Journal of Information Technology Education: Innovations in Practice

An Official Publication of the Informing Science Institute
InformingScience.org

JITEiip.org

Volume 25, 2026

DESIGN AND DEVELOPMENT OF AR INSTRUCTIONAL MATERIALS FOR LIGHT AND SHADOW ART

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ABSTRACT

Aim/Purpose	This project focuses on blending AR technology with painting, with specific emphasis on one of the most basic concepts in art education: light and shadow.
Background	The instructional materials based on AR help convert two-dimensional, abstract information in traditional education into three-dimensional, interactive materials.
Methodology	This research has been conducted on AR tools, the concepts of light and shadow in the field of art, and applications such as Unity and Vuforia.
Contribution	The application of 3D models and various gaming techniques has helped students gain a hands-on learning experience.
Findings	Through this approach, an improvement is brought about in the engagement of students and their overall learning experience. AR brings together scientific tools with elements of art. It evolves with technological advances, making education more accessible to students from different corners of the world.

Accepting Editor Aaron M. Glassman │ Received: August 13, 2025 │ Revised: November 3. November 28, 2025; January 9, 2026 │ Accepted: January 15, 2026.
Cite as: Shi, H., Karim, A. A., Husnin, H., & Hua, X. (2026). Design and development of AR instructional materials for light and shadow art. *Journal of Information Technology Education: Innovations in Practice, 25,* Article 3. https://doi.org/10.28945/5702

Recommendations for Practitioners	Educators can integrate the AR module into studio-based lessons to visualize and manipulate light effects on 3D objects.
Recommendations for Researchers	Future research should entail systematic empirical testing through pre–post assessments.
Impact on Society	One can also witness a transformation in the traditional methods of imparting education.
Future Research	Future research should entail systematic empirical testing through pre–post assessments.
Keywords	augmented reality, unity, light and shadow art, augmented reality instruction

INTRODUCTION

Textbooks have served as an essential tool in conventional education. At present, advances in technology and changes in the educational field have led to a setback in the use of textbooks and conventional teaching methods. According to Li (2023), conventional teaching approaches are a hindrance in the fast-moving modern world while technology integrated approach can yield better learning outcome. The development of augmented reality (AR) in education proved to be a turning point, according to researchers (Akçayır & Akçayır, 2017; Bacca et al., 2014), filling gaps left by the conventional education method. This has led to changes in teaching methodology, models, and teaching aids (Garzón et al., 2019). By fostering innovation in academia, augmented reality (AR) helps learners conceive abstract ideas by breaking them down into smaller pieces and simplifying them through real-time visualization (Jadhav et al., 2020). Such a system has provided a new avenue for students to improve learning outcomes.

Microsoft's white paper titled "Immersive experiences in education" by Bonavio (2019) depicted how AR can be used in the classroom and help in better understanding theoretical concepts. Through its innovative methods that include games and interactive sessions, AR can help create a rich teaching-learning experience for teachers and students alike. This is evident from Ibáñez and Delgado-Kloos (2018) and Saidin et al. (2015). AR, if applied correctly, can offer several advantages, including expanding curriculum content, boosting learning outcomes, and affordable implementation. It is in these areas where traditional teaching methods fall short compared to AR.

With the continued development of AR technology, its scope has broadened from higher and vocational education to K-12 education (Boel et al., 2024). This supports the emergence of AR-based education as an important aspect of instructional strategies and methods. By introducing new teaching models and methods, AR leads to a transformation of the traditional classroom system. AR has the potential to foster deep learning and give meaning to abstract content through three-dimensional visualizations and engaging real-world scenarios (Dunleavy & Dede, 2014). AR enhances deep learning and visualization of the invisible (Bougsiaa, 2016). Along with enriching curriculum content, this also helps in resource sharing beyond physical constraints.

One of the most important aspects of AR is its ability to merge virtual elements with real-life experiences and environments, providing users with an engaging sensory experience. By merging spatial and temporal data, AR helps make distant or complex visual information accessible in real time (Lichty, 2019). As a result, AR has overcome the limitations of traditional educational methods. According to Wang (2022), the incorporation of AR into printed materials, such as pictures and books, enhances the scientific content and engagement with academic and educational resources. In this regard, the integration of AR into the teaching-learning process has improved the educational field.

Previous research has focused on the use of AR within STEM and engineering fields (Ibáñez & Delgado-Kloos, 2018; Iriqat & Vatansever, 2025). However, they are relatively less focused on the use of

AR in visual arts education. Although aesthetic learning through AR is considered in Bougsiaa (2016), there remains a significant gap in empirical research on conceptual issues, specifically regarding light-and-shadow pedagogy. The study will fill this important gap in the literature by specifically designing AR materials for abstract visual-art concepts, blending aesthetic appreciation with interactive visualization.

Based on the above understanding, this project focuses on blending AR technology with painting, with specific emphasis on one of the most basic concepts in art education: light and shadow. Thus, the study followed the following research questions:

RQ1: How can augmented reality be integrated into art education to enhance the students' understanding of concepts about light and shadow?

RQ2: What are the design and functional components of augmented reality instructional materials that best bridge the gap between theory and practice?

RQ3: How do students engage in and respond to the augmented reality-based instructional materials developed for the learning of light and shadow?

The elements of light and shadow in art training possess a symbolic value and emotional significance. The visual appeal of paintings and their artistic value are both enhanced through the inclusion of these elements. According to Song and Puntien (2024), knowledge of light and shadow helps art students develop psychological and emotional associations with subsequent creative and aesthetic capabilities. Modern digital media, such as Virtual Reality (VR), animation, and AR, also incorporate elements of light and shadow. Along with technology, art reshapes artistic experience for students and enriches the learning process, as stated by Tyler and Likova (2012). With the implementation of realistic lighting events in virtual environments, the educational and creative horizon seems to be broadened.

This research applies AR technology to the teaching unit known as Art of Light and Shadow. This project aims to develop an all-around AR educational experience with Unity and Vuforia. In this respect, a printed textbook called Art of Light and Shadow is incorporated along with an appropriate AR mobile application. This teaching material facilitates student interaction with simulated light and shadow scenarios, enhancing student engagement, supporting autonomous learning, and allowing exploration and expression of artistic abilities. The project is divided into three phases: early planning, mid-stage, and developmental phase. First, the early planning stage where, through content gathering of light and shadow, determination of the visual style, and selection of presentation formats are made through material review; secondly, a mid-stage to shift the focus towards functional interaction and visual material design, in which the AR functionalities of the mobile app are defined, along with the creation of UI and graphic elements for the book using Photoshop, 3DMax, and Cut software; and lastly, the developmental phase where materials are integrated into an AR learning tool through Unity 3D and Vuforia to build an Android-based application. By following these steps, a fully designed AR teaching resource was created that engages students in the concepts of light and shadow, offering a rich, exploratory learning experience.

Thus, this article identifies the pedagogical challenges of teaching concepts of light and shadow in art education. It then puts forward the design and development of an AR-based solution to these instructional issues. Finally, it describes the implementation process and discusses the implications for education of using AR to improve engagement and conceptual understanding.

Conceptual Framework

Figure 1 shows the conceptual framework followed in this study. The conceptual framework presents how this study addresses the educational challenge through its design process and learning outcomes. The starting point is the difficulty students face in learning the abstract concepts of light and shadow through traditional teaching. In this respect, the AR-based instructional materials were designed to turn theory into interactive, visual experiences through 3D modeling and real-time simulation. Planning, development, and classroom integration using the Unity and Vuforia platforms have been completed during the implementation process. This shows how AR technology enhances visualization, participation, and understanding in effectively bridging the gap between theoretical learning and practical application in the arts.

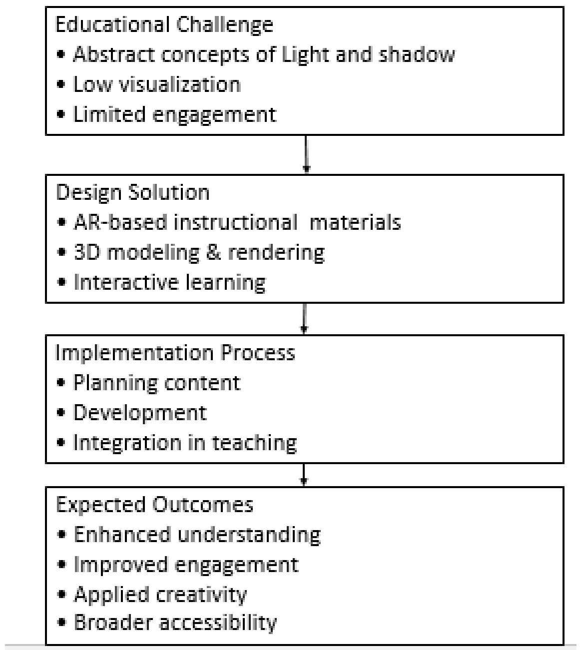

Figure 1. Conceptual framework of the study

CURRENT EDUCATIONAL CHALLENGES AND DEMAND ANALYSIS

TARGET USERS

This study was designed for students majoring in digital media technology, based on a drawing course. The students participating in this study come from the disciplines of science and engineering. These are the students who grasp practical concepts easily, but struggle when it comes to dealing with theory. Therefore, in the field of art, these students seem to struggle. This problem can find its solution in the introduction of augmented reality, which helps bring theory and practice closer together (Iriqat & Vatansever, 2025). AR presents content in a 3D format, enabling students to understand complex problems visually. According to Papanastasiou et al. (2019), this integration of AR proves to be helpful for students, enhancing their comprehension abilities and learning skills.

TEACHING OBJECTIVES

This study focuses on helping students understand the concepts of light and shadow in art education, two very abstract elements. To do this, textbook content has been transformed into AR visual elements. By integrating AR into real-world scenarios, students' theoretical knowledge has increased, leading to better comprehension of concepts and greater engagement. Figure 2 presents a structured concept map emphasizing the key elements of light and shadow within the conceptual and visual framework. It thereby emphasizes elements important to the conceptual and visual framework.

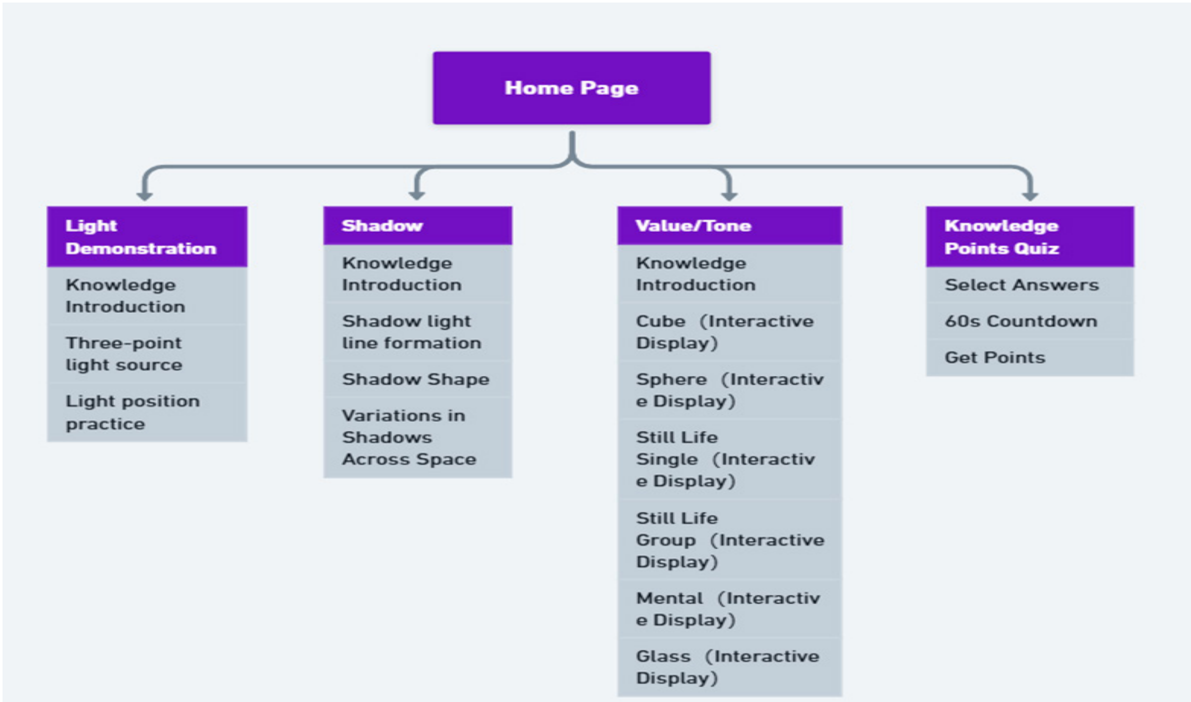

Figure 2. Designing a mind map

TEACHING CONTENT

Teaching content is established in order to ensure the consistency and systematic nature of the content, helping students to learn the process step by step. As depicted in Figure 1, the elements of light and shadow throughout the project have been designed based on the structured concept map and a few of the following important elements:

Light demonstration

Knowledge introduction: This section presents knowledge about light and shadow conveyed in art education, essential for helping students understand these concepts, their depth, and how they affect mood and perception. There are two sources of light – natural (sunlight) and artificial (lamps).

Three-point light source: The three-point light source, also known as area lighting, is used for lighting a smaller area of the scene. The three lights used here include the main light, auxiliary light, and contour light. The main light is used to illuminate the main object and its surrounding area. The primary function of highlighting the main object is usually done with the help of a spotlight. The spotlight, in turn, helps illuminate the auxiliary light to create a soft, uniform, indirect light source. The power of the auxiliary light is usually 50-80% of the main light. Finally, the role of the contour light is to separate the object from its background, helping to highlight the contours, shapes, and depth of the space.

Light position practice: Students are made to practice and understand how the position of light affects different objects and background scenes. The four basic lighting positions are front lighting, side lighting, back lighting, and top or bottom lighting.

Shadow

Knowledge Introduction: A shadow is a dark shape that forms as a result of light hitting an opaque object. A shadow formed may be of different types, depending on the angle of the light, the nature of the object, and the distance between the object and the surface on which the shadow is formed. There are two types of shadows: cast shadows and form shadows.

Shadow formation: When an opaque object blocks a source of light, it creates a shadow behind that object due to the lack of direct light. The edges of a shadow are blurred due to the spread of light and scattered light that comes from the surrounding environment.

Light position: Light position refers to the position of the source of light that falls on the object. There are seven basic light positions: forward light, side light, front metering light, side backlight, backlight, bottom light, and top light. These light positions can be used alone or can be integrated and used as well. Additionally, there are certain special lights as well, such as Rembrandt light, butterfly light, hero light, and drama light.

Shadow Shape: As already mentioned, the shape of a shadow may vary depending on the object, the angle of light, and the type of light.

Variations in Shadow across Space: Shadows tend to change with changes in the position of the object or the source of light, or when interacting with different environments. When the source of light is moved, the direction of shadow changes, while changes in the texture of the surface may also lead to disfigured shadows being formed.

Value/Tone

Facets and Tones: In art education, facets and tones constitute the basic concepts that introduce users to light and shadow. The three major facets are bright, grey, and dark sides, which depict the most basic relationship between objects and light. This relationship is known as the bright-grey-dark relationship or the bright-dark contrast relationship. The five major tones, on the other hand, refer to the five black and white levels that represent the three-dimensional levels of objects. The five major keys are highlight, middle tone, light and dark border, reflection, and projection, arranged from light to dark.

Reflection: When light hits an opaque and smooth surface, it bounces back at an angle. The reflecting surface may be of different natures, depending on whether the reflection may be classified as specular (mirrors) or diffuse (paper), creating a number of different light and shadow effects.

Perspective and Refraction: When light penetrates a glass containing any liquid, it appears to be distorted along with the background, creating a unique visual experience. This phenomenon is known as refraction.

SELECTION OF TEACHING METHODS

The integration of AR with theories of education helps in creating an engaging learning atmosphere, providing a personalized learning experience to the students. The following teaching methods may be incorporated in this regard:

1. **Interactive Learning**: As is clear from the discussions above, AR supports interactive learning by allowing students to interact with virtual content that includes voice commands and gestures. This creates a learning environment that is exploratory and encourages experiential learning for students.
2. **Situational Learning**: In this type of learning, AR is used to create or simulate virtual learning environments wherein students can grasp abstract concepts, create learning situations in touch with the real world, and enhance their power of retention and memory.

Based on the conducted demand analysis that conceptualized the difficulties faced by students, the following section explains how the identified educational needs have guided the design and development of AR-based instructional tools.

Design & Implementation of AR-Based Instructional Solutions

3D Modeling and Rendering

The creation of artistic effects of light and shadow depends on designers who use 3D modeling software such as Blender and Maya to create virtual 3D objects and scenes. 3D models are beneficial because they enable users to interact with them by touching, dragging, or even activating functions such as turning on lights or zooming in on the model scene. This contributes significantly to user experience, enriching their knowledge. The 3D models used are made by 3D Max, which are then combined with the real world through AR development platforms like Unity3D. This helps users realize the effects of light and shadow and their interaction with one another. Figures 3, 4, and 5 help depict 3D modeling, lighting, and material rendering.

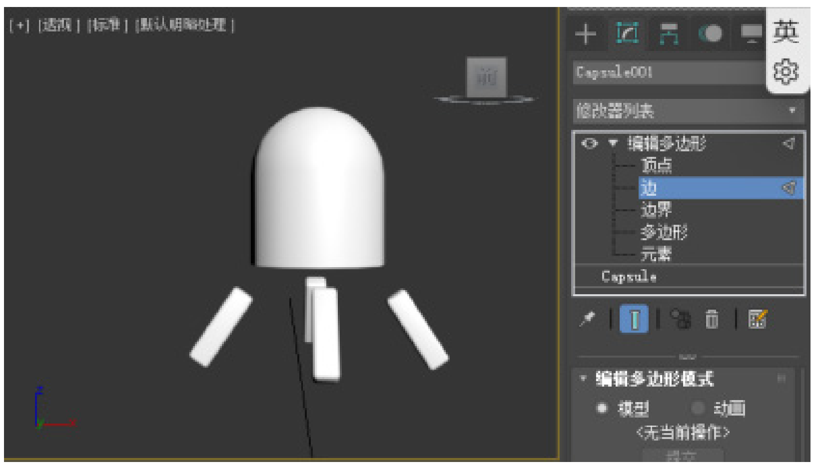

Figure 3. Spot model

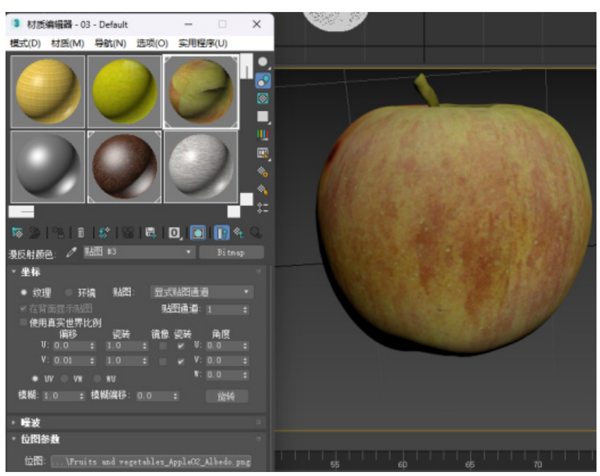

Figure 4. Apple material display

Figure 5. Glass material illustration

INTEGRATION OF AUGMENTED REALITY TECHNOLOGY

To design and develop AR technology, the Vivo S6 is used as the development and test platform. After capturing the real environment through its camera, digital information is superimposed on the screen to create a connection between the virtual world and reality. This process requires sensitive algorithmic support like image recognition, location tracking, and 3D registration technology, which ensures a secure and accurate connection between the virtual content and reality.

When it comes to AR devices, mobile phones are quite common, which may be due to a number of underlying factors. Compared to other devices, using mobile phones for AR is cheaper, as users only need to download the AR application, with no additional hardware costs. Users can also use these applications as and when they want, according to their terms, with no restrictions on location. There are a number of applications, such as Unity and Vuforia, that have aided in the development of AR at a fast pace and helped in the creation of various projects with AR in them.

IMAGE RECOGNITION AND TRACKING

When it comes to the development of AR, the application Vuforia is used as the platform that helps develop the AR experience. The recognition map is the most important element that helps activate virtual content in the AR-based application. Initially, a significant step is to register Vuforia and import the recognition map into it. With this, the probable location and orientation of the virtual content are identified through certain environmental markers found on the map. Figures 6-8 depict three parts of a science page: projection, tone, and light demonstration.

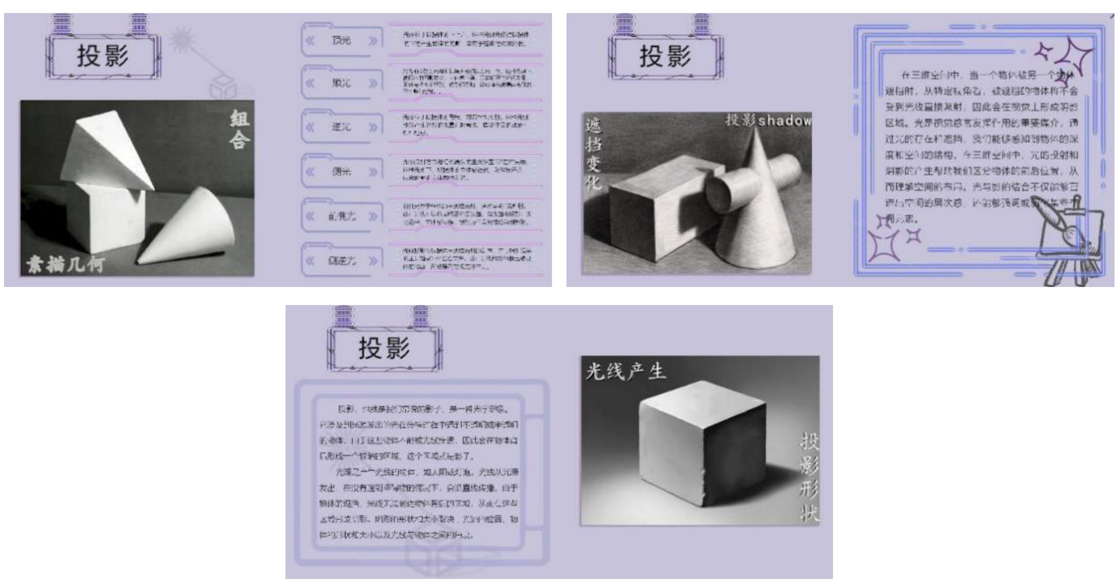

Figure 6. Shadow display

Figure 7. Color

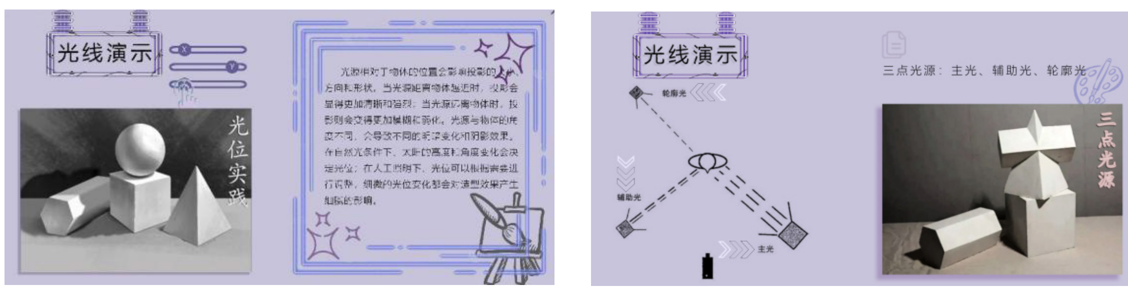

Figure 8. Light demonstration

INTERACTION DESIGN

The aim of this project, in terms of interaction design, is to provide students with an educational experience that integrates virtual elements with their respective function buttons. One of the major benefits of AR is its simulation of actual scenes that help users gain a hands-on learning experience. It is safe, cost-effective, engaging, concrete, and helps retain memory. The interaction between the virtual concepts and users is designed to help learners explore and better understand the concepts of light and shadow. A few interaction functions are mentioned below.

Background music and video interpretation audio settings

Figure 9 shows how background music can be imported into the scene resource folder and the audio source into the empty object. After this, the corresponding music material should be selected, and attributes should be adjusted. The loop function must be checked to understand how the background music is played automatically in a loop. In the audio section of the video, the Play On Awake button should be unchecked, enabling users to control it through the play and pause buttons.

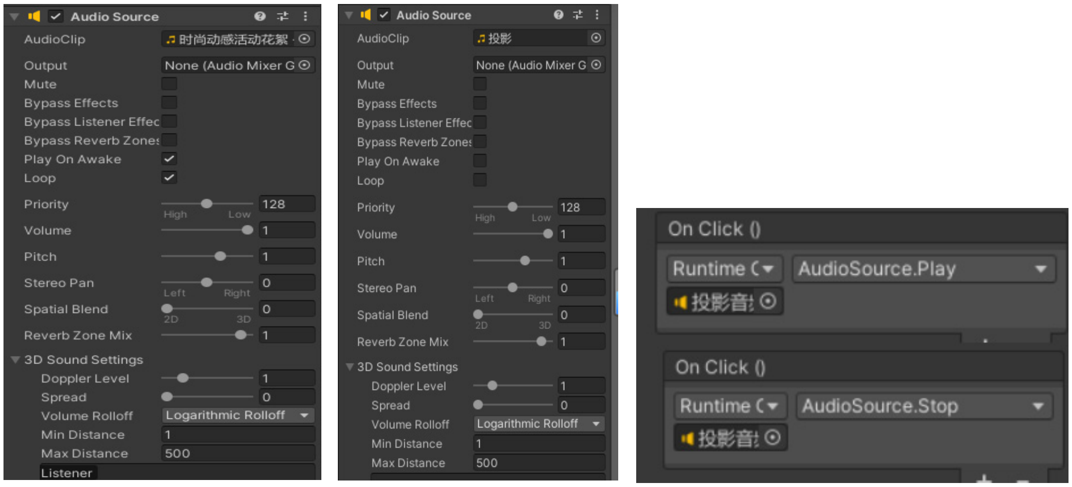

Figure 9. Adding background music and setting audio

Scene switching

The work in question involves more than one scene. Thus, it is essential to involve script codes to realize the switch between scenes. For example, the Load Scene function is used to remove the current scene and load the specified new scene. The steps to do this are shown in Figure 10. Mount the script to an empty object first. Then, an On Click event should be added to the corresponding button. The back button on a particular scene can be clicked to return to another scene.

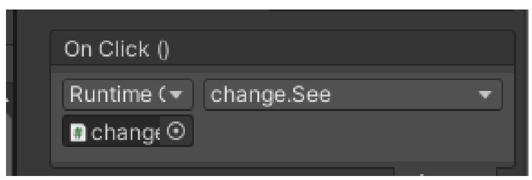

Figure 10. Triggers the event addition

Control the video playback feature

The video describes the common features between perspective and projection. In an image projected by 3D objects on a 2D plane, its propagation depends on light in a straight line. The point of intersection of these lines passes through the 2D plane and is connected to obtain the perspective image. The following steps can be followed to play a scene:

- The video should be put in the Resources Folder.
- Right-click to create the Render Texture.
- Create a new Raw Image.
- Add the component of Video Player.
- The video and the rendered texture should be put in the corresponding field to play the scene.

In video playing, the interactive functions include playing and pausing, dragging the time progress bar, adjusting the volume, and doubling the speed at which it is played (Figure 11).

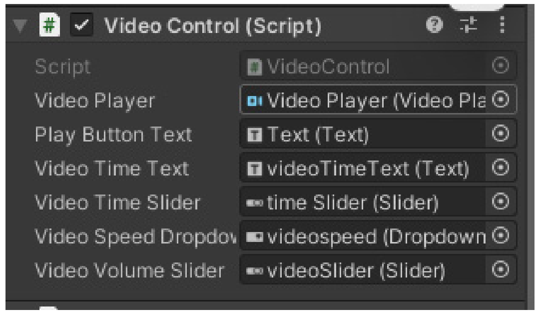

Figure 11. Video playout script mounting

Control the appearance of the model object

The codes kai () and guan () can be used in the script to activate or disable the respective model object (Figure 12).

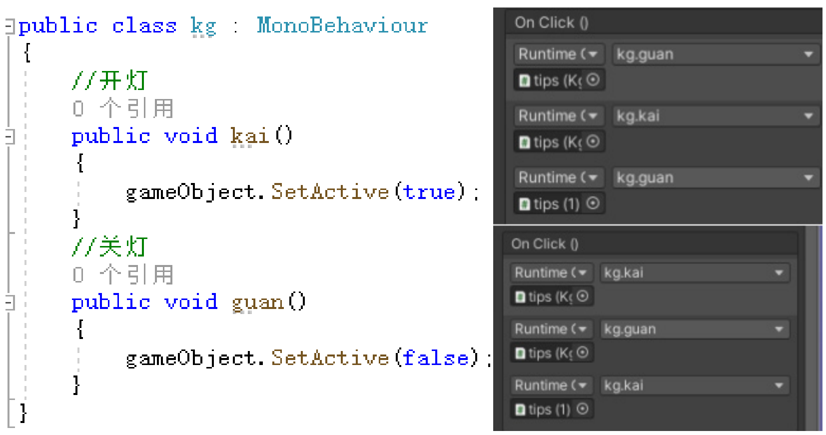

Figure 12. Control object switch code, two buttons added to trigger the event

Figure 13 depicts the different shapes of shadows.

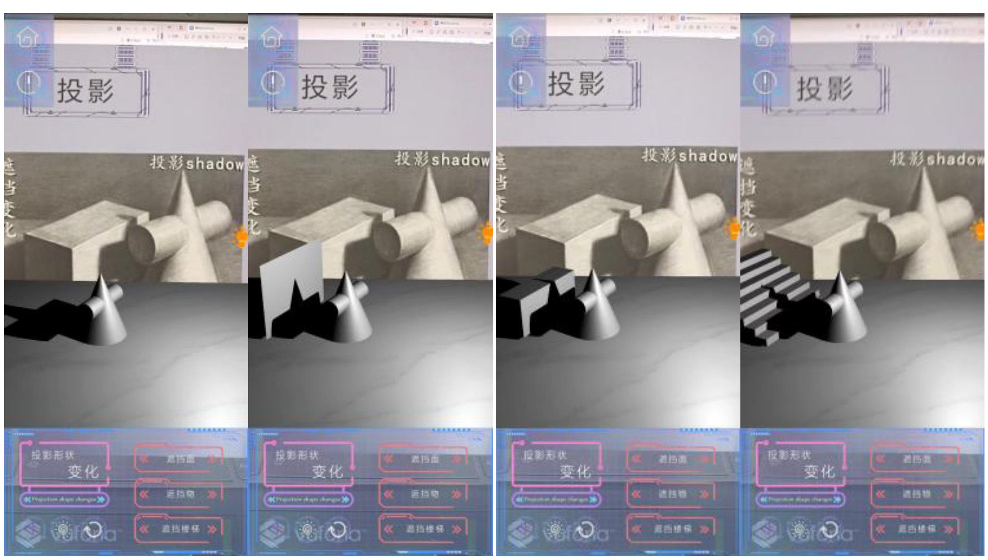

Figure 13. "Shadow of Shape Change"

Bake with light

An efficient way to achieve lighting effects globally is light mapping. Lighting information is gathered from the scene and baked into lightmaps. These light maps are used to simulate the effects of static light sources without the performance overhead of real-time updates. Compared to normal sources of lighting, the process of light baking contributes significantly to accurately controlling the light distribution of a scene. It helps in simulating a time of day, such as dawn or dusk.Thus, it creates an emotional atmosphere that enriches the experience of the users. Additionally, it also aids in creating more realistic light and shadow effects, generating shadows that are soft, natural, and improve the realism of the scene. Figure 14 illustrates the process of light baking.

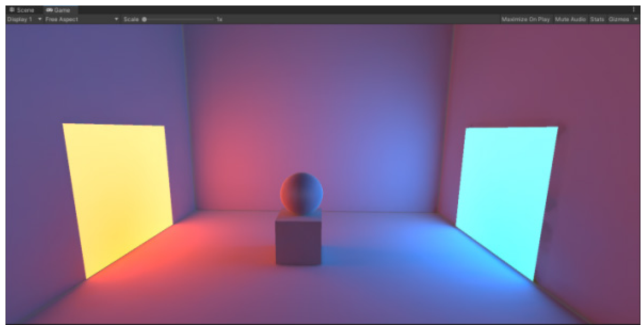

Figure 14. Illustration of light baking

Light position practice (push and pull)

With regard to AR learning, light position practice makes up one of the most important interactive functions that enables learners to operate the position of the light source in a 3D space. This helps in understanding the role of light position in the formation of shadow and illuminating the objects. Through the elements of UI and different scripts, the movement of light can be controlled. The MySlider script helps in understanding the way the light moves and how each UI slider is bound to a particular axis (X, Y, or Z). The position of the point light is adjusted using the slider. The script, using the HandleValueChange method, responds to the change in value. The Axis enumeration helps determine the line along which the axis is moving. left_bottom_back and right_up_forwards refer to the movements of the slider. The difference between these two is calculated as D_value.

```
public GameObject target;
public Slider slider;
public Axis axis = Axis.X;
public float left_bottom_back = 2;
public float right_up_forward = 2;
private float D_value;

Unity 消息|0 个引用
void Start()
{
    D_value = right_up_forward - left_bottom_back;

    switch (axis)
    {
        case Axis.X:
            target.transform.position += new Vector3(-target.transform.position.x + left_bottom_back + D_value * slider.value, 0, 0);
            break;
        case Axis.Y:
            target.transform.position += new Vector3(0, -target.transform.position.y + left_bottom_back + D_value * slider.value, 0);
            break;
        case Axis.Z:
            target.transform.position += new Vector3(0, 0, -target.transform.position.z + left_bottom_back + D_value * slider.value);
            break;
    }
```

```
        slider.onValueChanged.AddListener(delegate { this.handleValuChange(); });
        if (!target)
        {
            Debug.Log("missing target!");
        }
        if (!slider)
        {
            Debug.Log("missing slider!");
        }
    }

    1 个引用
    public void handleValuChange()
    {
        switch (axis)
        {
            case Axis.X:
                float Xpos = left_bottom_back + D_value * slider.value;
                target.transform.position += new Vector3(-target.transform.position.x + Xpos, 0, 0);
                break;
            case Axis.Y:
                float Ypos = left_bottom_back + D_value * slider.value;
                target.transform.position += new Vector3(0, -target.transform.position.y + Ypos, 0);
                break;
            case Axis.Z:
                float Zpos = left_bottom_back + D_value * slider.value;
                target.transform.position += new Vector3(0, 0, -target.transform.position.z + Zpos);
                break;
```

The Start method helps in calculating D_value and places the light at the starting point of the axis that has been selected. When the value of the slider changes, HandleValueChange updates the current position of the light. With the Unity editor, the target is set as the point light. The slider is connected to its respective UI element, and the axis is chosen (X, Y, or Z). The functions of left_bottom_back and right_top_forward are customized (Figure 15).

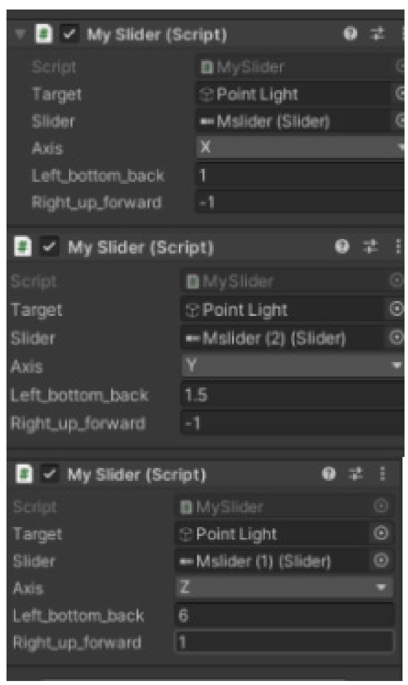

Figure 15. A drag-and-drop script mount

Figure 16 depicts the before and after effects of moving the slider along the X-axis. With the movement of the slider, the point light shifts either to the left or to the right along the X-axis. With this, there is a change in the shadows of the 3D model as well. This helps students understand how small changes in the position of the light may affect the shape of the shadow being formed, its angle, and its length. Through this experiment, the abstract concept of light and shadow is expressed visually, helping to bridge the gap between theory and practice.

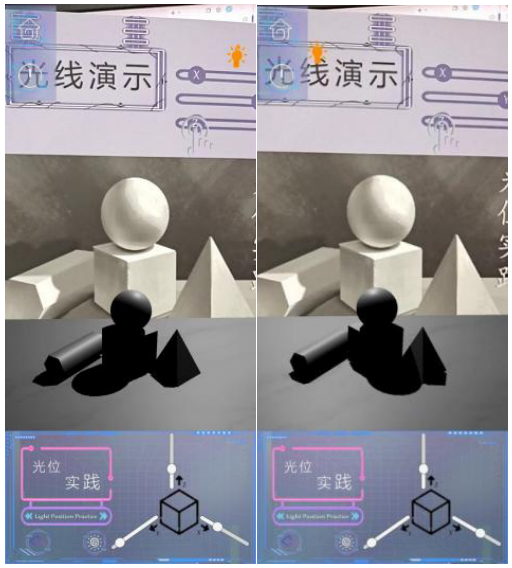

Figure 16. The X-axis is taken as an example to show the effects of light push and pull

Line renderer

An important feature of a learning environment based on AR, the line renderer is a component that visualizes the path of light rays when they travel from the source to the object. This helps users understand the behavior of light when it comes in contact with different surfaces. It also aids in understanding how and why the different shapes of shadows are formed.

In the Unity editor panel shown in Figure 17, two positions form a single line segment. The width is set to a specific value for clarity, and a color is selected that differentiates between the path of the light and other elements. Default functions, like Stretch and View, maintain a specific rendering at various angles. A live scene using purple lines is depicted below, connecting a source of light to several points on an object. These lights show the direct pathway taken by the light source to fall on the object and the projection rays that form the shadow of the object on the surface. This experiment shows how light travels in a straight line, how it interacts with an object at different angles, and how it defines the borders of a shadow.

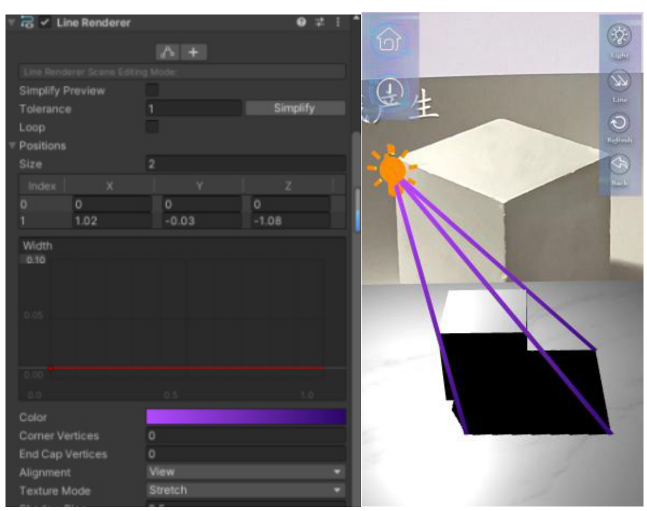

Figure 17. Line renderer properties and effect

This component enables users to interact and engage in a dialogue with the principles of light and shadow. It helps transform theoretical concepts into a practical reality. It enhances the AR learning experience and provides a concrete definition when it comes to the behavior of light. Thus, it helps in bridging the gap between theory and practice and forms an essential component in this project.

Model zoom interaction

This refers to a specific action wherein users can use two fingers to touch the screen and zoom the model (Figure 18). The model size can be changed and adjusted according to what the user wants. This will help the users view the model in a more detailed way. While trying to zoom in on the model, the section where the screen was previously touched is compared with the new touch points to understand whether the object needs to be enlarged or reduced in size. This function is conducted using a specific code. This code is illustrated below.

```
If (Input.touchCount == 2)
{
        if (Input.GetTouch(0).phase == TouchPhase.Moved || Input.GetTouch(1).phase ==
TouchPhase.Moved)
        {
          Vector2 temPos1 = Input.GetTouch(0).position;
          Vector2 temPos2 = Input.GetTouch(1).position;
          if (isEnLarge(oldPos1, oldPos2, temPos1, temPos2))
          {
            float oldScale = transform.localScale.x;
            float newScale = oldScale * 1.01f;
            transform.localScale = new Vector3(newScale,
```

Figure 18. The model resize interaction

Model rotation interaction

With this function, the user can rotate the model on the screen with their touch (Figure 19). The Object Rotation script is used to do this work. Just like model zoom interaction, the difference between the old and new touch points is calculated. The object may rotate up and down as well, according to its own coordinate points.

```
if (Input.touchCount == 1)
    {
        Touch touch = Input.GetTouch(0);
        if (touch.phase == TouchPhase.Moved)
        {
            Vector2 deltaPosition = touch.position - lastTouchPosition;
            float deltaY = deltaPosition.y / Screen.height * rotateSpeed;
            transform.Rotate(Vector3.right, deltaY, Space.Self);
        }
        lastTouchPosition = touch.position;
```

Figure 19. Model rotation interaction

Virtual button interaction

Virtual buttons are used in place of traditional physical buttons to operate a range of devices and appliances. This helps users understand the operation of the appliances more easily, reducing the need for physical contact (Suvedhini et al., 2023). By clicking the virtual button, the five elements of the light surface, grey surface, dark side, light and dark boundary, and projection of the object can be viewed quickly. Figure 20 depicts virtual button interactions that control the display of objects.

Figure 20. Virtual button interaction

Points match

The points race is a test based on previous knowledge and AR practice. In this design, the goal is to complete 10 multiple-choice tests in 60 seconds, each worth 10 points. After the completion of the test, the total score is obtained. To create the test, 10 texts are administered in multiple-choice questions, and a toggle button is added in front of each question. After selecting the answer, click "OK," which leads to 10 points being gained. If a wrong answer is selected, it is displayed on the screen, and no points are awarded. When "Next Question" is clicked, the current question interface is hidden, and the next question is displayed. After the completion of the test, the "End" button is clicked, which leads to the generation of the overall test score.

This entire operation can be done with the help of two scripts. The variable declaration is the one that includes the score as the current score, Countdown Text is the countdown text UI, and the initial countdown time of 60 seconds is the Countdown Time. The text used by UI to end the interface and to display the score is end_score and score_ui, respectively. The end of the interface, correct answer interface, and incorrect answer interface are represented by end_ui, true_ui, and false_ui, respectively.

Figure 21 shows multiple functions that are used to handle the integration of scores, score display, and correct and incorrect answers. The answer link is controlled by a different answer script that includes the choice made by the user, the judgment of right and wrong, and the move to the next question. The variable declaration includes the "next" button and the four options – A, B, C, and D. Other components include "Answered," which is the answered question, and "Toggle Group," which ensures that the user can select only one question.

Figure 21. Script implementation effect

Content Integration and Publishing

After completing the design mentioned above, all the elements are integrated and grouped into a single web application using AR tools. If the project is completed on Unity PC, it is installed on Android to complete the process and run the operation. This completes the work related to AR.

Summary

This study brings together AR-related technologies, such as image recognition, 3D modeling, and interactive designs, to increase engagement and better conceptual understanding among students. The study has also blended the concepts of light and shadow in art with the real-world environment, creating a learning environment that is both real and virtual. The development of interactive functions enhances the learning experiences of users through the incorporation of factors like touch screens, gestures, and voice commands. This also helps in the development of a learning process that is active and effective. The project opens up a special area of learning for scholars through the introduction of AR effects that increase the enthusiasm of students and aid in their full participation. With increased understanding of the aesthetic value of light and shadow, people also gain an appreciation for works of art. Thus, educators can incorporate resources using AR that incorporate studio-based art education to improve students' understanding of light and shadow.

While this study focuses only on the concepts of light and shadow, it is hoped that AR elements will prove to be useful to other courses of art and painting as well in the future. One drawback of this study is that there is no evaluation of real-life or practical projects. Thus, the effectiveness of AR teaching in increasing the efficiency and knowledge of students cannot be determined. With the demand for AR teaching gradually increasing with time, there are still a few uncertainties with regard to this new concept. The large-scale application of these techniques tends to face challenges like proving its educational efficiency, improving the efficiency of users, and addressing security concerns. However, with the development of technology and the increasing demand for educational resources of high quality, it can be said without a doubt that AR teaching aids will continue to expand and exert their influence.

The current work, though focused on design and development, was subjected to a small-scale classroom demonstration with digital media students. Observations revealed increased engagement and conceptual clarity in the manipulation of light. Future work will involve systematic empirical testing through pre-post assessments and student feedback to validate the effectiveness of these AR materials.

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