International Journal for Innovative Engineering and Management Research

PEER REVIEWED OPEN ACCESS INTERNATIONAL JOURNAL

www.ijiemr.org

# HUMANOID ROBOT FOR CHILDREN EDUCATION USING EMBEDDED AND IOT

**Shaik BajidVali[1], C.V. Sai Sree Harini[2*], V. Nanditha[3], M. Abbasi Begum [4], S. Lava Kumar[5], V. Hemanth Kumar[6]**

Department of Electronics and Communication Engineering,

Chaitanya Bharathi Institute of Technology (CBIT), Proddatur, Andhra Pradesh, India, 516360 E-mail: cvsaisreeharini@gmail.com

Funding: No Funding was received for this research.

Keywords: Smart Learning System, Voice Based Interaction, Speech Recognition, Homework Remainder System, Digital Educational Platform.

## Abstract

In the present digital era, students require an intelligent, structured, and interactive learning companion that goes beyond traditional educational tools. This project introduces an AI-Powered Smart Learning Assistant, designed to support students from Class 1 to Class 10 with comprehensive academic guidance, task management, and voice-based interaction. The system provides access to curriculum-aligned study materials across multiple subjects, ensuring conceptual clarity and structured learning for school students. It includes features such as automated homework reminders, personalized study scheduling, daily greetings, motivational messages, and real-time doubt clarification. A key highlight of the system is its voice interaction capability, enabling students to communicate naturally with the assistant. Through speech recognition and response generation, users can ask questions, receive explanations, and interact hands-free, creating a more engaging and accessible learning experience. The platform also integrates intelligent notifications, progress tracking, and adaptive assistance to enhance productivity and consistency in learning. By combining AI, automation, and user-centric design, this project aims to bridge the gap between traditional schooling and smart digital education.

## 1. Introduction

Humanoid robotics is the field which is increasing in popularity day by day. Many groups are working on some issues like interacting, learning and controlling for applying them in human robotics. Currently, many types of robots are being used for learning goals and they range from simple robots to humanoid robots. The choice of the robot is generally dictated by the area of study and the age group of the student [1] (Sharkey, 2016). Compared to a human teacher, humanoid robots can help resolve issues related to shyness, frustration, reluctance and confidence better, and are being commonly used in many countries, especially for special education. In the twenty-first century, the educational landscape is rapidly evolving, driven by

International Journal for Innovative Engineering and Management Research
PEER REVIEWED OPEN ACCESS INTERNATIONAL JOURNAL
www.ijiemr.org

the integration of artificial intelligence (AI) and robotic technologies into traditional pedagogy. While educational robotics has long been a subject of research, the recent proliferation of social humanoid robots—machines characterized by a human-like form, gestures, and interactive capabilities—has opened new frontiers in early childhood and primary education. Unlike traditional, static educational tools, humanoid robots exist in the same physical space as students, creating a tangible and interactive learning environment that facilitates both cognitive and social-emotional development.

In education specifically, there are several areas where humanoid robots have been found to support learning and engagement. They have been shown to help develop computational thinking in young learners and foster greater engagement from pupils across a wide array of subjects in the curriculum. Humanoid robots are a wonderful educational aid in teaching children on the autistic spectrum. Having a human form has been proven to invoke a stronger connection and a sense of ownership in the students, and this has been especially effective using 'learning by teaching' and care-giving educational styles. The rapid advancement of technology enables the development of innovative approaches in education. In special education, technological tools used to address the individual needs of students have gained significant importance [2] (Bargagna, Stefania, et al). In this context, educational robots stand out as innovative tools that can be used to support students learning processes, enhance their social interactions, and develop their individual abilities. [3,4]

Educational robots are seen as potentially powerful tools to support students with special educational needs, such as autism spectrum disorder [5], intellectual disabilities und motor impairments [6] and learning disabilities [7]. These robots can help children improve their social skills, increase their attention spans, and engage with learning materials in a more interactive way. Another important aspect here is how the use of educational robots in special education, may evolve in the future. Current technological advancements are making these robots smarter, more accessible, and more adaptable. However, critical questions still need to be addressed, such as whether the infrastructure is sufficient for the widespread use of these technologies, how educators can access these technologies, and whether such technology use might risk exacerbating inequalities in education [8].


Fig 1: Humanoid Robot Structure

## 2. SYSTEM ARCHITECTURE AND DESIGN

A humanoid robot for children education is an intelligent robotic system designed to assist students in learning through interactive communication, visual teaching, and smart responses. The system combines hardware components such as sensors, controllers, motors, and output devices with software technologies like Artificial Intelligence (AI), Speech Recognition, and Internet of Things (IoT). The architecture is designed in layers to ensure smooth interaction between students and the robot. The system architecture of an educational humanoid robot is designed for high-level interaction, social cues, and safety, typically organized into three layers: a perceptive AI system, a motion control system, and a physical robot body. It uses cameras, microphones, and sensors for environmental awareness, processed via ROS (Robot Operating System) to enable interactive, customized tutoring. Ultrasonic sensors are another popular choice for obstacle detection, particularly in environments where cost and simplicity are critical factors. There are a number of challenges in using technology to support education. Using a social robot adds to this set of challenges because of the robot's presence in the social and physical environment and because of the expectations the robot creates in the user. The social element of the interaction is especially difficult to automate: Although robot tutors can operate autonomously in restricted contexts, fully autonomous social tutoring behavior in unconstrained environments remains exclusive. Robot tutors should be able to not only correctly interpret the user's responses to the educational content offered but also interpret the rapid and nuanced social cues that indicate task engagement, and attention.

Robots can also be peers or learning companions for humans. Not only does a peer have the potential of being less intimidating than a tutor or teacher, peer-to-peer interactions can have significant advantages over tutor-to-student interactions. Robovie was the first fully autonomous robot to be introduced into an elementary school. It was an English-speaking robot targeting two grades (first and sixth) of Japanese children. Through field trials conducted over 2 weeks, improvements in English language skills were observed in some children. In one case, longer periods of attention on learning tasks, faster responses, and more accurate responses were shown with a peer robot compared with an identical-looking tutor robot. A long-term primary school study showed that a peer-like humanoid robot able to personalize the interaction could increase child learning of subjects. Often, the robot is presented as a more knowledgeable peer, guiding the student along a learning trajectory that is neither too easy nor too challenging. However, the role of those robots sometimes becomes ambiguous (tutor versus peer), and it is difficult to place one above the other in general. Learning companions , which offer motivational support but otherwise are tutoring, are also successful cases of a peer-like robot.

International Journal for Innovative Engineering and Management Research
PEER REVIEWED OPEN ACCESS INTERNATIONAL JOURNAL
www.ijiemr.org

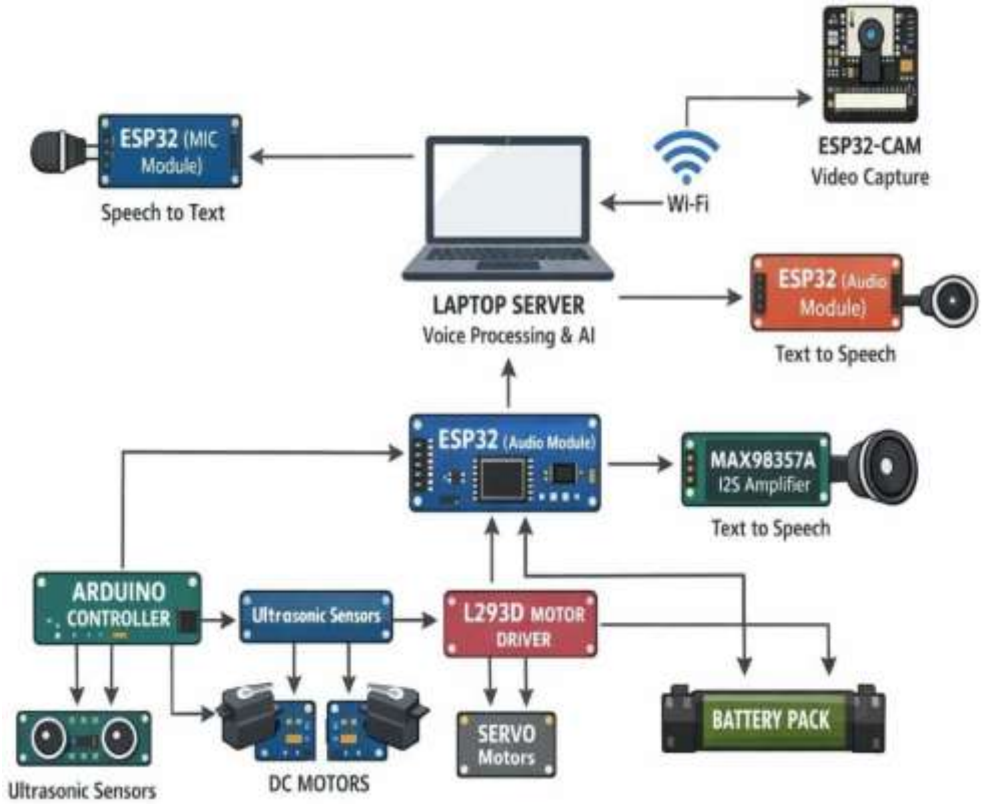


Fig2: illustrate the overall architeture of the humanoid robot for children education using embedded system & IOT

## A. Hardware Components

The ESP32-CAM integrates an ESP32 microcontroller with an OV2640 camera sensor. It supports video resolutions up to 1600×1200 pixels; however, a resolution of 640×480 pixels is selected in this project to balance detection accuracy, processing speed, and memory limitations.

The Arduino Uno, based on the ATmega328P microcontroller, acts as the central processing and control unit.

The ultrasonic sensor provides proximity-based object detection. It emits ultrasonic pulses and calculates object distance using echo return time. The detection range typically varies between 2 cm and 400 cm.

The servo motor provides physical visualization of tracking movement. It rotates between 0° and 180° using PWM signals generated by the Arduino. The servo aligns toward the detected object direction.

### B. Software Components

The software components for a humanoid robot, based on the provided system diagram, would primarily involve functionalities for interaction and processing. These include Speech to Text for converting spoken language into commands or data, Voice Processing & AI for interpreting the input and making decisions, and Text to Speech for generating audible responses. These components allow the robot to listen, think, and speak, which are essential for educational interaction with children. The system also incorporates Video Capture capabilities, which, while linked to specific hardware (ESP32-CAM), implies software for processing visual information to enhance interaction and environmental aware

Based on the system diagram, the software architecture for this educational humanoid robot is a distributed system that balances local control with high-level AI processing. High-Level Processing & AI: A laptop server acts as the primary processing unit. It runs software for Voice Processing & AI. This includes Speech-to-Text (STT) to transcribe speech, a conversational AI model to generate educational responses, and Text-to-Speech (TTS) for the robot's voice. The server also handles Video Capture processing from the ESP32-CAM via Wi-Fi. It potentially uses libraries like OpenCV for face or object recognition to make the interaction more engaging.

Communication & Middleware: The system uses Wi-Fi to connect the laptop server and the robot's hardware. Software on the ESP32 modules manages wireless data exchange to transmit voice commands and video feeds in real-time.

Low-Level Control & Hardware Interfacing: Microcontrollers (ESP32 and Arduino) at the robot's physical layer run embedded code to manage hardware directly. An Arduino controller executes logic for Ultrasonic Sensors to avoid obstacles. It also commands the L293D Motor Driver to control DC and servo motors for movement. Dedicated ESP32 modules handle audio input and output. One captures sound via a microphone and another converts digital signals into audible speech through an I2S Amplifier.

## 2.1. IMPLEMENTATION METHODOLOGY

### A. Hardware Integration

The proposed framework requires a multidisciplinary and multiple-methods approach that will include applied, qualitative and quantitative aspects. Whilst respecting the integrity of the different paradigms, we propose the utilization of different ways of knowing to expand our understanding of the potential ways in which humanoid robots can be used in Smart Learning Environments to promote student learn quickly. With such a research design, we can expand the scope of our understanding as different methods will be used to assess different aspects of the phenomenon. By combining qualitative and quantitative aspects in our evaluation of humanoid robots in the Smart Learning Environment, we incorporate both subjective experiences and objective observations. In this point out method/ Algorithm.

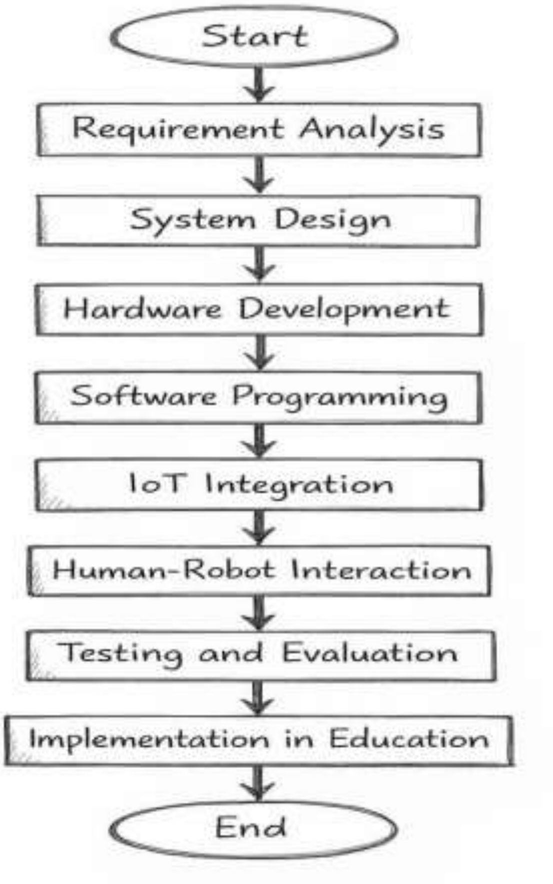


Fig3: Flow Chart of Humanoid Robot

## B. Methodological Implications (step by step formation):

Step-by-Step Methodology

**Step 1: Requirement Analysis:**

First, the requirements of the educational robot are identified. The robot should be able to interact with children, explain lessons, and respond to commands. Educational content such as alphabets, numbers, and simple questions is prepared.

**Step 2: System Design**

In this step, the overall system architecture is designed. Hardware components like microcontroller, sensors, motors, speaker, and display are selected. Communication between the embedded system and IoT platform is planned.

**Step 3: Hardware Development**

All hardware components are assembled. The microcontroller (embedded system) is connected with sensors, servo motors for movement, microphone for voice input, and speaker for audio output.

**Step 4: Software Programming**

Programs are written in the microcontroller to control robot movements, speech output, and interaction with children. Educational content and responses are stored in the system.

**Step 5: IoT Integration**

The robot is connected to the internet using IoT modules (such as Wi-Fi). Through IoT, the robot can access online learning materials, update lessons, and store student interaction data.

**Step 6: Human-Robot Interaction**

The robot communicates with children using voice, gestures, and display. It can ask questions, provide answers, and guide children through learning activities.

**Step 7: Testing and Evaluation**

The system is tested to check movement, communication, and learning performance. Errors are corrected and improvements are made for better educational interaction.

**Step 8: Final Implementation:**

After testing, the humanoid robot is implemented in the learning environment such as classrooms or home learning setups.

| **Parameter** | **Traditional Teaching Method** | **Educational Software** | **Humanoid Robot Using Embedded and Iot** |
|---|---|---|---|
| Teaching style | Teacher explains using board, books, and notes | Interactive lessons through multimedia and animations | Robot explains lessons using voice, gestures, and movements |
| Student Engagement | Moderate engagement depending on teacher interaction and communication | High engagement using videos, quizzes, and games | Very high engagement through robot interaction and communication |
| Personalization | Limited personalization for students | Some adaptive learning algorithms | High personalization using sensors and IoT data analysis |
| Interaction Level | Mostly one-way communication | Two-way interaction via touch or keyboard | Multi-modal interaction (voice, gestures, sensors) |

| | | | |
|---|---|---|---|
| Practical Demonstration | Limited demonstration due to time/resources | Virtual simulations on screen | Real-time demonstrations using robot movements and actions |
| Accessibility | Only available in classroom | Available on mobile phones or computers | Accessible through robot and IoT remote monitoring |
| Learning Motivation | Moderate | High for short duration | Very high due to humanoid interaction |
| Monitoring & Feedback | Teacher manually checks progress | Automatic quiz feedback and progress reports | Real-time monitoring using IoT dashboards and analytics |
| Technology Integration | Low technology integration | Medium technology usage | High technology (Embedded systems, sensors, IOT connectivity) |
| Future Scalability | Limited improvement | Scalable with software updates | Highly scalable with IoT updates and AI integration |

Table 4.1: Confirmation Table On Proposed System Of Humanoid Robot For Children Education.

## 2.1.1. RESULTS AND DISCUSSION

Although an increasing number of studies confirm the promise of social robots for education and tutoring, this Review also lays bare a number of challenges for the field. Robots for learning, and social robotics in general, require a tightly integrated endeavor. Introducing these technologies into educational practice involves solving technical challenges and changing educational practice. With regard to the technical challenges, building a fluent and contingent interaction between social robots and learners requires the seamless integration of a range of processes in artificial intelligence and robotics. Starting with the input to the system, the robot needs a sufficiently correct interpretation of the social environment for it respond appropriately.

Several studies explore how humanoid robots play a role as a tutor. It is said to be the most promising and pragmatic role for educational robot. As a tutor, the robot supports the learning of a single learner or a small group of students. In the literature, Kanda et al. (2004) used Robovie robots as English peer tutors for Japanese students. The robots successfully encourage some students to improve their English. Similarly, Lei and Rau (2021) and Vogt et al. (2019) adopted NAO robots as private tutors. that a robot can take on the role of an instructor and involve at various levels in the learning task. It can also take a passive role as a teaching aid or participate actively as a co-learner, peer or companion.

Participants also showed body movements while interacting with the robot. Children showed communicative body gestures in front of the robot. They leaned toward the robot to answer questions, and all children grabbed its hand when the robot required a physical touch to continue. During error situations and idle time, children were often distracted, but they never walked away from the robot and returned immediately when the interaction resumed again.

| Response Time (Seconds) | Content Rate Size(%) |
|---|---|
| 1.2 s | 70% |
| 1.0 s | 75% |
| 0.9 s | 80% |
| 0.8 s | 85% |
| 0.7 s | 90% |
| 0.6 s | 93% |
| 0.5 s | 95% |

Table 5.1: Discussion Table Of Humanoid Robot

## 3. Application

Th The most common applications of humanoid robots are in manufacturing and logistics (warehouse material handling, assembly line support), healthcare (patient interaction, rehabilitation), education (STEM teaching, tutoring), retail (customer service, product demonstration), and entertainment. Manufacturing and logistics dominate commercial deployments, accounting for the majority of the estimated 16,000 units installed globally in 2025.

Humanoid robots in healthcare perform hospital logistics (delivering supplies and medications), patient engagement (companionship, cognitive exercises), physical rehabilitation coaching, and telemedicine support. Robots like Moxi reduce nurse walking time by up to 30%, while Pepper provides cognitive stimulation for dementia patients in over 2,000 healthcare facilities.

As well as power sources, one of the main concerns for humanoid robots is energy-efficiency. Although they are an order of magnitude lighter and smaller, they can generate the same force as robot motors. Before real-world applications, experiments that include results from simulated and physical humanoid robots should be conducted.

Expected that humanoid robots provide user-friendly programming interfaces so that they make it easy for teachers and students to learn and play with them. Hence, they need to be equipped with a set of versatile educational kits to make their users be able to work with them without high programming complexity and experience.

Although some humanoid robots are easy to be programmed, most of them fail to provide versatile programming tools. Research studies show that a humanoid robot is a great learning tool and students are very enthusiastic about it and enjoy the human-like interaction in the classroom. Nevertheless, the students wanted the humanoid robot to adapt its behaviour to their feelings and display a broad range of emotions and expressions

is project has introduced an IoT-based Smart Water Monitoring System that involves multi-parameter sensing, processing on ESP32 and cloud analytics. The system not only monitors the quality of water and the amount used but also has a built-in protection system to avoid supply of contaminated water.

The scalable and modular architecture can be deployed in both small-scale, in individual households, and large-scale, in larger distribution networks. The improvement opportunities in the future could be the inclusion of pH sensors, machine learning-based anomaly detection, and remote installations with renewable energy as the power source.

## 4. Conclusion

This paper has proposed a framework that addresses an under-researched and not well-understood aspect of humanoid robots. Rapid technological progress in robots needs to be balanced with a holistic approach to research that attempts to support human adaptation in rapidly changing socio-technical system dynamics. With such a multidisciplinary framework, we offer the possibility to move beyond extending the technical possibilities to evaluating how technological advancements can be used in an ethical way to benefit individuals and society through education.

In particular, the multidisciplinary framework presented here integrates the technological, pedagogical, psycho-social and ethical aspects of HRI. Further, this paper has presented a possible way to apply and evaluate the framework, methodologically, along with an example of a case study.

It is hoped that readers will be inspired to adopt this interdisciplinary framework as their starting point for research into how humanoid robots can be used effectively in SLEs and contribute to the development of the research base within this field. Although this study includes concrete suggestions regarding the application and evaluation of the proposed interdisciplinary framework along with a case study describing its application in a real setting with a focus on learning mathematical and programming.

Although humanoid robots are currently very far away from being autonomously situated in pre- primary and primary schools because of technological limitations such as emotion recognition and inaccurate speech, they can be used in classrooms as learning tools since they have the ability to provide real-time feedback to students. On the other hand, while humanoid robots are increasingly being used to teach students in the classroom setting for a number of subjects across language, mathematics and science, students enjoy learning with them, but teachers are a bit reluctant at first to use them in the classroom setting because appropriate interfacing mechanisms that allow the teachers to control the humanoid robots with minimal training which is needed in order to facilitate the easy integration of the humanoid robots in the classroom setting. In fact, the intention of most researchers in the robotics field is not for robots to replace teachers. Instead, the design goals of most humanoid robots are to function as an aid in the classroom setting and to increase the benefit they can bring as a stimulating and engaging educational tool. Humanoid robots may have a great impact on the way the students learn and make the teachers' lesson plans much more motivating. Cognitive, conceptual, language and social skills are the major areas that humanoid robots can influence the development of children's skills.

## Acknowledgements

Dr. Shaik BajidVali provided overall guidance, supervision, and technical direction for the project and reviewing the methodology and manuscript. C.V. Sai Sree Harini carried out the system design, implementation, experimentation, and manuscript preparation. V. Nanditha assisted with model integration, testing, and result analysis. M. Abbasi Begum and S. Lava Kumar Reddy contributed to literature review, documentation, and formatting. V. Hemanth Kumar overall support hardware setup, data collection, and experimental validation.

## Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this project.

## References

[1]. Sharkey, A. J. (2016). Should we welcome robot teachers? Ethics and Information Technology, 18(4), 283–297.

[2]. Bargagna, Stefania, et al. "Educational robotics in down syndrome: a feasibility study." Technology, knowledge and learning 24 (2019): 315-323. https://doi.org/10.1007/s10758-018-9366-z

[3] Alimisis, Dimitris. "Educational robotics: Open questions and new challenges." Themes in Science and Technology Education 6.1 (2013): 63-71.

[4] Zawieska, Karolina, and Brian R. Duffy. "The social construction of creativity in educational robotics." Progress in Automation, Robotics and Measuring Techniques: Volume 2 Robotics. Springer International Publishing, 2015

[5]. Pennisi, Paola, et al. "Autism and social robotics: A systematic review." Autism Research 9.2 (2016): 165-183. https://doi.org/10.1002/aur.1527

[6]. Robins, Ben, et al. "Scenarios of robot-assisted play for children with cognitive and physical disabilities." Interaction Studies 13.2 (2012): 189-234.

https://doi.org/10.1075/is.13.2.03rob

[7]. Conchinha, Cristina, Patrícia Osório, and João Correia de Freitas. "Playful learning: Educational robotics applied to students with learning disabilities." 2015 International

symposium on computers in education (SIIE). IEEE, 2015. https://doi.org/10.1109/SIIE.2015.7451669

[8]. Xia, Liying, and Baichang Zhong. "A systematic review on teaching and learning robotics content knowledge in K-12." Computers & Education 127 (2018): 267-282. https://doi.org/10.1016/j.compedu.2018.09.007