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Work in Progress: Code Name 7408 - Gamifying the Logic Gate Chip Learning through Immersive Virtual Reality

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Introduction

‘Electronics’, and similar courses with different titles, is a foundational subject for Engineering and Technology disciplines that deals with the design and application of devices and systems. It forms the basis of modern devices and has applications across various domains, such as communication systems, automation, robotics, renewable energy, aerospace, and automotive engineering. This makes electronics a key component of modern technological solutions.

Understanding electronics enables engineers and technologists to design, troubleshoot, and innovate these devices. The subject equips students with core skills in circuit analysis, microprocessors, embedded systems, and signal processing, which are essential for building and improving electronic systems. Students with a solid grasp of electronics are better equipped to develop innovative solutions to real-world problems by designing efficient, cost-effective, and sustainable electronic systems.

Learning electronics, nevertheless, can be challenging for many students due to the subject's abstract concepts, mathematical analysis, and practical applications [1]. Electronics involves invisible phenomena like electric currents, voltages, electromagnetic waves, and semiconductors that are hard to visualize; thus, understanding how circuits work, analyzing them, and solving complex circuits with multiple components like resistors, capacitors, transistors, and diodes can be overwhelming for novices. Furthermore, electronics requires a strong foundation in mathematics, particularly in areas like Ohm’s Law and Kirchhoff's laws. Many students struggle with applying mathematical concepts to circuit problems [2], especially during the lab when wiring circuits, debugging, and handling equipment like oscilloscopes, multimeters, and breadboards. Besides, students may struggle to understand how theoretical knowledge applies to real-world applications, making the subject seem disconnected from practical use, and consequently lose interest, dedication, and patience, which are essential for consistent practice needed to master this subject.

XR-assisted Learning and Gamification

Extended Reality, also known as XR, encompasses technologies that blend the physical and digital worlds, including Virtual Reality (VR), Augmented Reality (AR), and Mixed Reality (MR). Literature has reported using AR for learning electronics, as it creates interactive, visual, and immersive experiences [3], [4]. AR apps can overlay 3D models of components like resistors, capacitors, diodes, transistors, etc., on a physical circuit board. Students can point their smartphones or tablets at a breadboard or schematic diagram, and the AR app will show each component's labels, connections, and explanations. Some AR apps can simulate virtual circuits in a 3D environment, where learners can build circuits by selecting components from and connecting them virtually without the risk of damaging physical components [5]. These simulations allow students to test circuits in real-time and see how current flows, voltages change, and components behave under different conditions. AR apps can act as virtual lab assistants [3], [6], guiding students step-by-step through circuit assembly, soldering, and testing processes. AR can display instructions directly on the circuit board, showing exactly where to place components and how to connect them.

Comparatively, VR-based solutions can also help students learn electronics [7], [8]. It allows students to visualize circuits, interact with components, and simulate real-world scenarios in a risk-free, virtual lab. VR makes learning more engaging by enabling students to practice complex tasks without physical limitations. VR environments can help students learn component functions and theories by showing 3D models of components like resistors, capacitors, transistors, and diodes, along with interactive explanations of their functions and applications. Students can visualize the current flow and see how components interact in a circuit [9]. VR can create virtual electronics labs where students can work with virtual breadboards, oscilloscopes, multimeters, and circuit components without physical equipment. Learners can assemble circuits, measure voltages, and troubleshoot errors in a fully simulated environment while access to physical labs is limited or unavailable. In VR, students can drag and drop components to build circuits quickly. They can test circuits in real-time, modify connections, and observe how changes affect the circuit's behavior [10].

Gamification is the application of game design elements and game principles in education. When applied to STEM (Science, Technology, Engineering, and Mathematics), gamification can transform learning into an engaging, interactive, and motivating experience. It promotes critical thinking, problem-solving, and collaboration [11], [12], [13], making STEM subjects more accessible and enjoyable. Using gamification strategies such as challenges and quests, storytelling and narratives, and instant feedback and rewards systems can keep students focused and increase engagement. Failure in games is less frustrating [13], enabling the learner to develop persistence and adaptability. Besides, students can tackle real-world problems in a safe environment and retain knowledge through active participation instead of preferred trial-and-error approaches.

Project 7408

The IC 7408 is a quad 2-input AND gate with a wide range of applications. It is a fundamental building block for constructing digital circuits, arithmetic and logic units (ALUs), and control systems for industrial automation. In the electronics lab, students learn about digital logic using IC 7408 to build basic circuits such as signal gating, data communication, or security systems. However, students' learning performance may vary. As shown in Figure 1, the chip's 14-pin layout might not be as intuitive as other components on the circuit, e.g., resistors, capacitors, etc., can be easily mixed up without a closer examination of the schematic and the actual chip. Furthermore, while the utilization of individual AND gates seems straightforward and has been used to reinforce the learning of the truth table, hands-on exercises could cause confusion if the pins of the AND Gate, power, and ground are not connected correctly.

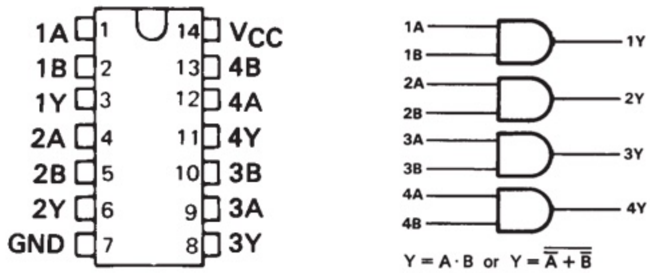

Figure 1. IC 7408 pin layout corresponding to its AND Gates from the SN74LS08 spec sheet

This paper discusses the ongoing development of a VR-based gaming environment for learning the 7408 logic chip. The current build uses Unity 2023 LTS, and the VR app is tethered, meaning the Meta Quest 2 headset is connected to the computer. The player will interact with the environment using the factory controllers. Using a scaffolding strategy, this educational game has different levels for the player to learn the operations and applications of IC 7408:

The player starts in a small room with a locked elevator door. The goal is to solve puzzles of the 7408 IC (Quad 2-input AND Gate) to manipulate objects and progress to the next level. Each level introduces new challenges and increases in difficulty, with the player learning more about AND Gates and the IC's functionality as they progress.

- Level 1 - Understand how an AND gate functions at the component level: The player interacts with the virtual AND Gate by flipping the switches (Figure 2) of its inputs and observing the reaction of its output. The player can move to the next level once the' AND' condition is achieved.

Figure 2. The flipping of the input switch

- Level 2 – Assemble the 7408 IC with 4 AND Gates: The player will place four AND Gates provided on the 7408 baseboard with the pins and connect the necessary power, ground, and input/output pins according to the schematic provided (Figure 3). Once the assembly is completed and the IC is functional, the player moves to Level 3.

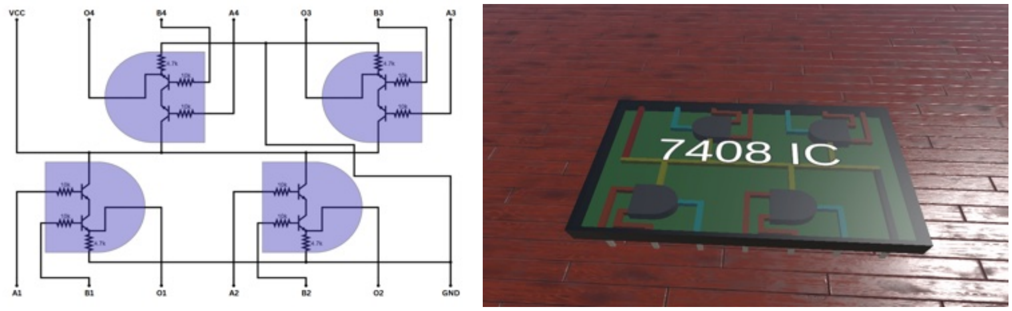

Figure 3. The schematic and building of the virtual 7408 chipset

- Level 3 – Control a Light Connected with the 7408 chipset: The player will connect two switches to the input pin of an AND Gate in IC 7408 and connect a desk lamp to the same AND Gate output pin. Once the chipset is energized, the switches are set to 'on,' and the lamp is 'on' (Figure 4), the player can move to the final level.

Figure 4. Turn on a desk lamp

- Level 4 – Use 7408 to fulfill multiple conditions: As shown in Figure 5, to escape from the confinement, the player has to meet the following conditions in the room: (1) the desk lamp is 'on,' (2) the ceiling fan is 'on,' (3) six ceiling lights are 'on,' and (4) the elevator door is open. All four AND Gates in 7408 will be utilized to fulfill the conditions.

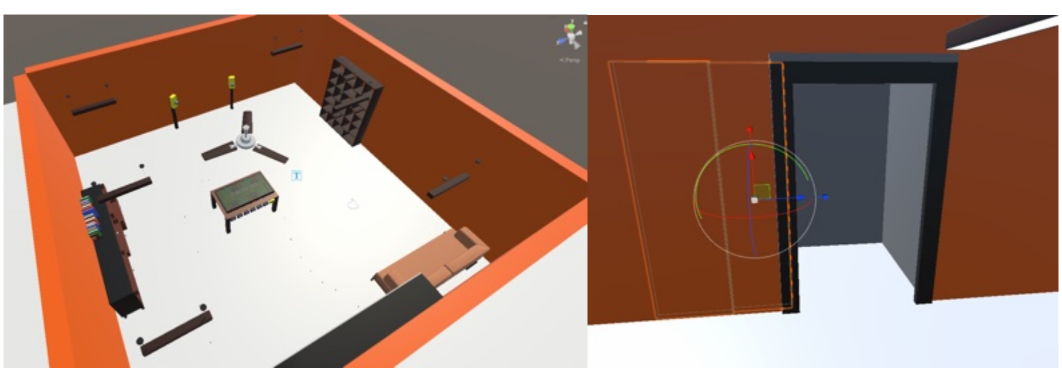

Figure 5. The confinement and the elevator door

Pedagogy and Assessment

To incorporate this VR-based learning environment into the Electronics class, the following is the sequence of the suggested pedagogy:

1. Lecture on the theory of how the AND Gate and the truth table work. 2D simulation, such as the logic gate simulator, can be used to demonstrate the device virtually.
2. Introduce the 7408 IC, including its conceptual design, e.g., the composition of four AND Gates, and the pin layout.
3. Bring in this immersive educational game and allow students to try and error to clarify confusion or muddy points.
4. Hold a timed competition for students to reinforce their learning activity.
5. Deploy the physical lab, where students can use the 7408 chip to develop control circuits for various contexts, such as production line automation, security locks, or multi-factor verification.

As suggested in the above list, the VR learning environment will be utilized in Steps 3 and 4. The expected benefits include:

1. The virtual AND Gate will allow the students to visualize how the AND Gate works before building the physical circuit.
2. Escaping confinement aims to familiarize students with the content, motivate their learning, and increase engagement.
3. The time-based competition may realize the deep-learning process as the participants are encouraged to solve a problem under stress.

To evaluate the effectiveness of this VR application, we plan to conduct an experiment once approved by the university's IRB. Participation will be voluntary; students can receive the game-based VR training before performing the fifth step in the suggested pedagogy. The following data will be collected from both the controlled and experimental (VR) groups:

1. The build speed and quality of physical circuits using the 7408 IC in step 5.
2. The knowledge retention of IC 7408 six weeks after the VR exercise.
3. Self-reported survey with quantitative and qualitative feedback and comments.

Project Outlook

The student-inspired project is currently at the minimum viable product (MVP) stage, meaning the key assets (e.g., the AND Gate, the switches, the room) and scripts (e.g., how the assets will behave according to event triggers) are functional but not perfect. Before putting the VR environment to the field test, iterative pilot tests will be necessary for debugging and usability improvement. We also plan to make the environment tetherless, e.g., standalone and sideloading to the Quest 2 headset, with hand gesture recognition to increase its intuitiveness (eliminating the extensive practice of how the hand controllers work) and immersive level.

Reference

[1] A. Amida, I. Chang, and D. Yearwood, “Designing a practical lab-based assessment: A case study,” *J. Eng. Des. Technol.*, vol. 18, no. 3, pp. 567–581, 2019.

[2] J. Qi and L. Buechley, “Sketching in circuits: designing and building electronics on paper,” in *Proceedings of the SIGCHI Conference on Human Factors in Computing Systems*, Toronto Ontario Canada: ACM, Apr. 2014, pp. 1713–1722. doi: 10.1145/2556288.2557391.

[3] C. Avilés-Cruz and J. Villegas-Cortez, “A smartphone-based augmented reality system for university students for learning digital electronics,” *Comput. Appl. Eng. Educ.*, vol. 27, no. 3, pp. 615–630, May 2019, doi: 10.1002/cae.22102.

[4] S. Martin *et al.*, “Design of an augmented reality system for immersive learning of digital electronic,” in *2020 XIV Technologies Applied to Electronics Teaching Conference (TAEE)*, IEEE, 2020, pp. 1–6.

[5] P. Lucas, D. Vaca, F. Dominguez, and X. Ochoa, “Virtual circuits: An augmented reality circuit simulator for engineering students,” in *2018 IEEE 18th International Conference on Advanced Learning Technologies (ICALT)*, IEEE, 2018, pp. 380–384.

[6] Z. Pan, J. Polden, N. Larkin, S. Van Duin, and J. Norrish, “Recent progress on programming methods for industrial robots,” in *ISR 2010 (41st International Symposium on Robotics) and ROBOTIK 2010 (6th German Conference on Robotics)*, VDE, 2010, pp. 1–8.

[7] S. Nuanmeesri and L. Poomhiran, “Perspective Electrical Circuit Simulation with Virtual Reality.,” *Int. J. Online Biomed. Eng.*, vol. 15, no. 5, 2019.

[8] D. A. Albarracin-Acero, F. A. Romero-Toledo, C. E. Saavedra-Bautista, and E. A. Ariza-Echeverri, “Virtual Reality in the Classroom: Transforming the Teaching of Electrical Circuits in the Digital Age,” *Future Internet*, vol. 16, no. 8, p. 279, 2024.

[9] E. Wolbach, M. Hempel, and H. Sharif, “Leveraging Virtual Reality for the Visualization of Non-Observable Electrical Circuit Principles in Engineering Education,” in *Virtual Worlds*, MDPI, 2024, pp. 303–318.

[10] S. K. Vasudevan, S. N. Abhishek, N. K. Keerthana, R. Priyanka, A. Aravinth, and M. Divya, “An Interactive and Intelligent Tool for Circuit Component Recognition Through Virtual Reality,” in *Intelligent Systems Technologies and Applications*, vol. 683, S. M. Thampi, S. Mitra, J. Mukhopadhyay, K.-C. Li, A. P. James, and S. Berretti, Eds., in Advances in Intelligent Systems and Computing, vol. 683. , Cham: Springer International Publishing, 2018, pp. 370–379. doi: 10.1007/978-3-319-68385-0_31.

[11] P. Boonbrahm, C. Kaewrat, and S. Boonbrahm, “Using Augmented Reality Interactive System to Support Digital Electronics Learning,” in *Learning and Collaboration Technologies. Technology in Education*, vol. 10296, P. Zaphiris and A. Ioannou, Eds., in Lecture Notes in Computer Science, vol. 10296. , Cham: Springer International Publishing, 2017, pp. 3–11. doi: 10.1007/978-3-319-58515-4_1.

[12] K. Stoeffler, Y. Rosen, M. Bolsinova, and A. A. von Davier, “Gamified performance assessment of collaborative problem solving skills,” *Comput. Hum. Behav.*, vol. 104, p. 106036, 2020.

[13] C. V. Angelelli, G. M. de Campos Ribeiro, M. R. Severino, E. Johnstone, G. Borzenkova, and D. C. O. da Silva, “Developing critical thinking skills through gamification,” *Think. Ski. Creat.*, vol. 49, p. 101354, 2023.