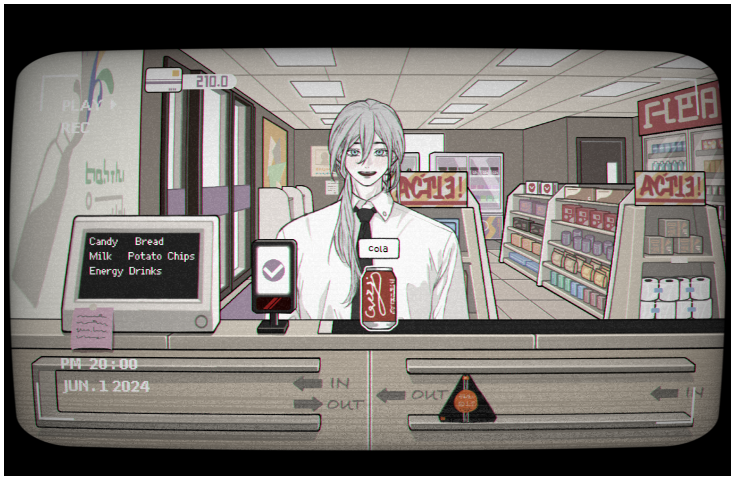


Figure 6: The game system of *Convinience Store 31: part 1*

At 8 PM each in-game day, the convenience store closes, and the game shifts into an evaluation mode designed to assess the player's learning progress. During this period, players will be tested on their understanding of the concepts they have encountered before. Players have the option to interact with a randomly selected store character to undergo these assessments. Successfully answering the questions and completing the evaluation challenges earns players rewards. Specifically, for each successful assessment, players are granted an opportunity to flirt with the store characters by different means.


Figure 7: The game system of *Convinience Store 31: part 2*

Table 1: Educational Components of *Convenience Store 31*

| **Mini-game** | **Algorithm Concept** | **Implementation in Game** |
|---|---|---|
| Checkout Transactions | Stack and Queue | Players arrange items using stack/queue |
| Business Trip | Binary Tree | Players arrange items using stack/queue |
| Inventory Management | Hash Tables | Players organize store inventory using hash tables |
| Data Upload | Huffman Coding | Players use Huffman Coding to upload sales record |

### 3.4.3 Player Interactions

The game incorporates several forms of interaction that can be classified as romantic or flirting. These interactions are designed to deepen the player's engagement with the characters and include, but are not limited to: romantic dialogues, kissing and touching, or in some scenarios, players can direct characters to perform certain actions, such as removing upper cloth, which is presented in a context that respects the game's narrative and character dignity. According to PEGI guidelines, the content described is permissible within games rated 16 and older, provided it is handled appropriately and does not include explicit material [23]. Our game design adheres strictly to these guidelines, ensuring that all interactions are suitable for the intended target group and contribute positively to the game's immersive experience.

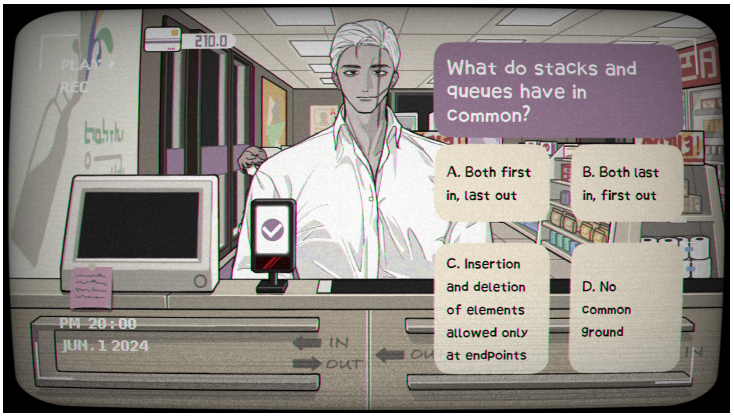


Figure 8: The game system of *Convinience Store 31: part 3*

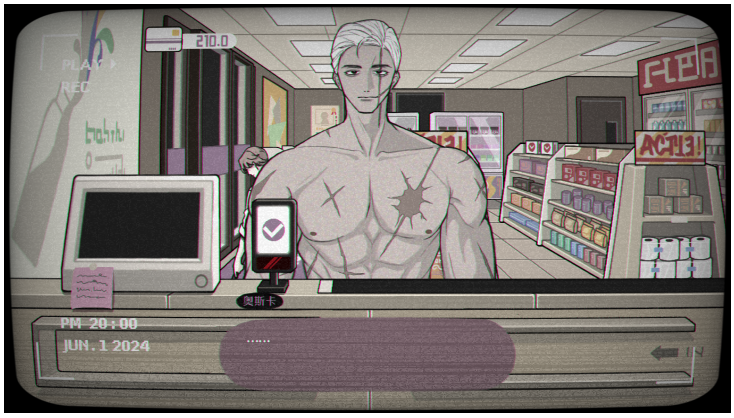


Figure 9: The game system of *Convinience Store 31: part 4*

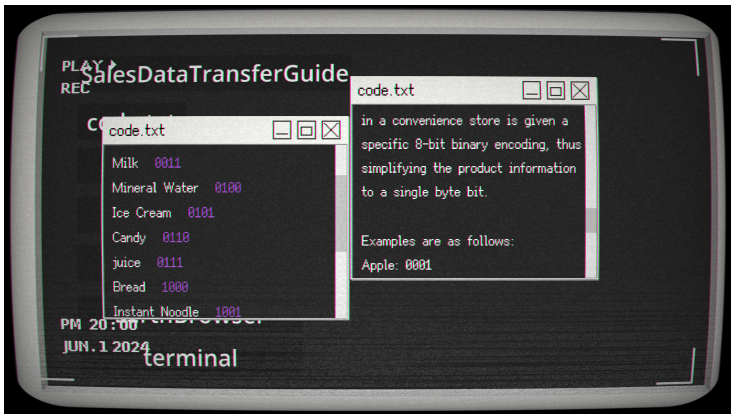


Figure 10: The game system of *Convinience Store 31: part 5*

The flirting component serves as an interactive device designed to stimulate player engagement and learning motivation through emotional connections between characters. These interactions are quite common and popular in the current otome games. We referenced interactive content from popular games on the market and incorporated it into our game design. By linking the successful completion of tasks to interactive rewards, the game motivates players to retain and apply the knowledge they have acquired. Romantic narratives and graphics are integrated into the game through dynamic character interactions. These interactions are designed not only to foster a deeper emotional connection but also to motivate learning by tying romantic progress to educational achievements. Interactive dialogues and relationship-building scenarios are strategically placed to coincide with key educational milestones, thereby using the game's romantic storyline to reinforce learning and retention. The blend of educational assessment with engaging interactions enhances the overall learning experience and helps solidify key knowledge points. The game encourages players to solve as many puzzles as possible by using its storyline, interactions with NPCs, and different endings as rewards. This approach blends the story with educational content to make learning engaging and interactive.

### 3.4.4 Game Conclusion and Outcomes

Eventually, on the fifth day, the game concludes with a final evaluation. Based on the player's performance throughout the game, they will receive different ending outcomes. These outcomes are determined by how well the player completed tasks, interacted with characters, and mastered the educational concepts presented.

## 3.5 Analyses

We conducted a comprehensive analysis of the survey data collected from participants, methodically structured to ensure an in-depth evaluation of the educational game's impact. First, we analyzed participants' background information, including their prior interest in computer science, previous experiences

with similar educational games, and initial confidence in solving data structures and algorithms problems. Second, we conducted a detailed comparison of participants' understanding of data structures and algorithms before and after the gameplay. This was achieved through pre-tests and post-tests designed to measure specific knowledge and skills. By statistically analyzing these results, we were able to identify learning improvements and evaluate the substantive educational impact of the game. Third, focusing on perceived usefulness (PU) and perceived ease of use (PEU), we calculated average scores and standard deviations, which provided insights into how participants assessed the educational value and overall usability of the game, serving as an indicator of the game's effectiveness in facilitating learning and its accessibility. Fourth, we reviewed qualitative feedback from survey questions where participants provided deeper insights into their experiences with the game to help us understand how the game influenced their learning preferences, self-confidence, and overall satisfaction with the educational content.

# 4 Results

This section presents the findings from our survey, which was conducted to evaluate the effectiveness and acceptance of the game. We begin by examining the gaming habits of the participants to understand their frequency of engagement with video games. Most of the players who participated in the survey are highly active gamers who are extremely involved in video games. On the question of how often they play video games, out of 10 points, we got an average score of 9.6. The standard deviation was 0.4, suggesting that most participants consistently reported high engagement with video games.

Additionally, 33% of participants indicated that they had previously engaged in gamified learning, but most of their experiences were with more entertainment-focused gamification tools, such as *Duolingo* and *Minecraft Education Edition*. However, their exposure to serious games was much more limited, with only two participants mentioning that they had played *Human Resource Machine* before, and one participant reported playing *Epistory - Typing Chronicles*, a game focused on improving typing skills. On the other hand, the remaining 67% of participants said that they had never participated in gamified learning experiences. This may state that the use of serious games in education is still in its early stages of development.

We also asked participants about their preferred learning methods. Learning by watching online videos was the most popular way of learning, with 12 people choosing this method. 8 players chose to take an online course, indicating that some players want to learn through a structured curriculum. This type of learning usually includes video lectures, tests, and interactive tasks, which can provide a more complete learning path and feedback mechanism. 5 participants chose offline courses. They valued face-to-face interaction and immediate feedback and felt more comfortable in a traditional classroom setting. In addition, 2 players chose books and 3 chose practice programs. Both require a greater investment of time and resources and are considered complementary to other learning methods. The relative lack of interactivity and real-time feedback in these two approaches makes it more difficult to interest non-specialists.

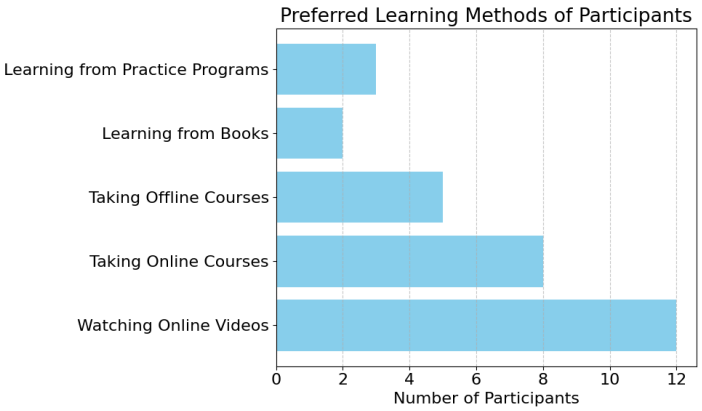


Figure 11: The distribution of participants' preferred learning methods

## 4.1 Prior Experience

In the educational level survey of the participants, we collected their educational background and level of understanding of data structures and algorithms through four questions. The results showed that the participants consisted of 12 students in high school and 18 students in college. The professional backgrounds of these college students covered a wide range from liberal arts to natural sciences, as well as technical and engineering disciplines. Specifically, two college students specialized in computer science and related majors, and three studied information technology but did not major in computer science, in addition to majors in economics, business, liberal arts, and natural sciences. For the two students who majored in computer science, In spite of their major selection, they had not yet thoroughly explored their computer science courses at the time of the study, which suggests that their current level of knowledge in data structures and algorithms still fit our experiment. Therefore, their participation is unlikely to skew the overall effectiveness of the game, as they have not yet reached a level of expertise that would markedly differentiate them from other non-specialist participants. Additionally, their prior exposure to the subject matter allows them to compare the game's content and pedagogical approach to their initial learning experiences in computer science. Their feedback can thus contribute constructively to understanding the game's utility as an introductory educational tool.

The majority of participants had a low level of understanding of data structures and algorithms, especially those in high school. Specifically, 15 rated their level of understanding between 0 and 3, indicating a relatively low level of understanding; 12 rated their level as moderate, with ratings between 4 and 6, while only 2 college students rated between 7 and 8, showing a high level of understanding, and all of these students were from computer science or related majors. Overall, participants' mean level of understanding score for data structures and algorithms was 3.6, reflecting a low level of overall understanding. In terms of programming experience, most of the high school students had no experience, while the college students had some programming exposure but generally had little experience.

Regarding participants' overall perception of the difficulty of working with computers, 26.7% of participants found it very easy to interact with computers, scoring between 0 and 2, indicating a high degree of confidence and familiarity with technology, 40% of participants scored between 3 and 5, reflecting a more neutral stance where they feel somewhat challenged by computers but manage basic tasks. Other participants scored between 6 and 8, expressing that they find working with computers relatively difficult, likely due to a lack of skills or a sense of intimidation towards technology.

## 4.2 Quiz Performance

We tested all 30 participants on their knowledge of data structures to assess the effectiveness of the game in improving learners' computer knowledge. We first asked participants to answer 10 questions about data structures to get a sense of their knowledge base before they were exposed to the game and asked them to answer the same 10 questions again after playing the game. Each question in the quiz presented four possible answers along with an additional option of "I don't know". Participants were instructed to select the answer they believed to be correct. Scoring for the quiz was straightforward: each correct answer was awarded one point, and each incorrect answer or selection of the "I don't know" option received zero points. Thus, the total possible score for each participant could range from 0 to 10, depending on the number of correct answers. The results are shown in Table 2.

Table 2: Pre- and post-game performance

| Test | Mean | Standard Deviation |
|---|---|---|
| Pre-game test | 3.3 | 2.0 |
| Post-game test | 8.1 | 1.2 |

From the table, we can see that before the game, the average score of the participants was 3.3, showing that their knowledge base in data structures was weak. The standard deviation is 2.0, indicating a large variation in scores among participants. Some participants had basic knowledge, but overall mastery was uneven, which made the variability in performance among the group more significant. In the post-game data, participants' mean scores increased from 3.3 to 8.1, and the standard deviation narrowed to 1.2.

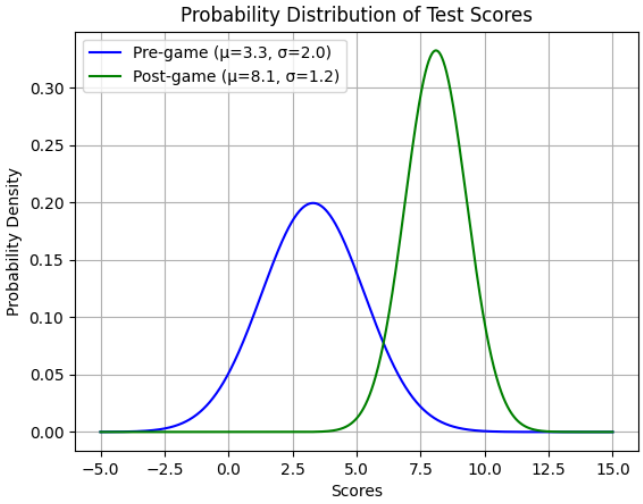


Figure 12: The probability distribution of pre- and post-game performance

To evaluate the improvement in participants' knowledge of data structures from pre- to post-game, a paired t-test was performed. The paired t-test setup was as follows :

- Null Hypothesis (H0): There is no difference in the mean scores of participants before and after the gameplay. This implies that the game did not have any effect on the participants' understanding of data structures.
- Alternative Hypothesis (H1): There is a difference in the mean scores of participants before and after the gameplay. This implies that the game had a positive effect on the participants' understanding of data structures.

The paired t-test, a statistical method used to compare two related samples, was utilized to determine the effectiveness of the game. The test calculates the difference between each pair (pre- and post-game scores) to determine if the average difference across all pairs is statistically significant. The t-statistic was computed using the formula:

$$t = \frac{\overline{X}_D}{(s_D/\sqrt{n})}$$

where $\overline{X}_D$ is the mean of the differences, $s_D$ is the standard deviation of the differences, and $n$ is the number of participants. The t-statistic was then used to determine the p-value, which helps in assessing the significance of the results. A p-value less than 0.05 typically indicates that the changes are statistically significant. After the calculation, we got the p-value of $1.491733800255979 \times 10^{-43}$.

## 4.3 Perceived Usefulness

Perceived Usefulness is one of the core variables in the Technology Acceptance Model (TAM), and refers to a user's subjective expectation of the possible benefits of using technology, implying the effectiveness of the game in helping the user achieve their learning goals. Six questions were used to assess this aspect. Specifically, participants gave a mean score of 8.8 to the view "I believe this game is a useful learning tool", indicating that the majority of participants considered the game to be an effective learning tool, and a standard deviation of 1.2 indicates a high degree of agreement on this point of view, with almost all learners agreeing that the game enhanced their learning experience.

The mean score of 7.8 for the perception that games enhance learning efficiency is slightly lower than the rating of the usefulness of games but still shows the potential of games to enhance learning efficiency. However, the standard deviation for this metric was slightly higher (1.4), suggesting that there was some variation in participants' perceptions of games' efficiency gains. In addition, the mean score of 7.3 for interest in data structures and algorithms further proves that gamified situations and role-playing can

Table 3: Perceived usefulness of the game

| Question | Mean | Standard Deviation |
|---|---|---|
| I believe this game is a useful learning tool. | 8.8 | 1.2 |
| Using this game enhances my effectiveness in my learning. | 7.8 | 1.4 |
| After playing this game, I am interested in data structures and algorithmic knowledge. | 7.3 | 1.5 |
| I am more inclined to further explore computer science or related fields after participating in this game. | 6.8 | 1.3 |
| I will strongly recommend others use it. | 9.0 | 1.1 |
| I have a desire to continue to learn more about it using this game | 8.3 | 1.6 |

Table 4: Composite score of perceived usefulness of the game

| | |
|---|---|
| Sum of mean scores | 48.0 |
| Average composite score | 8.0 |

effectively arouse players' curiosity and desire to explore knowledge points. The score for recommendation behavior is 9.0, and the desire to continue using the game is 8.3, showing its long-term appeal and educational potential. It is worth noting that the relatively lower score of 6.8 on the question regarding further exploration of computer science can be attributed to the modest scope and intent of the game. Given that the game was designed as a light introduction to the subject rather than a comprehensive educational tool, it naturally resulted in a more moderate influence on participants' deeper academic interests or career inclinations.

## 4.4 Perceived Ease of Use

Perceived Ease of Use (PEU) is another core concept in the Technology Acceptance Model (TAM), which refers to a user's subjective expectation of how easy it will be to use a particular technology. PEU describes the degree to which a user believes that using a particular technology will not require too much effort. PEU is particularly important for educational games, as it directly affects the ability of the user (learner) to play the game smoothly and thus absorb and learn new knowledge in a stress-free manner.

Table 5: Perceived ease of use of the game

| Question | Mean | Standard Deviation |
|---|---|---|
| I find this game/tool to be easy to use. | 8.4 | 1.2 |
| I find that interacting with this game/tool doesn't demand much care or attention. | 7.2 | 1.5 |
| I am confident that I can overcome any obstacles when playing this game. | 7.0 | 1.8 |

From Table 5, we can see that the game performs well in terms of PEU. The game's ease of use is highly rated (average score of 8.4), which shows that there is a consensus among the majority of players that this game is intuitive and simple to use. At the same time, we found that the game's interactions required appropriate attention from players, with an average score of 7.2. This score suggests that while the game's design requires players to devote attention, it is not overly complex, with a good balance between challenge and ease of use. In response to players' confidence in overcoming obstacles in the game, we note that the mean score is 7.0, while the higher standard deviation of 1.8 indicates a significant difference in confidence levels between players.

## 4.5 Background Information and Motivation

In analyzing players' scores before and after the change in their interest in computer science, we observed the average player interest score in data structures and algorithms was only 3.5 before the game experience, whereas after the game experience, this score increased to 7.8. We also asked players about their considerations regarding enrolling in computer-related fields. Out of the participants, 10 had never con-

Table 6: Composite score of perceived ease of use of the game

| | |
|---|---|
| Sum of mean scores | 22.6 |
| Average composite score | 7.5 |

sidered entering the field when choosing their majors. Three others had considered it but did not pursue it; one gave up due to a lack of interest in the field, while the other two are thinking about switching their majors to computer science, mainly due to better job prospects in the field. Additionally, five participants are actively engaged in studying computer science, possessing a relatively deep understanding of the subject and practical experience from their coursework.

After participants had experienced the game content, we asked them again if they were more inclined to explore computer science or related fields. The data showed that 18 players (60% of the total) indicated that they were now more inclined to explore these fields further. They generally indicated that the game, through its interactivity and immediate feedback, has reshaped their perceptions of their abilities and the difficulty of computer science. Through the game's challenge and achievement system, players gradually realized that they were able to master and apply this knowledge, thus enhancing their sense of self-efficacy. 8 players (27%) indicated that their interests were not affected by the game, suggesting that even well-designed games may not appeal to all types of learners. This group of players may already have established areas of interest or career goals, and computer science is not high on their list of priorities. 13% of the players indicated that they were uncertain about whether to explore computer science further.

When we asked the participants about their reason for choosing to participate in this study, 50% of the participants indicated that they were curious about this pedagogical approach. 27% of the participants' primary motivation was "just wanting to play games". 17% of the participants explicitly stated that they engaged in the study to learn about data structures and algorithms.

# 5 Discussion

The findings from our results provide some compelling insights about the effectiveness of the game. First of all, the consistently high engagement levels observed among the survey participants suggest that active gamers possess significant familiarity with and enthusiasm for gaming, which could predispose them to more readily accept and integrate serious games as effective learning tools. However, just a minority of participants had prior experience with serious educational games, indicating a significant untapped potential within the educational gaming market. Even though these gamers are familiar with entertainment-focused gamification, such as Duolingo, they still have limited exposure to games that are explicitly designed with educational outcomes in mind.

Furthermore, the diversity in preferred learning methods highlights the need for educational games to incorporate a variety of educational techniques. The preference for dynamic and visual learning through online videos suggests that integrating similar interactive elements into serious games could enhance their educational value. Meanwhile, the interest in structured online courses and traditional classroom settings underscores the importance of including clear learning pathways and feedback mechanisms within game designs to meet different learning styles and preferences.

## 5.1 Quiz Performance

The increased performance on the post-game test compared with the pre-game test suggests that the game not only improved participants' understanding of data structures overall, but also effectively reduced the knowledge gap between participants. The decreased standard deviation (from 2.0 to 1.2) suggests that the design of the game does have its advantages in helping learners from different backgrounds to improve their knowledge acquisition.

In addition to quantifying participants' knowledge acquisition before and after the game, we also observed their subjective feelings and behavioral responses when faced with the test questions. This data was gathered by summarizing participants' spontaneous comments made in the Discord group chat after

the experiment. Most of the participants did not find the questions in the test difficult, mainly because these test points were covered during the game. This suggests that the design of the game successfully incorporated the key concepts into the tasks and challenges, allowing participants to absorb and understand these points naturally in practice. However, for those participants who did not have any prior knowledge base of data structures before the game, they still felt a certain degree of difficulty even in the post-game test. This suggests that although the game enhanced the level of knowledge acquisition overall, additional support and guidance may still be needed for learners with no foundation at all. In particular, among the participants who had already attended college, students who were engaged in science and engineering majors performed better in game-based learning than students in other majors. This phenomenon may stem from their more frequent exposure to technology in their daily studies and lives, resulting in higher acceptance and familiarity with technological tools and digital platforms [4]. This also reflects a potential challenge for game-based learning: how to ensure that all participants, regardless of their initial level, can achieve a basic level of understanding and mastery in a short period.

Encouragingly, at the end of the experiment, most participants volunteered to get the correct answers and explanations by messaging us. In addition, several participants reported actively searching for relevant answers online after the game. These behaviors demonstrated their awareness of active knowledge acquisition and motivation to learn, showing that participants were willing to use external resources to supplement the learning content in the game to gain a more comprehensive understanding. The interest shown by the participants in furthering their understanding and consolidating their knowledge suggests that the game not only succeeded in motivating them to learn but also prompted them to continue exploring and learning outside of the game. This kind of initiative is crucial for the long-term retention of educational effects and provides important feedback for game designers: games can be used not only as a closed learning environment but also as a starting point to stimulate a wider range of learning activities.

## 5.2 Perceived Usefulness and Perceived Ease of Use

In this part, participants rated the game highly as a useful learning tool, with a consensus about its effectiveness in enhancing learning efficiency. This reflects the game's successful integration of educational content in an engaging format, which resonates well with users. However, there was some variation in perceptions of the game's impact on learning efficiency, likely influenced by individual differences such as learning styles and prior gaming experience. The moderate scores for increased interest in computer science topics and further exploration in the field highlight a critical area for further development. Although the game successfully introduces participants to data structures and algorithms, the scores suggest that it may not sufficiently motivate all players in computer science. This could be addressed by incorporating more complex challenges and detailed content that could bridge the introductory nature of the game to more profound educational engagements. The high score for recommending the game indicates that players found the experience enjoyable and valued the learning aspect enough to advocate for its use. This strong recommendation behavior reflects the game's successful fusion of educational content with romantic and social elements that specifically appeal to female players. In addition, the desire to continue using the game is also high, indicating that the game not only has initial appeal but also continues to maintain player interest and engagement, showing its long-term appeal and educational potential.

The participants also highly rated (average score of 8.4) the game's ease of use, which shows that there is a consensus among the majority of players that this game is intuitive and simple to use. When we asked them about their confidence when playing the game, we observed a relatively high standard deviation (1.8), which indicates some level of difference in confidence levels between players. Players' prior experience had a significant impact on their confidence when facing new challenges. Those players who have been previously exposed to the concepts, especially those who have had success in these areas, may demonstrate higher levels of confidence in the game. This confidence stems from their perception of their abilities and memories of previous successes, which are key components of self-efficacy. Conversely, those players who have had negative feedback during the learning process may exhibit lower self-confidence. This fear may lead to avoidance behaviors when players face in-game challenges, which may reduce their learning efficiency and gaming experience. In addition, these players may be skeptical of their own abilities, which in turn affects their problem-solving approach and overall game performance. When designing the game, we used a positive feedback mechanism to enhance the self-efficacy of these players. Players received immediate encouraging feedback (i.e., interactive content with NPCs) for every mini-challenge they completed. Participants reported that this positive feedback not only enhanced players' sense of

accomplishment but also supported them psychologically. Players generally stated that romance-related interactions did motivate them to continue with the game to some extent. Players showed positive responses to those elements of the game, a phenomenon that demonstrates the positive impact of otome games on gaming education. Players generally thought that these romantic elements not only added to the fun of the game but also served as an important motivation for them to continue to participate in the game when they felt their self-confidence was low.

All the data suggests that the game's design successfully exploits the engaging elements of gamification to deliver educational content effectively. It indicates that otome games have been successful as an educational intervention tool to stimulate players' interest in exploring computer science.

### 5.3 Background Information and Motivation

The significant rise in interest scores from 3.5 to 7.8 post-game underscores the effectiveness of the educational game in making data structures and algorithms more appealing and accessible to players and also reflects the fact that the game succeeded in stimulating players' interest and engagement in learning by combining educational content with the engaging elements of an otome game. This is a good step forward, as one-third of the participants had never thought about a career in a computer-related industry before. These participants did not provide specific reasons, but their lack of consideration could stem from various factors, including a lack of understanding of the field or a belief that it does not align with their interests and career goals. This indicates that despite the rapid development and widespread application of computer science, it may still seem distant or irrelevant to some individuals. Still, some of the players showed their ambiguity about exploring computer science further. This uncertainty implies that players' absorption of new knowledge is not yet fully formed. Players generally responded that the short game length did not allow them to have a more in-depth understanding. If more exploratory elements could be introduced into the game, it might help players transform this uncertainty into motivation for deeper learning.

In conclusion, the data affirm that well-designed educational games have the potential to significantly influence learners' interest in and perceptions of academic fields, particularly in areas they might not have previously considered. To maximize the effectiveness of gamified learning, it is crucial to continue refining game designs to better align with diverse learner needs, motivations, and educational outcomes, ensuring that such tools are not only engaging but also broadly effective across different learner profiles.

## 6 Conclusion

This study explored the design and effectiveness of an educational game specifically targeted at female players, integrating romantic elements with fundamental concepts of data structures and algorithms. The game's objective was to address the gender disparity in computer science by creating an engaging and supportive learning environment for female players. The game utilized interactive challenges to teach key computer science concepts, aiming to increase participants' engagement and motivation to learn. The findings from the study indicate that the game was generally well-received by the participants, who reported high levels of perceived usefulness and ease of use. The positive feedback on the game's design and educational impact suggests that incorporating gender-specific elements into educational tools can be a viable strategy for increasing female participation in computer science. Furthermore, the analysis revealed that the game significantly improved participants' understanding of the targeted computer science concepts, as evidenced by the substantial increase in quiz scores from pre- to post-test. This indicates that the game was not only successful in capturing the interest of the players but also in facilitating meaningful learning outcomes. However, while the positive feedback on the game's design and educational impact suggests a successful integration, it's crucial to substantiate these findings more rigorously. As the game encompasses multiple elements that could influence engagement—such as interactive challenges and educational content—the specific impact of the romantic elements alone remains less distinct. Without direct queries about the romantic components, it is challenging to isolate their specific contribution from the overall game experience.

The definition and content of otome games are evolving with the changing times. In the early days, features such as simple game controls and connectivity to other media were categorized as otome games [26]. With time, the content of otome games has gradually diversified, and is no longer limited to purely roman-

tic themes, but has begun to incorporate more elements of adventure, suspense, history, fantasy, and so on. But emotional labor is always present as a criterion for winning a game [17]. With the development of the times, the needs and expectations of players have gradually become more diverse. Developers have begun to try to incorporate more diverse characterization into their games, as well as exploring real-world issues.

We chose this game category to develop a serious game for females primarily because they contain romantic elements that have broad appeal to the female population. This design strategy utilizes the romantic element as a powerful attraction tool to engage female players and increase their engagement with the game content. It is worth noting that the romantic element does not only appeal to female players; it has great appeal as a universal game element across all groups. Nevertheless, classifying romance elements in female-oriented video games itself reflects certain stereotypes in the current social context. Some argue that the close association of romantic elements with female entertainment products is a result of the social and cultural environment that has continuously inculcated this notion in the female population, rather than the inherent attractiveness of romantic elements to females. To develop products that are truly responsive to the needs of females, game designers must stay aware of changing social and cultural trends. If, on a given day, romantic elements become significantly less appealing to females and other elements become the primary points of interest for female players, game producers should also quickly adjust their design strategies to keep their products relevant and appealing. This flexibility not only helps to eliminate stereotypes but also ensures that the game product remains aligned with players' interests and needs. Besides, the effectiveness of romantic themes may vary significantly across different cultures and demographics. What might be appealing in one cultural context could be less effective or even inappropriate in another. Educational games, therefore, need to consider cultural sensitivities and preferences to ensure that the incorporation of such elements is appropriate and effective. The current literature on educational games pays little attention to elements such as romance. The integration of romantic elements within the context of educational games is a nuanced area. The rarity of discussions linking educational content with romantic elements could largely be attributed to the inherently serious nature of education. Traditionally, educational methodologies have emphasized cognitive and behavioral strategies to maximize learning outcomes, often sidelining the potential emotional engagement that romantic elements could bring. However, the findings from this experiment suggest the possibility of integration of such elements. We hope to inspire further academic inquiry and practical experiments that will explore and potentially validate the benefits of integrating romantic elements into educational frameworks. Such research would not only broaden the scope of strategies in education but could also challenge existing paradigms about what makes learning effective, appealing, and comprehensive.

# 7 Limitations and Future Works

One significant limitation of this study is the relatively small sample size. With only 30 participants, the data collected may not fully represent the broader population of female learners. Besides, due to the participants being followers of my work, there is a potential bias in how they perceive and interact with the game, which might affect their feedback positively. A larger and more diversified sample would enable more generalizable results and a better knowledge of how different groups interact with and benefit from the game. Expanding the participant pool in future studies will help validate the findings and ensure that the educational tool is effective across a wider range of users.

Another limitation is in the duration of the game and the depth of the content covered. The game was designed to be relatively short, which, while beneficial for maintaining participant engagement, also limited the scope of the educational content. The concepts introduced in the game were fairly basic and may not have provided significant long-term benefits or a deep understanding of more complex data structures and algorithms. Future iterations of the game should consider extending the gameplay duration and incorporating a broader range of topics with varying levels of difficulty. This would allow for more comprehensive learning and better preparation for participants in real-world applications of computer science.

In conclusion, despite the noted limitations, this study provides valuable insights into the potential benefits of integrating romantic elements into educational games targeted at female learners. The positive feedback and increased interest in data structures and algorithms among participants highlight the efficacy of this novel approach in engaging learners. By expanding the scope of future studies to include a larger and more diverse group of participants, extending game duration, and deepening content complex-

ity, subsequent research can build on these initial findings to develop more effective and comprehensive educational tools.

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