AR4 Robot in the Classroom

A Multi-Disciplinary, Project-Based Learning Platform

Mechanical Engineering	Electrical Engineering	Manufacturing / 3D Printing	Programming (C++ & Python)

Suitable For:

• High School STEM / CTE	• Community College Mechatronics	• University Engineering	• Capstone / Senior Design

Suggested Course Structure (Modular)

MODULE 1 | MECHANICAL DESIGN & ASSEMBLY

TOPICS COVERED

- Technical drawings & BOMs
- Mechanical assembly processes
- Bearings, tolerances & fits
- Fasteners, torque & alignment
- Gear reduction & motion transmission

HANDS-ON ACTIVITIES

- Assemble AR4 robot structure
- Identify & install components
- Analyze joint construction & load paths

LEARNING OUTCOMES

- Interpret mechanical documentation
- Understand real-world assembly
- Develop hands-on mechanical skills

MODULE 2 | ELECTRICAL SYSTEMS & WIRING

TOPICS COVERED
- Wiring diagrams & schematics
- Stepper motors & drivers
- Power distribution & grounding
- Signal vs power wiring
- Basic troubleshooting

HANDS-ON ACTIVITIES
- Wire motors, drivers & control boards
- Validate connections & continuity
- Diagnose wiring issues

LEARNING OUTCOMES
- Read & implement electrical schematics
- Understand motor control fundamentals
- Apply safe wiring practices

MODULE 3 | ELECTRONICS & EMBEDDED SYSTEMS

TOPICS COVERED
- Arduino / microcontroller fundamentals
- Digital I/O, PWM, serial communication
- Sensors & feedback systems
- C++ programming for control

HANDS-ON ACTIVITIES
- Commission the robot control system
- Upload & modify firmware
- Control outputs & read inputs

LEARNING OUTCOMES
- Understand embedded control systems
- Modify & deploy firmware
- Interface hardware with software

MODULE 4 | ADDITIVE MANUFACTURING (3D PRINTING)

TOPICS COVERED
- 3D printing technologies (FDM)
- Materials: PLA, PETG, CF blends
- Print settings & optimization
- Design for additive manufacturing

HANDS-ON ACTIVITIES
- Print AR4 components (covers, spacers)
- Adjust slicer settings
- Evaluate print quality & strength

LEARNING OUTCOMES
- Operate & optimize 3D printers
- Understand manufacturing constraints
- Connect design to production

MODULE 5 | ROBOT OPERATION & PROGRAMMING

TOPICS COVERED

- Robot coordinate systems (Joint vs Cartesian)
- Motion types (Joint, Linear, Circular)
- Basic automation workflows
- Teach points & pathing
- Robot programming basics

HANDS-ON ACTIVITIES

- Use AR4 HMI software to control robot
- Create pick-and-place routines
- Define waypoints & sequences

LEARNING OUTCOMES

- Understand robot motion fundamentals
- Program basic robotic tasks
- Gain familiarity with industrial concepts

- *Video Resources: Robot Programming Basics & Move Configuration tutorials available*

MODULE 6 | PYTHON SOFTWARE & HMI DEVELOPMENT

TOPICS COVERED

- Python fundamentals
- GUI development (Tkinter-based HMI)
- Serial communication with hardware
- Extending software functionality

HANDS-ON ACTIVITIES

- Modify AR4 HMI interface
- Add custom buttons or features
- Develop automation scripts

LEARNING OUTCOMES

- Understand software-to-hardware integration
- Build & modify user interfaces
- Apply programming to real systems

MODULE 7 | ROBOTICS THEORY (ADVANCED)

TOPICS COVERED

- Forward kinematics
- Inverse kinematics
- Transformation matrices
- Coordinate frames (DH parameters)
- Workspace & singularities

HANDS-ON ACTIVITIES

- Analyze robot motion mathematically
- Compare theoretical vs actual positions
- Use provided tutorials & examples

LEARNING OUTCOMES

- Understand how 6-axis robots calculate motion
- Apply mathematical models to hardware
- Bridge theory with physical systems

MODULE 8 | SIMULATION & DIGITAL TWINS

TOPICS COVERED

- Offline programming
- Robot simulation environments
- Digital twin concepts
- Industry tools

HANDS-ON ACTIVITIES

- Simulate robot programs
- Validate paths before execution
- Compare simulation vs real-world performance

LEARNING OUTCOMES

- Understand modern industrial workflows
- Use simulation for validation & planning
- Gain exposure to industry-standard tools

■ *Tools: ABB RobotStudio (free education version) · RoboDK*

MODULE 9 | SYSTEMS INTEGRATION (CAPSTONE)

TOPICS COVERED

- End-of-arm tooling (grippers, etc.)
- Sensors & I/O integration
- Process automation
- System troubleshooting

HANDS-ON ACTIVITIES

- Build a complete automated task (pick/place, sorting)
- Integrate external devices
- Debug full system operation

LEARNING OUTCOMES

- Integrate mechanical, electrical & software systems
- Develop real-world automation solutions
- Work in team-based engineering environments

TEACHING APPROACH & REAL CLASSROOM EXAMPLE

Rotating Team Structure

■■ **Mechanical / Assembly Team**	Focuses on structural assembly, joints, and load paths.
■■ **3D Printing / Manufacturing Team**	Handles printing components, optimizing settings.
■ **Programming / Simulation Team**	Manages firmware, HMI, and simulation environments.

■ **8–12 Week Program**	Lecture (theory) · Lab (hands-on) · Simulation (digital tools)

Real Classroom Example

✓ Uses *Industrial Robotics Fundamentals* (Ross/Fardo/Walach, 4th Edition)

✓ Builds multiple AR4 robots per class

✓ Strong emphasis on kinematics theory

✓ Uses RobotStudio and RoboDK for simulation

✓ Team-based rotating lab structure across a full academic quarter (~3 months)

✓ Integrates with Canvas LMS for assignment tracking, lab docs & video-based instruction

WHY THE AR4 WORKS WELL IN EDUCATION

Fully Visible System	Not a 'black box' — students can see and understand every component.
Open-Source Software	Built on Python and C++, freely modifiable and extensible.
Real Industrial Concepts	Professional-grade robotics skills at a fraction of the cost.
Hands-On From Day One	Immediate, tangible engagement with hardware and software.
Scalable Curriculum	Supports both beginner and advanced topics in the same platform.

Theory + Application	Bridges classroom learning with real-world engineering practice.

Additional Opportunities

→ Capstone engineering projects

→ Research platforms (ROS2, AI integration, vision systems)

→ PLC integration (Allen-Bradley, etc.)

→ Vision systems and AI-based pick-and-place

→ Remote labs / virtual simulation environments

ROS2 Tutorial available at: youtu.be/9jmXEHAL-Vk