INTERNATIONAL RESEARCH JOURNAL OF HUMANITIES AND INTERDISCIPLINARY STUDIES

( Peer-reviewed, Refereed, Indexed & Open Access Journal )

DOI : 03.2021-11278686 ISSN : 2582-8568 IMPACT FACTOR : 8.428 (SJIF 2026)

# Design and Development of an Augmented Reality Application for Nuclear Power Plant Education

**Vaishali P. Bhosale**

Assistant Director/Assistant Professor,
Yashwantrao Chavan School of
Rural Development,
Shivaji University,
Kolhapur (Maharashtra, India)

**Sudhir B. Desai**

Associate Director/Associate Professor,
Yashwantrao Chavan School of
Rural Development,
Shivaji University,
Kolhapur (Maharashtra, India)

**DOI No. 03.2021-11278686 DOI Link :: https://doi-ds.org/doilink/05.2026-49825225/IRJHIS2605009**

***Abstract:***

*This research paper presents the design, development and implementation of a multi-modal Augmented Reality (AR) application for teaching the schematic of a Nuclear Power Plant to first-year engineering students. The application supports three distinct modes: Marker-Based AR, Markerless AR, and a standalone 3D Dimensional viewer, making it flexible for diverse learning environments. The 3D models of the nuclear power plant components were developed using industry-standard modelling tools, and the AR experience was built using the Unity 3D game engine and Vuforia SDK. Students can interact with labelled 3D components including the Nuclear Reactor, Boiler, Turbine, Condenser, Water Pump, Transformer, and Cooling Tower, with step-by-step guided interaction, audio narration, cross-section views, and informational pop-ups. This work demonstrates that AR-based immersive tools can substantially enhance the comprehension of complex engineering systems aligned with Education 4.0 and Industry 4.0 objectives.*

***Keywords:*** *Augmented Reality, Unity, Vuforia, Marker-Based AR, Markerless AR, Nuclear Power Plant, Industry 4.0, Interactive 3D.*

## 1. Introduction:

Traditional pedagogical approaches for teaching complex energy systems such as nuclear power plants rely primarily on two-dimensional textbook diagrams, static schematics, and lecture-based instruction[8-9]. These methods often fall short in conveying the spatial relationships, dynamic processes, and multi-component interactions inherent in nuclear power generation. The concept of Education 4.0, emerging in alignment with Industry 4.0, advocates the integration of immersive digital technologies into curricula to meet the demands of modern industry[10-12]. Augmented Reality (AR) is one such technology that superimposes computer-generated objects, text, and animations onto the real-world environment as viewed through a camera-equipped device[1-2]. Unlike Virtual Reality

(VR), AR preserves real-world context while adding digital enrichment, making it particularly suitable for educational settings where physical materials such as textbooks remain relevant[13-14].

This paper presents the complete design, development, and educational evaluation of an AR-based mobile application specifically created to teach the nuclear power plant. The application was developed using Unity 3D and Vuforia SDK and offers three learning modes: Marker-Based AR (where scanning a textbook image spawns the 3D model), Marker-less AR (where the 3D model can be placed on any real-world surface), and a standalone 3D Dimensional viewer.

This paper presents the complete design, development, and educational evaluation of an AR-based mobile application specifically created to teach the nuclear power plant schematic to first-year engineering students. The application was developed using Unity 3D and Vuforia SDK and offers three learning modes: Marker-Based AR (where scanning a textbook image spawns the 3D model), Markerless AR (where the 3D model can be placed on any real-world surface), and a standalone 3D Dimensional viewer.

**2. Objective of the Study:**

The specific objectives of this research are to design and develop a multi-modal AR application for nuclear power plant education, incorporating Marker-Based AR, Marker-less AR, and a 3D Dimensional viewer and to implement interactive features including component-level touch interaction, audio narration, cross-section visualisation, step-by-step guidance, and information overlays [15-17].

**3. Development Tools and Technologies:**

The AR application was developed using the following technology stack:

- Unity 3D (v2022.3 LTS): Primary game engine used for scene development, scripting, UI design, and application building.
- Vuforia Engine SDK: Integrated into Unity for image-target recognition (marker-based mode) and ground plane detection (marker-less mode).
- Blender / 3Ds Max: Used for 3D modelling, UV unwrapping, texturing, and animation of nuclear power plant components.
- C# Scripting: Interaction logic, UI management, step-by-step animation sequencing, audio playback, and cross-section reveal were scripted in C#.
- Android Build Tools (JDK + SDK): Application was compiled and deployed as an .APK file for Android smartphones.

**4. Application Development:**

**4.1 Application Architecture and Navigation Flow:**

The application is structured as a multi-screen Android application with a hierarchical navigation system. Upon launch, the student selects a Chapter (e.g., Chapter 05: Towards Green

Energy), then selects a Topic (e.g., Schematic of Nuclear Power Plant), and finally chooses a Mode (AR or 3D Dimensional). This clean navigation ensures minimal cognitive load during app entry. Figure 1 illustrates Chapter 05 (Towards Green Energy) and topic nuclear power plant selection interface, showing the open-book themed UI with chapters listed on the left panel and related topics on the right panel.


**Figure 1: Chapter and Topic Selection Screen**

**4.2 Mode Selection:**

After topic selection, the student encounters the Mode Selection screen (Figure 2). When AR is selected, a secondary screen reveals two sub-modes: Marker-Based AR and Marker-less AR. A prominent WARNING panel advises students to use the application under adult supervision and to be aware of their surroundings — addressing safety considerations inherent in AR camera-based applications. The 3D Dimensional mode requires no camera and serves as a standalone interactive viewer.

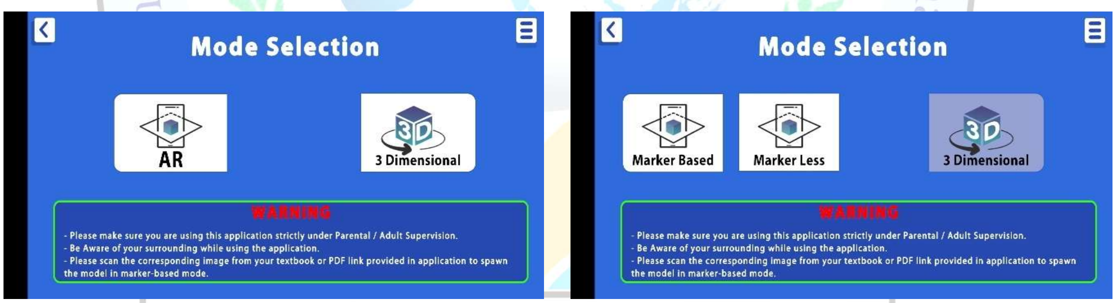


**Figure 2: Mode Selection Screen**

**4.3 Loading and Initialisation:**

A full-screen loading screen (Figure 3) with 'Loading...' text is displayed while the AR engine, Vuforia tracking systems, and 3D assets are initialised. This ensures the application is fully ready before the camera view is activated, preventing partial rendering or tracking errors during student use.

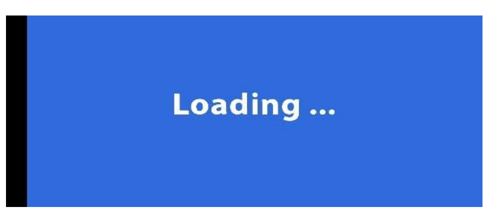


**Figure 3: Loading Screen displayed during AR engine and asset initialisation**

### 4.4 Marker-Based AR Mode:

When the AR camera is first activated, a User Guide overlay (Figure 4) instructs students on interaction gestures: single-finger rotation, pinch-to-scale, two-finger movement for repositioning, pinning and unpinning the object. This guide ensures that even first-time AR users can begin interacting with the model immediately.

Once the guide is closed, the 3D nuclear power plant model appears overlaid on the textbook page (Figure 4). The model includes components — Nuclear Reactor, Boiler, Control Pods, Turbine, and Cooling Tower — positioned accurately relative to the textbook's own diagram, creating a powerful dual-layer learning experience where the static 2D diagram and the interactive 3D model reinforce each other.

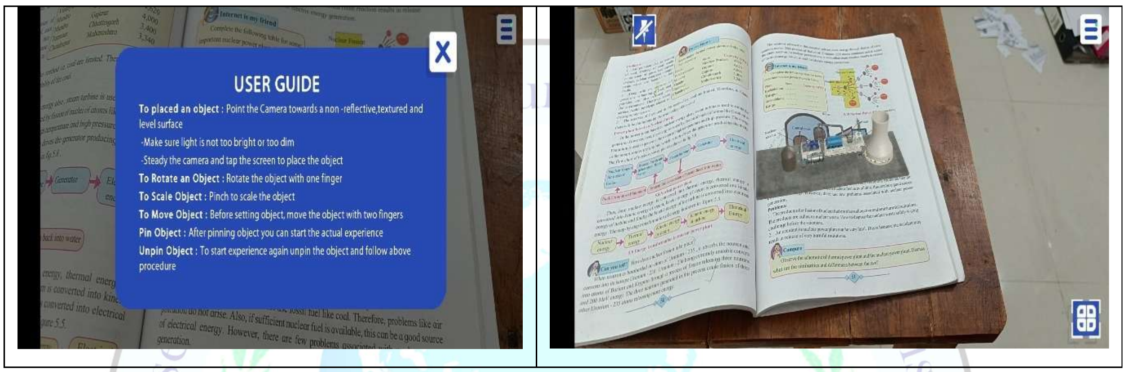


**Figure 4: User Guide and Marker-Based AR Augmentation**

### 4.5 Touch Interaction in Marker-Based AR:

Students can tap individual 3D components to trigger step-by-step guided interactions. Figure 5 shows the model with labelled components. A bottom prompt instructs the student to tap a specific component. Figure 5 shows a closer perspective of the turbine and generator assembly, with the instruction 'Tap on the turbine to drive the generator and produce electricity, turbine converts steam into low-pressure, low temperature.' This sequential interaction guides students through the complete thermodynamic cycle of the power plant.

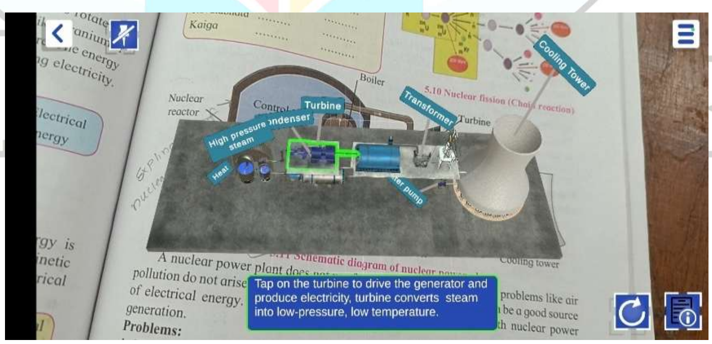


**Figure 5: Marker-Based AR with Touch Interaction prompt**

### 4.6 Information Panel and Cross-Section View:

Tapping the information (ⓘ) button launches an overlay panel (Figure 6) titled 'Nuclear Power Plant' containing a concise explanation that eliminates the need for students to refer back to the textbook, supporting a seamless learning flow.

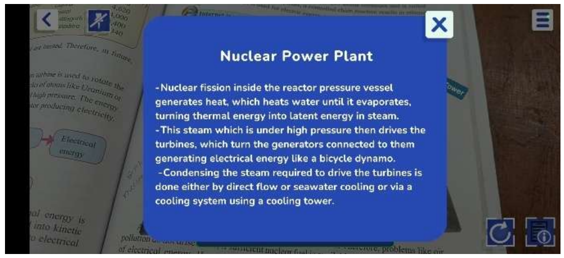


**Figure 6: Information Panel**

Figure 7 shows cross-section view that reveals the internal layout of the nuclear reactor and boiler system, allowing students to visualize components that are normally hidden.

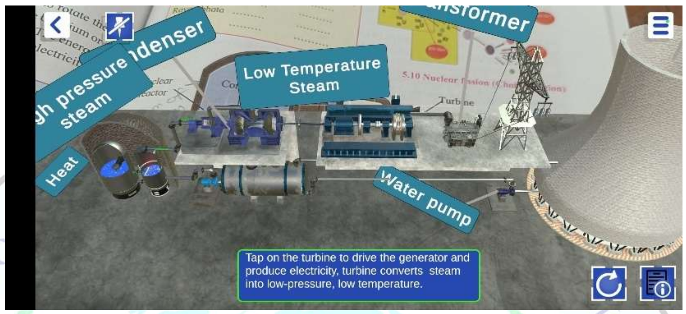


**Figure 7: Cross-section view**

**4.7 Marker-less AR Mode:**

In Marker-less AR mode, the Vuforia ground plane detection algorithm identifies horizontal flat surfaces in the camera's field of view. The student taps the detected surface to place the nuclear power plant 3D model, which then remains anchored to that real-world position. This mode is useful in scenarios where the student does not have the textbook available — for instance, in a laboratory, at home, or during a field visit.

Figure 8 shows the marker-less mode with the model placed on a surface, along with visible component labels. The model is fully interactive in this mode with all the same touch interactions available as in marker-based mode. The User Guide (Figure 6) is also displayed in this mode with marker-less specific placement instructions.

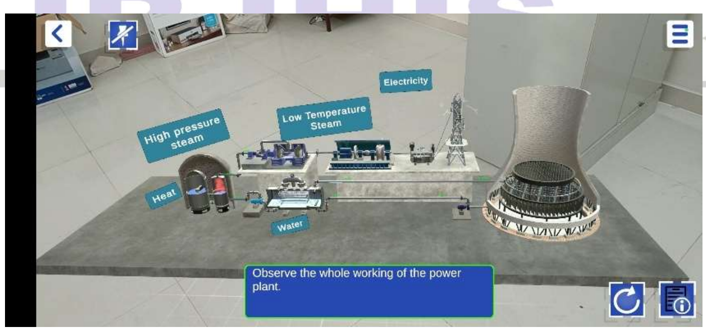


**Figure 8: Marker-less AR mode with 3D model on a flat surface**

**4.8 Standalone 3D Dimensional Mode:**

The 3D Dimensional mode provides a fully interactive 3D viewer that does not require a camera or physical marker. The model is rendered against a dark background simulating a virtual environment. Students can freely rotate the model 360°, zoom in/out, and tap individual components. The step-by-step interactive sequence is shown in Figure 9.


**Figure 9: 3D Mode**

### 4.9 Key Application Features Summary

Table 1 summarises all features of the developed application and their respective educational benefits.

**Table 1: Summary of Application Features and Educational Benefits**

| Feature | Description | Educational Benefit |
|---|---|---|
| Marker-Based AR | 3D model spawns on textbook diagram | Connects textbook content to 3D visualization |
| Markerless AR | 3D model placed on any real surface | Enables flexible placement in any environment |
| 3D Mode | Standalone 3D viewer without camera | Accessible without a physical marker/surface |
| Touch Interaction | Tap individual components to trigger animation | Promotes active inquiry-based learning |
| Cross-Section View | Internal view of reactor and components | Reveals hidden internal structure |
| Info Panel | On-tap text overlay with component details | Provides contextual information instantly |
| Audio Narration | Voice explanation of the working principle | Supports auditory learning style |
| Component Labels | Floating 3D labels (Turbine, Condenser, etc.) | Reinforces nomenclature and spatial layout |
| Step-by-step Guide | Sequential interaction prompts at bottom | Guides structured learning workflow |

### 4.10 Technical Stack and Build Configuration:

The application was built for Android platform using Unity's build system. Key technical settings included: OpenGL ES 3.0 graphics API (replacing Vulkan to ensure camera feed compatibility across diverse Android devices), minimum API level Android 7.0 Nougat (API Level 24), landscape-left default orientation, and Vuforia Engine 10.x for image recognition and ground plane detection. The final .APK file was tested on multiple Android smartphones with screen sizes ranging from 5.5 to 6.7 inches to verify cross-device compatibility.

**5. Conclusion And Future Scope:**

This paper presented the end-to-end development of a multi-modal Augmented Reality application for nuclear power plant education targeting first-year engineering students. The application uniquely integrates Marker-Based AR, Marker-less AR, and a standalone 3D Dimensional viewer within a single platform, offering comprehensive pedagogical coverage across different learning environments. The application directly supports the objectives of Education 4.0 by fostering immersive, technology-enhanced, student-centred learning aligned with Industry 4.0 competency demands.

Future scope includes expanding the application to cover other power plant types (solar, hydroelectric, wind etc) to complete the energy module. AI-powered adaptive feedback based on assessments and quizzes can be integrated.

**Acknowledgement:**

The authors express gratitude to the District Planning Commission, Kolhapur, for funding the development of the AR application.

**References:**

[1] Y. C. Chen, H. L. Chi, W. H. Hung, and S. C. Kang, "Use of tangible and augmented reality models in engineering graphics courses," Journal of Professional Issues in Engineering Education and Practice, vol. 137, no. 4, pp. 267–276, Oct. 2011, doi: 10.1061/(ASCE)EI.1943-5541.0000078.

[2] T. Serdar, "Integration of Augmented Reality into the CAD Process."

[3] S. 'Manjina, "AR mobile tool for Engineering education," American Society for Engineering Education, 2021.

[4] I. Börsting, C. Karabulut, B. Fischer, and V. Gruhn, "Design Patterns for Mobile Augmented Reality User Interfaces—An Incremental Review†," Information (Switzerland), vol. 13, no. 4, Apr. 2022, doi: 10.3390/info13040159.

[5] A. 'Ronald, B. 'Yohan, B. 'Reinhold, F. 'Steven, J. 'Simon, and M. 'Blair, "Recent Advances in Augmented Reality," IEEE Comput Graph Appl, vol. 21, no. 6, pp. 34–47, Nov. 2001.

[6] Handbook of Augmented Reality. Springer New York, 2011. doi: 10.1007/978-1-4614-0064-6.

[7] M. Kesim and Y. Ozarslan, "Augmented Reality in Education: Current Technologies and the Potential for Education," Procedia Soc Behav Sci, vol. 47, pp. 297–302, 2012, doi: 10.1016/j.sbspro.2012.06.654.

[8] M. Wang, V. Callaghan, J. Bernhardt, K. White, and A. Peña-Rios, "Augmented reality in

education and training: pedagogical approaches and illustrative case studies," J Ambient Intell Humaniz Comput, vol. 9, no. 5, pp. 1391–1402, Oct. 2018, doi: 10.1007/s12652-017-0547-8.

[9] M. J. G. Figueiredo, P. J. S. Cardoso, C. D. F. Goncalves, and J. M. F. Rodrigues, "Augmented reality and holograms for the visualization of mechanical engineering parts," in Proceedings of the International Conference on Information Visualisation, Institute of Electrical and Electronics Engineers Inc., Sep. 2014, pp. 368–373. doi: 10.1109/IV.2014.17.

[10] M. Osborne and S. Mavers, "Integrating augmented reality in training and industrial applications," in Proceedings - 2019 8th International Conference of Educational Innovation through Technology, EITT 2019, Institute of Electrical and Electronics Engineers Inc., Oct. 2019, pp. 142–146. doi: 10.1109/EITT.2019.00035.

[11] O. V Kanivets and E. O. Shmeltser, "Development of mobile applications of augmented reality for projects with projection drawings," 2020.

[12] O. Yilmaz, "Augmented Reality in Science Education: An Application in Higher Education," Shanlax International Journal of Education, vol. 9, no. 3, pp. 136–148, Jun. 2021, doi: 10.34293/education.v9i3.3907

[13] S. Mystakidis, A. Christopoulos, and N. Pellas, "A systematic mapping review of augmented reality applications to support STEM learning in higher education," Educ Inf Technol (Dordr), vol. 27, no. 2, pp. 1883–1927, Mar. 2022, doi: 10.1007/s10639-021-10682-1.

[14] H. Çetin and A. Türkan, "The Effect of Augmented Reality based applications on achievement and attitude towards science course in distance education process," Educ Inf Technol (Dordr), vol. 27, no. 2, pp. 1397–1415, Mar. 2022, doi: 10.1007/s10639-021-10625-w.

[15] A. Montero, T. Zarraonandia, P. Diaz, and I. Aedo, "Designing and implementing interactive and realistic augmented reality experiences," Univers Access Inf Soc, vol. 18, no. 1, pp. 49–61, Mar. 2019, doi: 10.1007/s10209-017-0584-2.

[16] A. Saeed Alqahtani, L. Foaud Daghestani, and L. Fattouh Ibrahim, "Techniques used to Improve Spatial Visualization Skills of Students in Engineering Graphics Course: A Survey," 2017. [Online]. Available: www.ijacsa.thesai.org

[17] T. Serdar, "Integration of Augmented Reality into the CAD Process."

[18] R. G. Boboc, R. L. Chiriac, and C. Antonya, "How augmented reality could improve the student's attraction to learn mechanisms," Electronics (Switzerland), vol. 10, no. 2, pp. 1–24, Jan. 2021, doi: 10.3390/electronics10020175

[19] T. Khan, K. Johnston, and J. Ophoff, "The Impact of an Augmented Reality Application on Learning Motivation of Students," Advances in Human-Computer Interaction, vol. 2019, 2019, doi: 10.1155/2019/7208494

[20] D. Scaravetti and D. Doroszewski, "Augmented reality experiment in higher education, for

complex system appropriation in mechanical design," in Procedia CIRP, Elsevier B.V., 2019, pp. 197–202. doi: 10.1016/j.procir.2019.04.284.

[21] D. Scaravetti and R. François, "Implementation of augmented reality in a mechanical engineering training context," Computers, vol. 10, no. 12, Dec. 2021, doi: 10.3390/computers10120163.

[22] C. Hedenqvist, M. Romero, and R. Vinuesa, "Improving the Learning of Mechanics Through Augmented Reality," Technology, Knowledge and Learning, vol. 28, no. 1, pp. 347–368, Mar. 2023, doi: 10.1007/s10758-021-09542-1.