University of Birmingham

School of Computer Science

MSc Summer Project

Computer Knowledge Visualization

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Abstract

This project is an innovative software development effort aimed at enhancing the quality and efficiency of basic computer science education through visualization techniques. The core objective of the project is to transform complex concepts such as sorting algorithms in data structures into intuitive 3D models and animations to enhance students' cognitive understanding and motivation to learn. Through a well-designed interactive learning platform, students are able to explore the principles of computer science in a dynamic and engaging environment.

The functional requirements of the system are closely aligned with educational theories, in particular Bloom's Taxonomy, to ensure that learning activities cover all levels from knowledge memorization to creative application. The user interface is designed to be intuitive and easy to use, ensuring that it is accessible to users from a wide range of backgrounds and technical proficiencies.The system is designed to ensure that it can effectively serve educational needs in the long term and adapt to future technological developments. A modularized design is adopted to facilitate future content updates and upgrades for maintenance. At the same time, considering the stability of the operating system, the system adds the logic of enforcement and reduces the Code Redundancy.

In order to ensure that the project is delivered on time and meets the needs of the users, the project team chose to use Agile development methodology for rapid iteration and testing. At the same time, the producers recognized the limitations of resource and time management when facing a project with a single person. Therefore, an effective project management strategy was actively adopted to ensure that the project schedule could be completed on time and the quality met the requirement standards.

The project was tested and evaluated in real time throughout the development process, and real-time testing feedback was incorporated to change the design and solve problems. The project was completed on time, the requirements set forth by the Institute were met, the educational concepts associated with the application materials were met, and the system performance met the design requirements standards and satisfied the user requirements goals.

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1.Introduction

1.1.Background of the study

In today's era, the rapid development and wide application of computer application technology has become a key force in promoting social progress and innovation. Since the birth of computer technology, its penetration and influence on various fields of society has been deepening, which not only greatly enriches the life of human beings, but also completely changes people's working mode and living habits. Key industries such as education, healthcare, finance and entertainment have all been profoundly affected by computer technology, and these changes have not only improved the efficiency and quality of the industry, but also brought unprecedented convenience and innovation to society.

With the continuous progress of information technology, education informatization has become an important trend in the development of global education. Against this backdrop, the demand for computer technology education has shown explosive growth. In China, for example, the enrollment plan for computer science majors in 2024 reached about 435,000, an increase of more than 40,000 compared to the previous year, with the growth rate remaining at a high level. Especially the top institutions have the largest increase in enrollment plans, reaching 14.69% [1]. This remarkable growth trend not only reflects the popularity of computer science majors in the field of education, but also foretells the urgent demand for computer technology talents in the future society.

In the field of higher education, computer science students are challenged to learn subjects that require complex spatial imagination such as data structures. As a core course in computer science, data structure [2] plays a crucial role in developing students' logical thinking, algorithmic analysis and practical ability. It not only lays a solid theoretical foundation for students' subsequent professional learning, but also is a key skill for students to engage in computer-related work in the future. However, the abstractness and complexity of data structures are a considerable challenge for most students, and traditional teaching methods are often difficult to effectively convey these abstract concepts, making it difficult for students to understand and master them.

P. H. Kvam suggested that active learning can improve the effectiveness of teaching and learning at most academic levels [3]. However, traditional computer teaching methods are often boring and difficult to stimulate students' interest and enthusiasm in learning. To make learning more engaging, people have chosen to try to gamify higher education [4]. Based on the multi-channel electroencephalogram (EEG) and skin conductance response (SCR) experiments recorded by volunteers, Tian Feng et al. concluded that, due to the improvement of environmental perception, the emotional stimuli in 3D environments are more intense, leading to a higher degree of emotional arousal, and the EEG power (21-30Hz) in 3D environments is higher than that in 2D environments [7]. As a result, 3D gaming technology has come into the limelight and has been used in education to enhance students' interest and engagement in learning.The theoretical basis for this conclusion has been enhanced by the research of Shudayfat, E. and Costley, K., who have found through experimental studies that assistive instructional tools and technologies can have a positive impact on students' teaching and learning [6].

1.2.Purpose of the study

Based on the above findings, this study proposes an innovative 3D visualization teaching platform in order to improve students' learning interest and to address the limitations of visualization tools in basic computer education.Umapathy, K., Ritzhaupt, A. D., and Xu, Z. in their data collection mentioned that the literature on second programming classes and intermediate programming courses such as data structures is very limited [5]. Therefore, this platform will focus on the partial knowledge of data structure and visualize the sorting algorithm and time complexity through animation, which will effectively bridge the gap between beginners' understanding of basic programming and algorithmic principles. Compared with traditional teaching methods, this platform enhances the comprehensibility of concepts through dynamic visualization, which improves students' motivation and engagement. In addition, through interactive visualization tools, students can understand the principles and applications of computer science more deeply.

This study has fully considered the limitations of computing resources to ensure that the platform can run smoothly even in environments with limited computing power. This design strategy not only improves the universality of the platform, but also provides a feasible solution for resource-constrained educational environments, which helps to narrow the educational resource gap between different regions and schools. In addition, the platform will provide a testing and feedback mechanism to provide students with personalized learning advice and tutoring by assessing their learning progress and understanding in real time.

The research results of this project not only enrich the visualization teaching methodology of computer science education in theory, but also provide an effective teaching tool at the practical level. The potential of 3D visualization technology in enhancing the effectiveness of computer science teaching is verified through empirical research, which provides strong support for the promotion of education informatization and education equity. At the same time, this study also provides valuable experience and data support for the direction of subsequent research on the application of 3D visualization technology in the field of computer science education.

In summary, the study of basic computing knowledge visualization is not only of great practical significance for improving the quality of computer science education, but also of far-reaching theoretical significance for promoting the development and innovation of educational technology. Through this study, we expect to provide more effective and vivid teaching methods and tools for the field of computer science education and contribute to the cultivation of future computer technology talents.

1.3. Domestic and international status

1.3.1.Domestic Status

In China, data visualization technology, as an important means of information presentation, has been widely used in the field of education to enhance the learning experience and teaching effect. For example, in the process of physics teaching, the dynamic changes of Newton's laws of motion and electromagnetic fields can be visualized through three-dimensional animation simulation technology, so as to deepen students' understanding of abstract physical concepts. This intuitive teaching method makes complex physical phenomena easy to observe and analyze, and helps students better master physical principles and their practical applications. In language teaching, word cloud maps generated by word frequency analysis are used to highlight key vocabulary in the text to help students grasp the main idea and style of the text. This visualization tool not only provides an intuitive view of the vocabulary distribution, but also stimulates students' interest in learning and deepens their understanding of the text. In addition, interactive crossword puzzle software is also used in language teaching, so that students can deepen their memory of the structure and meaning of Chinese characters in the process of solving the puzzles, and this kind of teaching method greatly improves students' motivation and participation in learning.

It is worth mentioning that data visualization technology also plays an important role in student performance analysis and education quality assessment. By collecting data on students' performance, engagement, homework completion, etc. and visualizing them using charts, heat maps, etc., teachers are able to quickly understand students' learning progress and effectiveness, and identify learning bottlenecks in a timely manner. At the same time, educational institutions can also use data visualization tools to assess the quality of teaching, through the analysis of student performance, teacher evaluation, course satisfaction and other multi-dimensional data, to form a visual report on the quality of education, to provide data support for improving teaching.

In biology teaching, virtual reality (VR) technology provides an immersive learning environment for students, enabling them to understand the complex phenomena of biology more intuitively. In chemistry teaching, 3D visualization of molecular models helps students understand the spatial structure and chemical reaction mechanisms of compounds, making abstract chemical concepts concrete and vivid. In geographic information system (GIS) education, the visualization and analysis of maps and geographic data enable students to intuitively understand and analyze complex phenomena such as topography, climate change, etc. The cultivation of this spatial analysis ability is of great significance to the future development of students in many fields.

To sum up, the application of data visualization technology in the field of education greatly enriches the teaching means, improves the teaching effect, and provides strong support for the overall development of students.

1.3.2. International Status

Internationally, visualization technology has become a key driver of educational innovation, which not only facilitates a paradigm shift in education, but also enriches teaching methods. For example, the flipped classroom model, which allows students to learn independently through visualization resources such as videos before class and more discussion and practical activities in class, has been widely used in higher education institutions in several countries. In addition, virtual laboratory technology enables students to conduct scientific experiments without physical laboratory equipment by simulating the experimental environment, which is particularly valuable in resource-limited educational environments.

The use of visualization techniques has become a common phenomenon in the field of computer science teaching. For example, visualization techniques are used to assist teachers in teaching programming.The Maze framework is a computer game development tool for educational purposes that allows students to design simple computer games and implement their ideas in a Java environment. By providing a modular programming structure and a clear and usable graphical user interface, the framework helps students focus on learning design principles and game implementation logic without having to delve into and become proficient in the underlying programming details [8]. This convenient visual programming environment helps students to construct computational thinking and understand the operation mechanism of programs. However, it cannot help students enhance and extend their underlying programming skills.

Another example of visual tutoring instruction is the Scratch programming language, a children's programming language that allows students to drag-and-drop blocks of code to create stories, games, and animations through a graphical programming interface [9]. This visual programming approach significantly lowers the barriers to programming, enriches students' programming learning experience, and stimulates their interest in computer science.

In data science and statistics education, visualization tools such as Tableau and Power BI are widely used for data presentation and analysis to help students understand the complex structures and patterns of data sets and draw conclusions. These tools make the process of analyzing data more intuitive and understandable through interactive charts and graphs.

However, despite the many advantages of visualization techniques in education, there are some limitations. For example, for beginners, over-reliance on visualization tools may neglect the understanding and practice of basic academic principles. In addition, some visualization tools may require high computational resources that are not available to students, resulting in visualization tools being available to only a subset of the population in resource-limited environments. Some tools can only be used as teaching aids for demonstration purposes and not for practical application.

1.4. Technical introduction

3D modeling and rendering technology: professional 3D modeling software is used to create a 3D model of the sorting algorithm, and high-quality images and animations are generated through rendering technology to visualize the execution process of the algorithm.

Interactive Programming Environment: Interactive user interface that allows students to complete the relevant test questions by clicking on the operation, so as to understand the principles of the algorithm in a deeper way.

Graphical User Interface (GUI) Tools: Use professional GUI design tools to create interface elements such as buttons, icons, and interface boxes.

Game engine: Use Unity game engines, which provide powerful physics engines and scripting systems that facilitate dynamic visualization and interactive features of the algorithms.

Data Compression and Optimization Algorithms: In order to ensure the usability of the platform in resource-constrained environments, data compression techniques will be used to reduce the storage requirements of models and animations, and to increase loading speed.

Accessibility design: Considering the needs of different learners, the platform will follow the accessibility design principle to ensure that all students can use and benefit from the platform equally.

2. Analysis

2.1.Problem analysis

According to Sweller's cognitive load theory [10], visualization can reduce the burden on working memory. By presenting information graphically, learners are able to recognize patterns and structures more quickly, thus improving learning efficiency. Similarly, Paivio's dual coding theory states that humans have two separate coding systems to process corresponding visual and verbal information [11]. Presenting basic computer science theory concepts through intuitive visual means can activate both coding systems simultaneously, leading to enhanced memory and understanding. Therefore, the core of the whole research problem lies in how to transform abstract computer science theoretical concepts into an intuitive and understandable form through graphic, animation, or other visualization element representations.

When designing a visualization scheme, researchers need to take into account the needs for visualization at different levels. This includes the macro level (e.g., showing the overall flow of the target algorithm) and the micro level (e.g., explaining the theoretical details corresponding to the algorithmic knowledge). At the macro level, the visualization design solution should be able to clearly demonstrate the overall ideological framework and operational flow of the data structure sorting algorithm, helping learners to establish an overall understanding of the sorting knowledge. On the other hand, at the micro level, the visualization design scheme needs to explain the details of the theoretical knowledge in depth, ensure that the knowledge is complete and without omission, and explain each step of the sorting algorithm structure through animation demonstration and annotations of the execution steps, etc., so as to help the learners to understand and master the specific implementation process of the algorithm.

In addition, researchers should also consider the cognitive characteristics and learning needs of different learners. Different learners may have different cognitive styles and learning habits, so the visualization design solution should be flexible and universal enough to meet the needs of different learners. For example, for learners with strong visual memory, knowledge can be presented through rich graphics and demonstration animations; for language learners, the system can provide detailed textual descriptions and audio explanations.

In conclusion, designing a suitable visualization scheme is an important and meticulous process, which requires researchers to fully consider multiple factors such as different levels of visualization needs, learners' cognitive characteristics and learning needs. By using scientific theories as the basis, it helps us to design and practice the scheme, transforming abstract basic computer science concepts into intuitive and easy-to-understand forms, and helping learners to better master and apply this knowledge.Through scientific design and practice, we can transform abstract computer science concepts into intuitive and easy-to-understand forms to help learners better master and apply this knowledge.

2.2. feasibility analysis

As mentioned earlier, educational psychology theories such as cognitive load theory [10] and dual coding theory [11] provide a theoretical basis for visualization, supporting the reduction of cognitive load and enhancement of memory and understanding through graphical means. The ultimate goal of this study is to improve the user's learning experience and efficiency, so the corresponding visualization tools for computer basics need to be adapted to different educational environments, including traditional classroom teaching, online educational platforms, and individual self-study. This requires visualization tools to be flexible and scalable to adapt to different teaching modes and learning scenarios. And with the development of computer graphics and human-computer interaction technology, current technological tools have been able to support the visualization of algorithms. Game engines (e.g., Unity and Unreal Engine) will provide powerful platforms that make it possible to transform abstract concepts into intuitive graphical representations to meet educational needs in different environments.

Platforms similar to this system have not been released in this university and are not affiliated with any organization in this system development, and there are no liability issues such as copyright infringement or any other hindrance. In the preliminary research, it is understood that the development of this system is in line with the intention of the users as well as the existing management system. There is no ethical issue involved in the development of this system and hence it is also feasible in terms of social factors.

2.3. Requirements Analysis

In order to capture an accurate system specification, functional and non-functional requirements have been identified and are listed in the following subsections.

2.3.1. Functional Requirements

The system want to develop to visualize the foundational computer knowledge and help the users to learn and understand the knowledge. Therefore, according to the initial research intention and user requirements, the system will be developed as an example of data structure sorting knowledge points. For this reason, the following functional requirements are proposed for the system:

1. Replacing the traditional teaching method with 3D model demonstration, which skillfully integrates the detailed introduction and visual demonstration of the basic knowledge of computer science, making it easier for students to understand.
2. Design dynamic interactive demonstration: support students to view the knowledge brief by clicking, drag and drop to control the demonstration and model interaction.
3. The interface should follow the principles of clarity, consistency and aesthetics to provide a user-friendly interactive experience. The interface elements should be intuitive and easy to operate, reducing the cognitive burden on the user.
4. The functional requirements of the visualization tool should be closely aligned with the goals of computer science education, including but not limited to conceptual understanding, skill acquisition, and problem solving ability development. At the same time, it should make knowledge learning more coherent and fluent, and form a mind map in students' learning to help them better review and recall the knowledge system in the future.
5. Add the function of comparing the difference and performance of different sorting algorithms: The system should provide a demonstration of multiple sorting algorithms and allow users to compare their differences and performance, such as

execution time, space complexity, etc., so that students can understand the characteristics and applicable scenarios of various sorting algorithms more deeply.

6. Learning Effect Evaluation and Feedback Function: The system should be able to evaluate the learning effect of students and provide immediate feedback and suggestions. For example, it can test students' understanding of the sorting algorithms and their application ability through quizzes, practice questions or interactive questions and answers. According to students' learning performance, the system can give personalized learning suggestions to help students consolidate their knowledge and improve their learning effect.

2.3.2. Non-functional requirements

In addition to the above functional requirements, the system should also meet the following non-functional requirements:

1. The system should be highly accessible and easy to use regardless of the user's skill level, which requires ensuring that the system application interface is designed to be user-friendly and easy for users to operate. The system operational requirements are simple and can be easily reached to ensure that all users can use the system.

2. The user interface interaction logic should meet the user's expectations, satisfy the learning and usage needs of different students, and conform to basic user habits so that teachers and students can easily get started, without training, and can effectively use the system as soon as they pick it up.

3. The overall system design should adopt a modularized structure to facilitate future expansion and maintenance. New visualization content and functions should be easily integrated into the existing system to improve system scalability.

4. The system provides stable and reliable services to ensure the continuity of the learning process and to avoid interruptions due to system failures or jumping errors. At the same time, the system should have good response time and processing capability to avoid long loading time or response timeout.

5.System performance needs to meet high standards, including fast data loading and rendering speeds, and low-latency interactive responses, to ensure that users do not encounter lag or delay problems during use.

6.In the process of system design and implementation, performance optimization should be fully considered, and appropriate data structures and algorithms should be adopted to improve the operational efficiency and stability of the system. At the same time, the system should be tested and evaluated for performance, so that potential performance bottlenecks can be identified and solved in a timely manner to ensure that the system can meet the needs of users.

2.4. Process Analysis

The object-oriented main body of this project is students, in order to solve the above problems and fulfill the requirements, its main workflow is as follows:

1. System login and function selection: the user logs into the system through the authentication mechanism and selects based on the function navigation presented on the interface in order to enter the corresponding module.

2. Parameter Input and Algorithm Selection: The user inputs specific values and selects a sorting algorithm on the interface, and then the system guides the user to the sorting demonstration page.

3. Dynamic Demonstration and Interactive Learning: The system provides a dynamic visualization of the sorting algorithm and a step -by-step explanation. Users can adjust the speed of the demonstration through interactive controls according to their learning needs.

4. Algorithm Principle Analysis: Users can view the principle pseudo-code and detailed analysis of the selected sorting algorithm. The system switches the view from the pseudo-code to the explanation of the algorithm complexity by clicking the event response.

5. Knowledge testing and cyclic learning: after completing the visual learning, the user enters the testing page to verify the knowledge. If the test passes, the user will return to the function selection page; if the test fails, the user will be guided back to the

explanation page, so as to repeat the demonstration and explanation, and realize cyclic learning.

6. Comparative analysis of algorithms: The user selects the comparison function, and the system shows the differences and summarizes the two sorting algorithms. Users can further switch to the comparison view of all sorting algorithms by clicking on the event, in order to conduct a comprehensive comparative analysis of algorithm characteristics and performance.

7. Summarize: In the comparison view of all sorting algorithms, the system provides a summary of the characteristics and application scenarios of various sorting algorithms to help users build a comprehensive knowledge framework.

2.5. Challenges

During the implementation of the Computer Basics Visualization project, project leaders will face a number of challenges that span multiple dimensions, including technical implementation, user experience design, accuracy and validity of educational content, and sustainability and scalability of the project. These challenges are analyzed in detail below:

First, in terms of technical implementation, the researcher needs to select appropriate visualization tools and design frameworks to ensure an accurate presentation of the theoretical knowledge of the algorithm. This requires the project leader to be familiar with a wide range of present-day visualization tools, from which he/she can choose the appropriate ones to handle the animation production and user interaction design.

Secondly, user experience design also needs to be emphasized, which is crucial to the experience of the project. It requires project leaders to clearly understand users' needs and learning habits, and to design intuitive and easy-to-use interfaces and interaction flows. The person in charge needs to conduct surveys and collect requirements from the user community, and the design needs to consider not only the design of visual elements including colors, layouts, fonts, and icons, but also how to improve user engagement and learning through interaction design, and address the needs and requirements raised by users. To achieve this goal, the project will conduct user research, including target user interviews, questionnaires, and usability testing, to collect user feedback and iteratively improve the design.

In terms of educational content, the project needs to be accurate and effective in terms of academic interpretation. The project should ensure that the visualization content is compatible with the educational philosophy, ideally with the goals and standards for teaching computer science, and should be adaptable to the cognitive levels and backgrounds of different learners. This means that we need to browse the research findings of educational experts that can be used to ensure the scientific validity and pedagogical effectiveness of the content. We also need to refer to educational research, such as literature reviews, teaching experiments, and impact evaluations, to ensure that our program is achieving its intended educational goals.

Finally, sustainability and scalability of the program is also something that program managers should focus on. The field of computer science is constantly evolving, so our program needs to be able to update its content regularly to keep up with the latest academic research and technological advances. Also, the design of the project should be scalable so that we can add new visualizations and features in the future. This requires the project manager to consider modularity and flexibility in the planning of the project, and to ensure that the project can adapt to future changes and needs. In order to achieve this, we may have to adopt agile development methods so that we can respond quickly to changes and continue to create value.

When it comes to the difficulties that a project may encounter, the project manager has to consider resource constraints such as time, resources and manpower. A one-person project may not have the advantage of teamwork, so the project manager may have to switch between multiple roles, which may affect the progress and quality of the project. To overcome these challenges, project managers should develop detailed project plans and schedules, allocate tasks and resources appropriately, and ensure that the project can be reached on time.

3.Research

3.1.System Design

3.1.1. Overall system design

The user interface design of this project will meet the requirements of intuitiveness and ease of use. By integrating functional modules such as function selection menu, parameter input form, dynamic demo area, test page, etc., we will provide users with a comprehensive and convenient operation environment. In order to achieve this goal, we have carefully designed interactive elements such as buttons and sliders to ensure a smooth and intuitive user experience. At the same time, we also took into account the adaptability of the interface design to different screen sizes and resolutions. This means that no matter what kind of device the user is using, he or she will get a consistent and high-quality interface experience. In terms of the functional design of the system, we followed Bloom's taxonomy theory [12] to build a suitable structure for the teaching and learning process. It helps students learn theoretical knowledge from the whole process of memorization, comprehension, application, analysis, evaluation, and creation to ensure the teaching effect. In order to ensure the quality of the system, we also developed a comprehensive testing strategy. This strategy covers all levels of unit, integration and system testing, aiming to be able to detect and solve potential problems in time and to ensure that the system meets the required quality standards before it is delivered to the users.

3.1.2. Subdivision design

1.Authentication Module: This module is the beginning of user access to the system and is responsible for realizing the user login function, including the process of user registration and identity verification.

2.Function Selection Module: This module provides a function selection and jumping interface through which the user can select and learn different sorting algorithms.

3.Parameter Input and Algorithm Selection Module: The main responsibility of this module is to develop a parameter input interface that allows the user to enter customized values as required and select the specific sorting algorithm they need.

4. Dynamic Display and Parsing Module: This module implements a dynamic visual display of the sorting algorithm,

including animation effects, speed control, and step-by-step explanations.

5.Algorithm Principle and Analysis Module: This module shows the pseudo-code and complexity analysis of the algorithm, and also provides a view switching function.

6.Test and Evaluation System: This module is responsible for designing the test page, generating related practice questions, evaluating the user's learning results and providing corresponding feedback.

7.Learning Cycle Management Module: This module implements a learning cycle management mechanism that guides users to repeat or move to the next learning stage based on their test results.

8. Algorithm Comparison and Analysis Module: This module provides the function of algorithm comparison, showing the comparison between the characteristics and performance of different sorting algorithms. Through intuitive comparison and analysis, users can understand the advantages and disadvantages of various algorithms, as well as their effects in different application scenarios.

9. Knowledge Summary and Overview Module: This module provides a summary of all sorting algorithms to help users build a complete knowledge system. Through the systematic summary and overview, users can better review and integrate what they have learned, and form a comprehensive and in-depth understanding of the sorting algorithms.

3.2. Project management

Project initiation phase (July 1 to July 7)

1. Project planning (July 1 to July 2): The purpose, scope and key nodes of the project need to be established. The manager prepares a detailed project plan, which covers the timetable, resource allocation and funding budget.

2. Requirements Analysis (July 3 - July 5): Managers gather and analyze information about project requirements, ensuring that all functional and non-functional requirements are identified and documented.

3. Risk Assessment (July 6): The person in charge identifies possible risks to the project, evaluates the impact of the risks, and develops risk response measures, leaving time for risk response.4. Resource Planning (July 6): Plan the technical and physical resources required.

5. Project Initiation (July 7): Start project implementation and ensure a clear understanding of the project plan.

System Design Phase (July 8 - July 16)

1. Architecture Design (July 8 - July 9): Design the technical architecture of the system and determine the project chunks and overall structure.

2. Interface Design (July 10 - July 11): Design the user interface and find suitable UI materials.

3. Database Design (July 12): Design the database model.

4. Detailed Design (July 13 - July 16): Write detailed design documents.

System Development Phase (July 17 - August 12)

1. Coding (July 17 - August 2): learn relevant software applications and corresponding function blocks, code according to the detailed design document, and develop various modules of the system.

2. Unit testing (August 3 - August 5): Conduct unit testing for each module. 3.

3. Correction and modification (August 5 - August 7): Modify and re-test the problematic modules.

4. Function Addition (August 8 - August 9): Add and test new functions, essence project, try to export the project and generate exe format file.

System Deployment and Evaluation Phase (August 11 - August 25)

1. Deployment Preparation (August 11 - August 13): Prepare the deployment environment, solve the problem of exporting and generating, add strong execution code to the project to ensure that the runtime jumps correctly after exporting.

2. System Deployment (August 14): Deploy the system to the production environment.

3. System Evaluation (August 15 - August 18): Evaluate the system performance to ensure that the system meets the performance requirements.

4. Documentation (August 19 - August 22): Complete the project documentation. 5.

5. project review (August 23 - August 24): project review, summarize the lessons learned. 6. project wrap-up (August 15 - August 18): assess the system performance to ensure that the system performance requirements.

6. project closeout (August 25): complete all project closeout work.

3.3.System realization

3.3.1. Authentication module

The Authentication module is the first gateway for users to enter the system, requiring them to enter their username and password on the login page to verify their identity.

In order to make it easier for developers to track the data loading process, we have added a log output function to the module. These logs record the user's actions and changes in the system state, which is very useful debugging information for developers. Also, to let the user know about possible problems or anomalies, we added a warning output so that the user can be alerted immediately if they are not doing something right or if the system is not working properly.

```
    Debug.Log("User data loaded from: " + filePath);
}
else
{
    Debug.LogWarning("User data file not found for username: " + username);
}
```

In addition, the module adds a ChooseControl script to initialize the game objects in the scene. This script handles various dynamic behaviors in the game, such as updating the display state of the interface when the user selects a different option, and setting whether or not a particular game object is active.

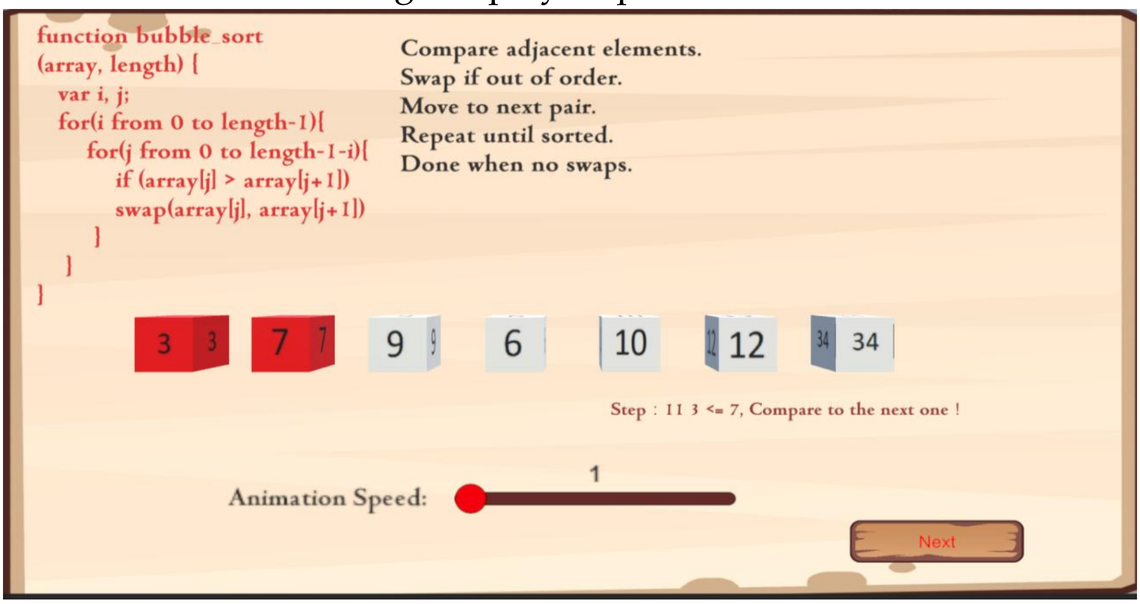
```
void Start()
{
    if (Data.chooseIndex == -1)
    {
        test.gameObject.SetActive(false);
        choose11.gameObject.SetActive(false);
        choose12.gameObject.SetActive(false);
        else1.gameObject.SetActive(true);
        else2.gameObject.SetActive(true);
    }
}
```

3.3.2. Function Selection Module

The function selection module is the starting point of user interaction with the system, where the user can enter specific values in the input box and select the preferred sorting algorithm to learn. The module not only increases the storage function of the input values to ensure that the data entered by the user can be correctly recorded and used by the system, but also sets up prompts under the input box, so that the user can understand the functional requirements at a glance when utilizing the module. In addition, in order to enhance the user's experience, the module also integrates an error alert mechanism, when the user inputs data values do not meet the requirements, the system will give prompts in a timely manner to guide the user to carry out the correct operation. The wrong value will not be able to jump into the target interface correctly. At the same time, enter the correct value, the system according to the user's choice, can make the correct response and jump to the corresponding sorting demonstration scene, so that the user seamlessly into the learning process.

3.3.3 Sorting Module

The Sorting module presents the internal logic of the sorting algorithm as a 3D animation. Taking bubbling sort as an example, after the user enters the sorting module, the system will generate a series of random values for him, and map them onto a 3D model - Cube. These Cubes are arranged in space according to the size of the values, and the whole process of bubble sort is simulated in the form of animation, which enables the user to observe intuitively how the algorithm sorts the values from small to large step by step.

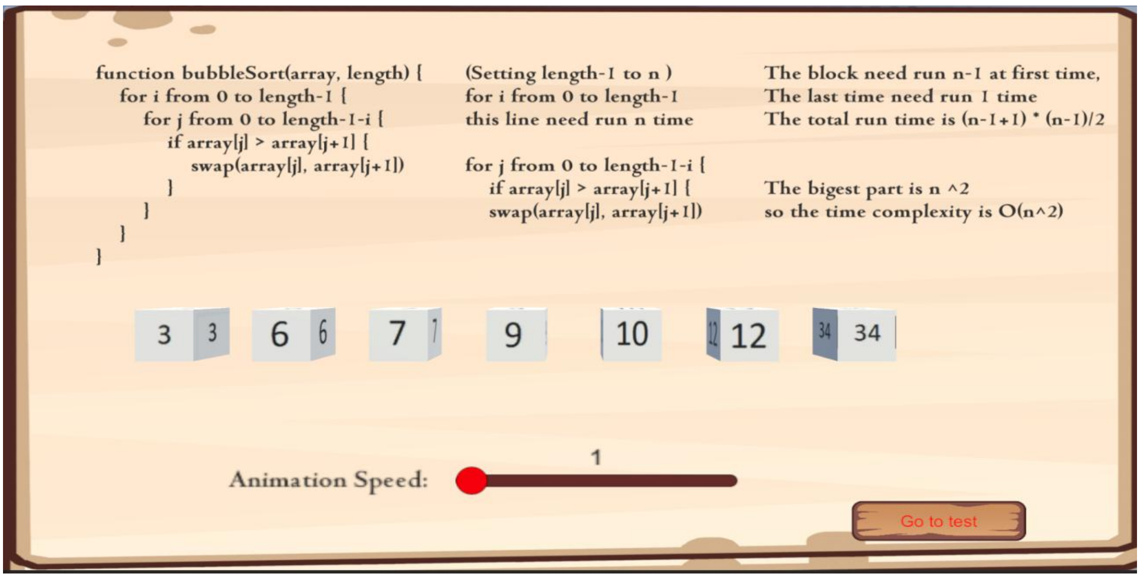


In the animation, in order to help users better understand the swapping action during the sorting process, the swapped Cube will be highlighted in eye-catching red color to visually emphasize this key step. This visual cue allows the user to focus more on the working mechanism of the algorithm.

```
void SwapCubeTextures(GameObject cube1, GameObject cube2)
{
    Texture2D tempTexture = cube1.GetComponent<Renderer>().material.mainTexture as Texture2D;
    cube1.GetComponent<Renderer>().material.mainTexture = cube2.GetComponent<Renderer>().material.mainTexture;
    cube2.GetComponent<Renderer>().material.mainTexture = tempTexture;
}
void SetCubeColor(GameObject cube, Color color)
{
    if (cube != null)
    {
        cube.GetComponent<Renderer>().material.color = color;
    }
}
```

The top half of the interface provides pseudo-code for the sorting algorithm, with a detailed explanation of the function of each line of code. This combination of code and animation allows the user to observe the actual execution of the algorithm while understanding its logic. The second half shows the specific execution when each exchange occurs, including the change of values before and after the exchange, and the effect of the exchange operation on the sorting result.

Users can flexibly switch the interface content from the pseudo-code view to the algorithm complexity parsing view by clicking the interactive buttons on the interface. In the complexity parsing view, users can learn the time complexity and space complexity of the algorithm, and observe the effect of the application of the code on different data sets.



In addition, in order to adapt to the learning habits and speeds of different users, the sorting module also provides a speed control function. Users can adjust the speed of the animated presentation by dragging the slider, thus adjusting it to their learning pace. This personalized learning experience allows users to focus on the learning process and memorize their knowledge of sequencing algorithms more effectively.

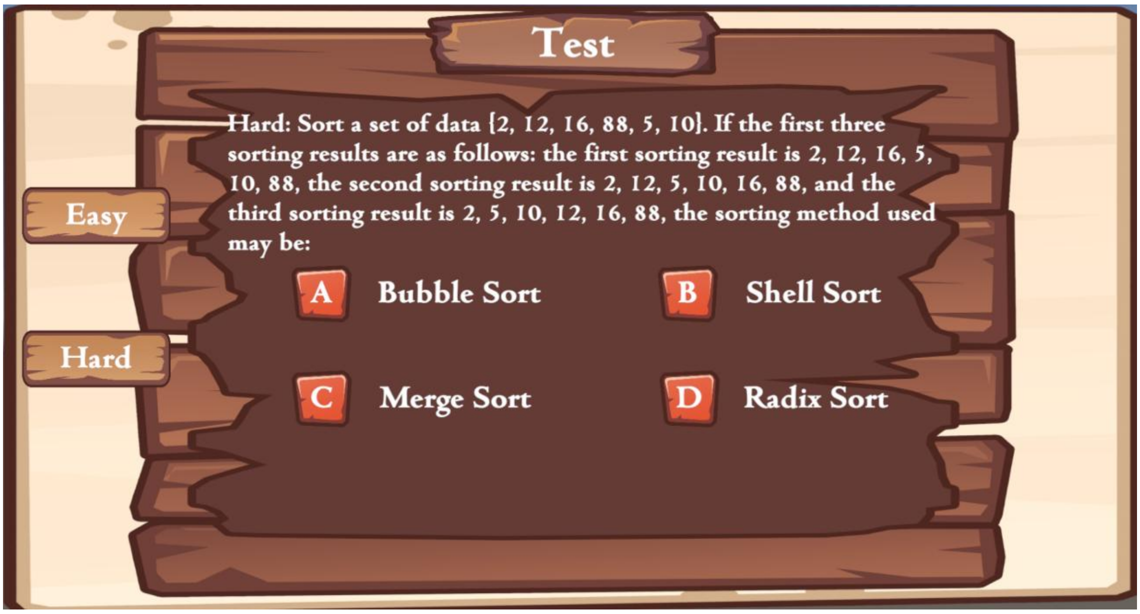
```
public class AnimSpeed : MonoBehaviour
{
    private Slider m_SpeedSlider;
    public Text m_SpeedText;

    // Start is called before the first frame update
    void Start()
    {
        m_SpeedSlider = GetComponent<Slider>();
        m_SpeedSlider.value = Data.speed;
    }

    // Update is called once per frame
    void Update()
    {
        m_SpeedText.text = m_SpeedSlider.value.ToString();
        Data.speed = m_SpeedSlider.value;
    }
}
```

3.3.4. Test and Evaluation Module

The Test and Evaluation module is designed to quantify the effectiveness of the user's learning and to demonstrate this effectiveness through immediate evaluation after an animated demonstration. The module is designed with an evaluation interface where the user can do a self-test after watching an animated demonstration of the sorting algorithm. The test questions are divided into different levels of difficulty, so that the user can choose the appropriate level of difficulty according to his/her learning situation.



During the assessment process, if the user answers incorrectly, the system will automatically guide the user back to the corresponding presentation screen, allowing the user to re-learn and re-understand the knowledge point. This learning cycle mechanism ensures that the user can focus on reviewing content that has not yet been mastered, thus improving learning efficiency.

When the user has answered the question correctly, the user will be redirected back to the initial function selection screen and will be rewarded with a corresponding number of stars based on the difficulty of the question. This encourages users to participate more in the assessment and allows them to visualize their learning progress and results.

In addition, the module also adds a user interface hiding function, which makes the switching between test questions smoother and improves the user experience.

```
if (sortStatus.IsLoggedIn)
{
    test.SetActive(true);
    Bubbletest.SetActive(true);
    Debug.Log("sortStatus.IsLoggedIn" + sortStatus.IsLoggedIn);
    sortStatus.IsLoggedIn = false;
    login.SetActive(false);
}
```

The system also has the function of recording, calculating and exporting the value of stars, and the number of stars will be displayed in the function selection interface. This not only provides data support for users' self-assessment, but also provides teachers with valuable information for studying users' learning behaviors and effects.

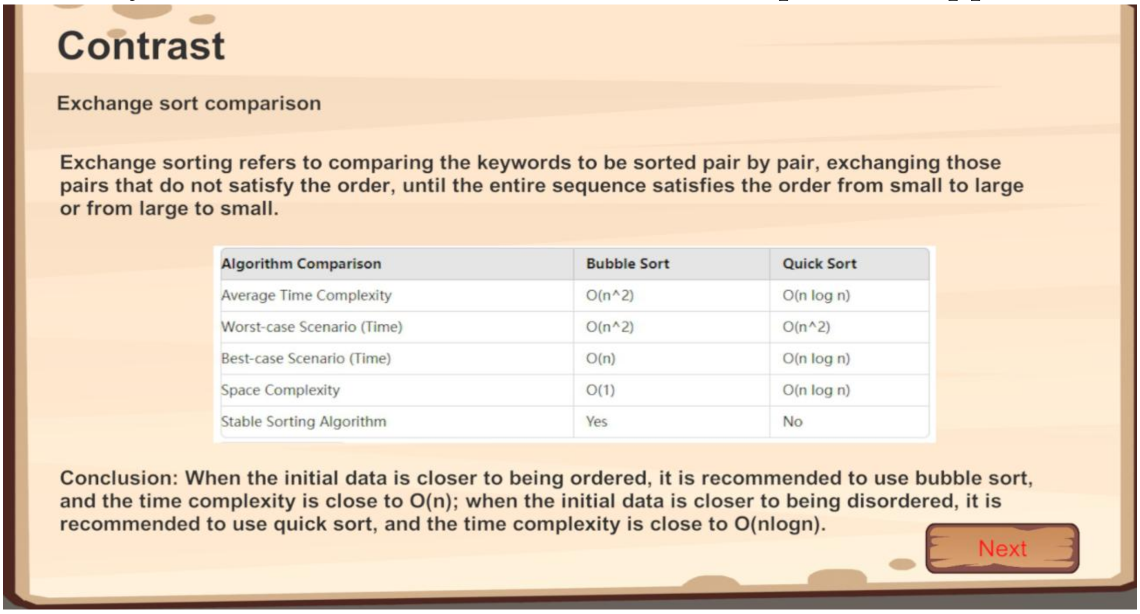
```
string ExtractStarValue(string path)
{
    if (!File.Exists(path))
    {
        Debug.LogError("File not found: " + path);
        return null;
    }
    string[] lines = File.ReadAllLines(path);

    foreach (string line in lines)
    {
        if (line.StartsWith("Start:"))
        {
            string[] parts = line.Split(':');
            if (parts.Length > 1)
            {
                return parts[1].Trim();
            }
        }
    }

    return null;
}
```

3.3.5. Algorithm Comparison and Analysis Module

This module is dedicated to the development of algorithm comparison function, through the intuitive interface to show the characteristics and performance comparison of different sorting algorithms, so that users can clearly understand the advantages, disadvantages and applicable scenarios of each algorithm. Through detailed charts and data analysis, this module helps users to deeply grasp the key indexes of sorting algorithms, such as complexity, efficiency and resource consumption, so that they can make more reasonable choices in practical applications.



3.4.System Testing

3.4.1. Test Environment

Operating system: Windows 10

Editor: Unity 3D

3.4.2. Test procedure

3.4.2.1. Input count test

Test Item	Test Case	Test Result	Conclusion
Numeric entry	Enter the values: 1,2,3,4,5,6,7. Clicked bubble sort	Successfully entered bubble sort	Numeric entry successful

Numeric entry	Enter the values: 1,2,3,4,5,6,7 Clicked quick sort	Successfully entered quick sort	Numeric entry successful
Numeric entry	Enter the values：1,2,3,4,5,6 Clicked bubble sort	Entry Failure	Numeric Entry Error
Numeric entry	Enter the values: 1 2 3 4 5 6 7 Clicked bubble sort	Entry Failure	Numeric Entry Error
Numeric entry	Enter the values: Clicked bubble sort	Entry Failure	Numeric Entry Error

3.4.2.2. Sorting and speed tests

Test Item	Test Case	Test Result	Conclusion
Numeric entry	Enter the values: 1,2,3,4,5,6,7. Clicked bubble sort	Successfully entered bubble sort to see the sorting	Successfully sorted
Bubble Sort	Enter the values: 1,2,3,4,5,6,7. Clicked bubble sort	Successfully entered bubble sort，Clicked next	Jump Success
Bubble Sort	Enter the values: 1,2,3,4,5,6,7. Clicked bubble sort	Successfully entered bubble sort, dragged slider	Successful speed control
Bubble Sort	Enter the values: Clicked bubble sort	Entry Failure	Sort Error
Numeric entry	Enter the values: 1,2,3,4,5,6,7. Clicked quick sort	Successfully entered quick sort to see the sorting	Successfully sorted
Quick Sort	Enter the values: 1,2,3,4,5,6,7. Clicked quick sort	Successfully entered quick sort，Clicked next	Jump Success

Quick Sort	Enter the values: 1,2,3,4,5,6,7. Clicked quick sort	Successfully entered quick sort, dragged slider	Successful speed control
Quick Sort	Enter the values: 1 Clicked quick sort	Entry Failure	Sort Error

3.4.2.3. Answer test

Test Item	Test Case	Test Result	Conclusion
Bubble Sort Test	Click easy, select D.	Answer correctly and return to the function selection screen.	Test Success
Bubble Sort Test	Click easy, select A.	Answer the error and go back to the demo screen	Test Success
Bubble Sort Test	Click hard, select A.	Answer correctly and return to the function selection screen.	Test Success
Bubble Sort Test	Click easy, select B.	Answer the error and go back to the demo screen	Test Success
Quick Sort Test	Click easy, select C.	Answer correctly and return to the function selection screen.	Test Success
Quick Sort Test	Click easy, select D.	Answer the error and go back to the demo screen	Test Success
Quick Sort Test	Click hard, select B.	Answer correctly and return to the function selection screen.	Test Success
Quick Sort Test	Click easy, select C.	Answer the error and go back to the demo screen	Test Success

3.4.2.4. Button Testing

In the keystroke testing phase of this project, we utilized both manual and automated testing methods to verify the functionality of all keystrokes in the user interface. The tests included function verification, state change, exception response, performance evaluation, compatibility testing, and security testing to ensure that each key responded accurately to user actions and met the design requirements. Through this process, we ensure that the user interface is easy to use and intuitive, providing users with a smooth interactive experience, which in turn improves user satisfaction and learning outcomes.

3.4.3. Test Results

The comprehensive test results of the system show that all functional modules have been successfully implemented and their performance indicators have met the expected requirements. The numerical input module, classification demonstration module, test and evaluation module, speed control function and key function tests all show good stability and reliability. The response time, data processing speed and animation demonstration fluency of the system meet the performance requirements, providing accurate and timely feedback to the users. In addition, the modular design of the system facilitates future maintenance and upgrades, ensuring the possibility of long-term stable operation. Nevertheless, we recognize that the system still needs to be continuously optimized and improved in practical applications in order to adapt to the changing needs of users and the development of educational technology.

4. Summary

4.1.Summary

This project takes the sorting algorithm in data structure as the research object, and adopts visualization technology means, aiming at transforming abstract computer science concepts into intuitive graphics and animation. The project successfully realizes the dynamic demonstration of the sorting algorithm, which shows the execution process of the algorithm to the user through animation, and at the same time provides code parsing and step-by-step hints to help the user understand the concrete implementation of the algorithm. In addition, the project also includes a detailed analysis of the complexity of the algorithm, as well as a comparative analysis of different sorting algorithms, which not only enhances the user's learning experience, but also deepens the understanding of the performance of the algorithm and the applicable scenarios. Through this interactive and dynamic learning approach, the project effectively realizes the visual teaching of the knowledge of sorting algorithms, meets the basic requirements of experimental teaching, and provides new perspectives and methods for computer science education.

However, some limitations and room for improvement are also revealed in the implementation of the project. First, the project currently focuses on the visualization of sorting algorithms, with a relatively single knowledge point coverage. In order to enhance the breadth and depth of the project, subsequent research can consider applying visualization techniques to more basic knowledge in the field of computer science, such as recursion, graph algorithms, dynamic programming, etc., in order to construct a more comprehensive knowledge visualization system. This comprehensive system will help students understand the complex concepts of computer science from multiple perspectives and improve their ability to solve practical problems.

Second, the program needs to be further enhanced in terms of user interaction. More interactive teaching modules can be designed in the future, such as transforming the practice questions in the Test and Evaluation module into a more manipulative sorting game, which requires users to simulate the sorting process by dragging and dropping small cubes to test and consolidate their learning outcomes. This gamification approach can increase user engagement and make the learning process more interesting and engaging. In addition, in order to enhance the user experience, the function of randomly generating values can be added to the function selection page, so that users can click the button to generate random values and start learning directly without entering specific values. This design not only stimulates users' interest in learning, but also provides a more flexible and convenient way of learning, thus improving the overall learning effect.

```
//RandomNumberGenerator(); //
```

4.2. Lessons Learned

Every step in the full software development lifecycle is critical, from project forecasting to final user testing. In the forecasting phase, we use market research, technology assessment, and feasibility analysis to develop a clear blueprint of the project, taking into account both direction and scalability. Requirements analysis requires an in-depth understanding of the needs of different user groups, and we use multiple surveys and user feedback to ensure that the product meets a wide range of user expectations.

During the development process, time management is especially important, we need to reserve enough time to deal with possible technical challenges and unexpected errors.Unity, as a powerful game development platform, provides us with a wealth of resources and tools, which makes cross-platform development more convenient. At the same time, the interface design should not only consider aesthetics, but also focus on user experience. We added high-quality material packs and tested adaptive layouts in real time to ensure a consistent user experience across different devices.

4.3. Contribution

This project brings significant innovation and contribution to the field of computer science education by visualizing sorting algorithms in data structures, enabling breakthroughs in educational applications. It utilizes intuitive 3D animations and interactive learning tools to help teachers improve student learning and interest. This visualization approach makes the learning of complex algorithmic logic and data processing compatible with educational concepts, which is easy for students to understand and remember, thus improving the quality and effectiveness of education.

In terms of providing teachers with real-time assessment tools, the program's built-in testing and feedback mechanisms provide teachers with the means to monitor students' learning progress in real time. In terms of expanding the accessibility of educational resources, the program serves as an online learning platform that provides students with learning resources anytime, anywhere. Students can access these resources via the Internet and continue learning outside of class and at home.

In terms of software development, the program demonstrates remarkable innovation. The interactive learning platform not only optimizes the learning process, but also enhances the user experience through dynamic presentations and real-time feedback mechanisms. The design and implementation of this platform demonstrates the latest technologies and trends in software development.

In promoting computer literacy, the project makes it easy for learners from non-specialized backgrounds to grasp complex computer science concepts by lowering the learning threshold. This kind of popular education helps to improve the computer literacy of the public and nurture more computer technology talents for the society.

In conclusion, this project makes important contributions to educational utilization, student motivation, personalized learning, optimization of teaching resources, educational equity, provision of teacher evaluation tools, and expansion of accessibility of educational resources. With the continuous development of technology and changing educational needs, this project is expected to play a greater role in the future and become an important force for innovation in computer science education.

4.4. The Future

This project is expected to integrate more cutting-edge technologies in its future development to further enhance the quality and effectiveness of computer science education. Among them, the introduction of Artificial Intelligence (AI) technology will provide powerful support for personalized learning path recommendation and adaptive learning content adjustment.The application of AI technology can provide customized learning resources and tutoring based on the user's learning behaviors and progress, thus maximizing learning efficiency. For example, by analyzing students' learning data through machine learning algorithms, the system is able to predict students' learning needs and automatically adjust the content and difficulty of teaching to ensure that each student can learn effectively at a pace that suits him or her.

In addition, Terry K. Smith's research noted that through example learning situations in virtual worlds and teacher observation data, students demonstrated 21st century skill behaviors in a question-and-answer/augmented reality (QA/AR) environment, through which they were able to better understand and apply relevant academic content.

This suggests that the convergence of Augmented Reality (AR) and Virtual Reality (VR) technologies will result in an immersive learning experience for learning programs. Users will be able to intuitively manipulate in three-dimensional space, thereby deepening their understanding of algorithms and data structures. For example, through VR equipment, users can “enter” the execution process of algorithms and observe the dynamic changes of data, which will greatly enhance students' learning motivation and knowledge absorption.

In future development, the program could focus on improving educational efficiency, enhancing learning experience and facilitating technology integration. By continuously exploring and applying the latest technologies, it is expected to become an innovative pioneer in the field of computer science education and provide richer and more efficient learning resources for learners worldwide.

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