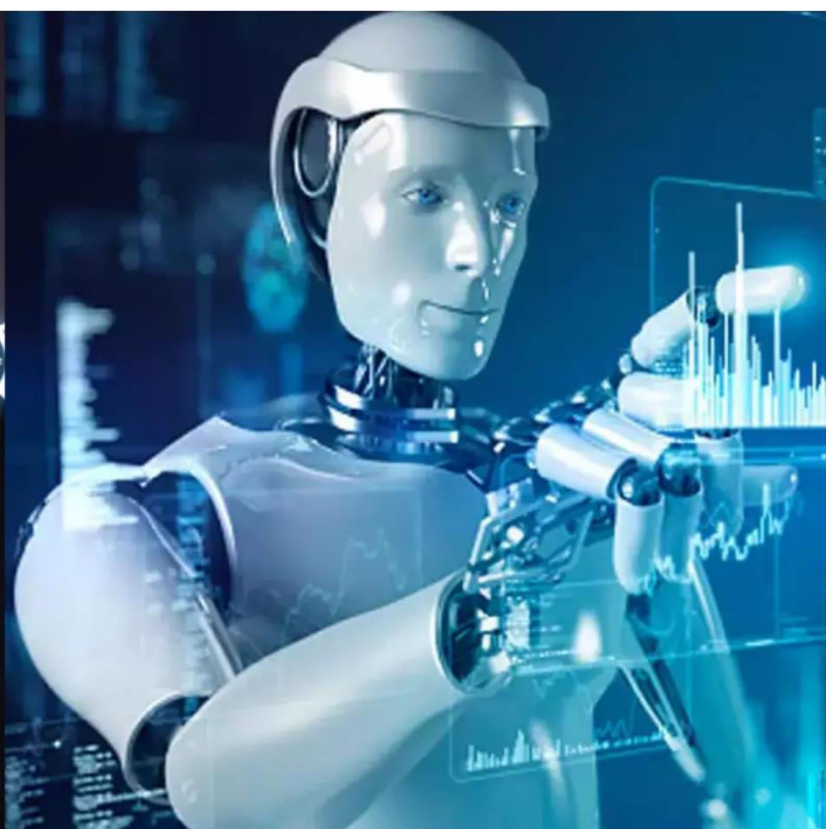




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AIM: The Role of Humanoid Robots in Science Education: Examining Their Impact on Student Learning Experiences

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ABSTRACT: Humanoid robots are emerging as new, innovative, and vital tools in science education, enhancing student comprehension skills through special interactive teaching, personalized settings, and inquiry-based learning. Their human-like qualities and demonstration abilities contribute to enhancing student interactions, motivation, conceptual learning, and academic performance. They also provide support for laboratory activities and promote collaboration through effective human-robot interaction. Yet technical limitations, high costs, teaching restrictions, and ethical issues can promote their implementation. Overall, humanoid robots have significant potential to enrich and improve science education when used as supportive tools alongside teachers.

KEYWORDS: Humanoid Robots, Science Education, Student Learning Experiences, Student Engagement, Student Motivation, Academic Performance, Inquiry-Based Learning, Human-Robot Interaction, Educational Technology.

I. INTRODUCTION

The integration of advanced technology and education has evolved significantly over the past decade, resulting in the transformation of teaching and learning experiences. Science, technology, engineering, and mathematics are some of the concepts taught through humanoid robots. Humanoid robots have generated a lot of attention because of their capability to communicate with students by talking and gesturing, as well as by facial expressions and social behaviors. The best thing about humanoid robots compared to other traditional educational technologies is that they offer a greater level of interaction and engagement for students in smart classrooms. These robots can now be trained to behave like humans, and this means that they can conduct themselves in a manner that varies from traditional teaching.

Science education is commonly full of complex ideas that tend to be hard to grasp and must be appropriately visualised, experimented with and actively learnt. This is a setback amongst teachers across the world. The solution to this is the need for researchers to focus on the implementation of humanoid robots as teaching aids, personal tutors, investigators, and beyond. They will be able to demonstrate and clarify the doubts of pupils,

Engage more in interactive learning and support activities to provide students with a learning ecosystem that is more student-centered. Even past studies have depicted positive outlooks associated with the use of humanoid robots in the educational world, including better student motivation, improved classroom participation, better visualisation, enhanced problem-solving skills, and greater interest in science, technology, engineering, and mathematics (STEM) subjects. Despite the potential benefits, there are technical issues with effectiveness, affordability, cost, accessibility, and long-term educational impact.

This study is about looking at how humanoid robots can be used in science classrooms and what effect they have on the way students comprehend. The study wants you to find out how the use of humanoid robots makes students more interested and excited about science, and how they help students comprehend science better. It also examines how students talk to others in class when humanoid robots are present. Also, looking at the things that result in problems that come with using humanoid robots, this study hopes to help people understand how to use them in a way that really works for teaching science. The goal is to help the area of robotics grow and to give teachers some advice on how to use humanoid robots in their science classrooms.

This study will help the educational world make rules to make choices about using robots to help kids learn science in a way that is more interesting and often amazing. The results of this research will help educators, educational institutions, and policymakers to make decisions about using humanoid robotic technologies to support innovative and effective science learning environments.

Body

1. Humanoid robot in education

Nowadays, many types of robots are used in the education industry, ranging from simple models to complex models. The choice of a variety of robots to use is widely dependent on the age group of students. Simple robots are used in robotics education, while complex humanoid robots are used in smart classrooms to interact and often teach a wide range of subjects from science to mathematics.

As shown in Figure 1, humanoid robots have the ability to provide real-time information due to their resemblance to human-like features, and their engagement with humans is easy and efficient. They are embedded with social sense, and well programmed to emote facial expressions and gestures along with appropriate body language. They can show all types of emotion, such as anger, happiness, surprise, crying, fear, and disgust.

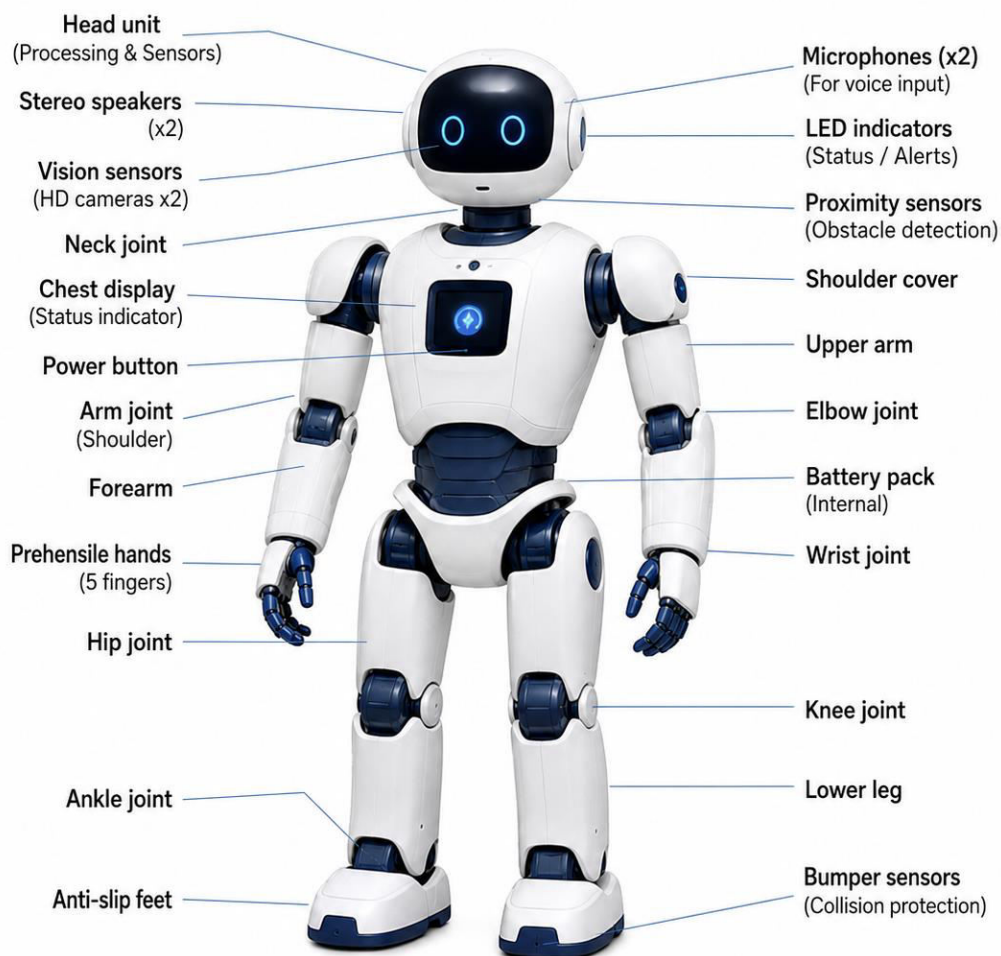


Figure.1. Humanoid robot

Studies have shown that humanoid robots can perform various educational roles in the classroom setting. They can work as teachers, teaching assistants, students' companions, and presenters. Unlike conventional computers, they do not lack a physical connection. They can support students through both verbal and non-verbal communications due to their human-like design. Traditional teaching methods often lead to a reduction in students' interest, especially in the case of complex concepts, which is often overcome by humanoid robots, as they are more engaging and interactive, leading to improved student interaction and motivation. This is often accompanied by quizzes, demonstrations, and personal feedback. Such studies often lead to the development of a child's brain to think more critically and analytically.

Humanoid robots can help to resolve problems of teachers, such as shyness, frustration, personal issues, or grudges with students, and result in better confidence and improvement of students. One of the major advantages of humanoid robots is that they do not get tired or frustrated with the number of mistakes a student makes. Humanoid robots provide an immediate response, which leads to instant resolution of doubts and saves much time.

Every child learns at a different pace depending on their understanding. Humanoid robots can adapt according to individuals by changing their content, providing detailed explanations and additional exercises. This can improve student performance and help in overcoming educational difficulties effectively. In special settings, humanoid robots can be used to provide special educational treatments to students with special needs, including students suffering from autism spectrum disorder.

II. APPLICATIONS OF HUMANOID ROBOTS IN SCIENCE EDUCATION

2.1 Teaching Scientific Concepts

Humanoid robots have been playing an important role in teaching advanced scientific concepts by making the lessons more interactive for students. The traditional science teaching method usually depends on textbooks and lectures, which in this case might not capture the interest of the student and make learning enjoyable, resulting in less interest in the complex and advanced subjects. The limitations of humanoid robots is through the use of words, movements, and demonstrations to make complex scientific concepts simpler. The application of science through the use of images in teaching students science-based concepts to facilitate their comprehension of difficult concepts is supported by my psychology.

A significant advantage of these humanoid robots is that they make use of real-time visual demonstrations. An example of such a complex concept is the explanation of complex concepts like gravity, sound waves, electricity, energy, etc., by the body movements and visualization done by the robot. Instead of relying on traditional sources of knowledge, students can often rely on a humanoid robot performing basic human operations, enabling them to understand the elementary principles of physics through practical performance. This enhances the learning of basic ideas and enables the students to relate learning in the classroom to real life. Humanoid robots are experiential and multimodal sources of learning that combine the lessons in school with visual demonstrations, leading to practical learning of different multifaceted results. Robots are able to show diagrams, carry out experiments and answer questions of students in real time.

Their ability to integrate technology and instruction enhances the interest of students studying STEM courses and builds analytical and problem-solving skills. They are even able to deliver individualized instructions, as humanoid robots have artificial intelligence which can tailor their explanations to the level of perception of that specific student. If a student finds a certain concept difficult to grasp, the robot can proceed to expound the same concept using plain and simplified language, in addition to other more relatable and realistic examples. This individualized learning enhances understanding and retention of scientific knowledge.

2.2 Laboratory Support

Humanoid robots will help make the science laboratory use much easier and more interactive in assisting students and teachers in their practical experiment. Science laboratories play a significant role in refining skills of experiments and understanding scientific concepts by engaging in practical activities. Nevertheless, laboratory sessions typically incorporate those circumstances that regard safety concerns, little direction, and strictness in executing and handling laboratory operations. Humanoid robots can provide help in handling these challenges by providing guidance, monitoring activities, and contributing to experimental procedures.

Among the key function of humanoid robots in the laboratories is to help perform demonstrations of physical experiments. The precision in executing the steps in a robot enables the students to learn the proper ways before the actual execution of the experiments themselves. This minimizes the chances of mistakes and helps the students to better understand the experimental methods. Laboratory safety and precautions have also been enhanced by humanoid robots. In the laboratories of chemistry and physics, some experiments can be carried out on the chemicals that are harmful to our health, at high temperatures, or on very sensitive equipment, which should be handled carefully. Robots will be able to perform rather risky operations and decrease the possibilities of accidents, providing the students with less exposure to danger and keeping the experiment safe. Students can also be reminded about safety protocols and proper lab practice with their help. The other important task carried out by humanoid robots is real-time guidance and feedback. Students might be challenged with procedural following or obtaining precise results during the laboratory activities. A robot, equipped with various kinds of sensors and artificial intelligence, can respond to inquiries, provide guidance, and assist in recognizing frequent errors. This instantaneous help boosts the confidence of students and builds up independent learning.

In addition, humanoid robots are also used to gather and record data by using experiments, which are more accurate. They are able to examine measurements and make accurate observations, minimizing the possibility of error by humans and enhancing experimental reliability. Such support enables students to focus more on the interpretation of the findings and the conceptual learning of science.

Additionally, humanoid robots can also help in providing students with virtual or simulated laboratory experiences, even if the physical resources are limited. By using interactive demonstrations and simulations, students can experience scientific experiments that might be too costly, difficult, or unsafe to carry out in a typical school laboratory.

Overall, these robots have proved to serve as a significant and valuable laboratory assistant that has improved the safety, accuracy, and learning efficiency of students. Since they facilitate practical demonstrations and individualized examples, they help create a more efficient and productive science learning atmosphere.

2.3 Inquiry-Based Learning

For years, differences have been highlighted between inquiry-based learning and traditional learning by teachers, but the reality is that they are on a continuum. Traditional institutions focus on instruction-based mechanisms, where teachers deliver knowledge in the form of lectures, assignments, and supervised demonstrations. But inquiry-based learning is a bit different in that a student learns concepts, asking questions, performing experiments, failing, and trying again and again, unlike passive retrieval of knowledge. This learning leads to better conceptual understanding, deep-rooted motivation, and stronger thinking skills. This is vital in this world as it works on the basis that solutions to the problems are not predefined.

In science education, inquiry-based learning helps students develop critical thinking, problem-solving, and storytelling. Humanoid robots have been developed as an emerging tool to effectively support inquiry-based learning. Their human-like features help them to act as a facilitator, guide, and learning companion in science education. They possess the ability to ask questions, encourage them to formulate hypotheses, and assist them in performing experiments. Robots provide an interactive platform that indeed helps students explore new scientific concepts rather than depending on the information delivered by teachers. One major benefit of humanoid robots is that they help increase student engagement and motivation. Their interactive and social nature results in active participation of students in the learning process. Often, students assume that humanoid robots are less judgmental and more friendly; therefore, they accept them as a learning companion. This results in a reduction of anxiety and increased confidence in students. Humanoid robots can provide hints and clues instead of providing a direct answer, which could help students think and gain a deep conceptual understanding of the real cause of the problem, and develop their thinking instead of direct spoon-feeding. Furthermore, humanoid robots provide instant feedback and personalised support during the learning process. They can assign a task, react to student responses, and identify misconceptions. Personalised learning can help them understand their problems and work on them at their own pace. By creating an interactive and encouraging educational environment, humanoid robots are improving inquiry skills, scientific approach, and overall learning outcomes. As advancements in the educational humanoid robot industry increase, it is expected that the role of humanoid robots will increase in transforming science education and teaching meaningful learning experiences.

III. IMPACT ON STUDENT ENGAGEMENT

Involvement of students is really a crucial factor in efficient conceptual understanding, as it affects students' attention, involvement, productivity, and overall academic performance. The usage of humanoid robots in the learning field, and specifically in the sciences, has revealed lots of promise in enhancing student engagement through an increased level of interaction in the learning process. Unlike the typical traditional teaching methods, which often rely on the study material present in the textbooks, humanoid robots involve students in the learning process through demonstrations and interactive activities.

Among the major ways that have helped these humanoid robots become more engaged is through students' interest in them. Their anthropomorphic appearance and their interaction ability arouse curiosity and interest among the students. Learners tend to be more attentive during classes where robots are involved, as the process of learning is stimulating and intriguing. This heightened concentration helps students concentrate on scientific concepts and classroom instruction. Active participation is also enhanced by humanoid robots. With these robots, students will find it easier to freely interact with them, by asking them their questions, responding to their prompts and discussing. This enhanced engagement can assist students who are one-sided listeners in becoming active learners, having direct participation in the learning process. These humanoids can assist in science courses where they can give quizzes, experiments, and problem-solving activities that require students to be able to think logically and to give their active participants.

Another aspect of this is that research has proposed the idea that students can easily find learning assisted by robots enjoyable and more advanced, which enhances their desire to learn. Humanoid robots are interactive and can make what seem to be complicated subjects of science seem not that hard. Due to this, students develop a positive attitude towards studying science and get more motivated to discover scientific phenomena and learn about them more easily. Humanoid robots are also used in interactive learning, and activities involving the use of robots in groups help students learn to collaborate and resolve problems through group work. This kind of cooperation assists not only in increasing the number of students engaged, but also in aiding in the development of communication skills and teamwork skills, both of which will be required in future professions in the STEM disciplines.

Overall, humanoid robots have a positive impact on student involvement by increasing their attention span, participation, and motivation. Their interactive and individualized strategy forms an interactive learning atmosphere where students engage in playing a leading role in learning science and the acquisition of good reasoning and scientific thinking.

IV. IMPACT ON STUDENT MOTIVATION

Students motivation is a critical element that influences outcomes, education levels, classroom dynamics, and perspectives towards study in the long term. Over the last few decades, humanoid robots have become novel educational tools that improve the motivation of students by engaging in their interactive, personalised and exciting lessons. Their human-like outlook allows students to engage in meaningful conversations, directly influencing their cognitive, emotional, and behavioral engagement and, in turn, improving motivation to learn new skills.

One of the most important features of a humanoid robot in improving student motivation is its ability to increase attention and curiosity. Their interesting appearance and behaviour naturally attract students' attention from the beginning of the lesson. This rise in curiosity helps students interact more actively during class and leads to greater participation in lectures. For example, in science education, humanoid robots can demonstrate experiments, engage students in problem-solving activities, interact with them, and make learning more attractive than traditional methods, which are often boring.

Often, motivation is linked with positive emotions like enjoyment, excitement, confidence, and satisfaction. Humanoid robots create a supportive environment through verbal communication, gestures, and interactive actions. Nowadays, children consider humanoid robots less judgmental, which leads to less stress and anxiety. They are more comfortable with a humanoid robot than with teachers and peers. So, as a result, their confidence and willingness to interact with others increase. Nowadays, the immediate response feature has a significant impact on student motivation as it allows them to track their mistakes and identify their areas for improvement. When students are constantly mocked by teachers and family members, they often believe that they are unwilling to do that particular task; on the other hand, when robots provide timely support, they feel motivated and enthusiastically look forward to that particular task or

assignment. This personalised support and help often feel like a sense of competence, which is a key part of the motivational journey. They promote internal motivation, which makes the task more enjoyable and interesting. Traditional methods include listening to boring lectures, completing lengthy assignments, and often involve passive learning. Whereas robots provide active learning in which students study through interaction, demonstration, exploration, storytelling, educational games, and hands-on activities. These experiences encourage students to learn new things, explore, and develop something valuable rather than solely focusing on academic scores and rewards. As a result, they develop a deep understanding, and learning is more self-motivated. They stimulate critical thinking and a sense of exploration. When students constantly interact and participate in new brainstorming activities, it results in a greater sense of satisfaction and motivates them to redo that activity. Their engagement often leads to a stronger understanding of the technical fields. They often help to maintain interest in a particular topic over time. The effectiveness of humanoid robots on student motivation often depends on several factors, such as robot design, instructional strategy, teacher support, and classroom context. Therefore, they can be a companion to teachers in the educational industry. They cannot replace teachers completely because there are experiences that a teacher can share that can not be done by a humanoid robot. They do not have that emotional connection.

V. IMPACT ON ACADEMIC PERFORMANCE

Humanoid robots have emerged as a promising educational tool with significant potential to improve academic results in different learning settings. Their impact is spread across technological skills and influencing people. As artificial intelligence and technological advancement have increased, humanoid robots have been working as tutors, teaching assistants, doubt solvers, and collaborative learning partners. The most basic way in which humanoid robots support an increase in academic performance is by increasing student engagement and attention. Traditional teaching often involves student interaction and attention in subjects that include abstract concepts, which are overcome by humanoid robots because they create a dynamic learning environment.

In educational settings, humanoid robots act as personalised teaching assistants; they can simplify complex concepts, answer questions, clear doubts, provide feedback, and correct students' mistakes when necessary. Their interesting appearance and attractive behaviour help students to easily engage themselves in a learning environment, which indeed improves focused study and understanding of complex concepts. Robots have a special ability to adapt themselves according to students' understanding and learning pace. These help students to improve with additional support at their own pace, resulting in academic advancement. Moreover, they can provide an immediate response, which often reduces learning gaps and results in better comprehension. Humanoid robots have the capacity to respond instantly and provide correct guidance immediately without delays. Students have accepted robots as their study companions in comparison to other technological advancements, resulting in greater participation, involvement, and attention during learning lessons. These are directly proportional to increased attention, better knowledge retention, and academic achievement. Unlike traditional teaching, which often faces challenges in addressing students' needs, robots can overcome this challenge with the use of artificial intelligence, as AI can generate personalised outcomes leading to a better understanding of their problems. In science education, especially in inquiry-based learning, they play a crucial role in promoting active learning. They deliver knowledge in the form of questioning, hypothesizing, and concluding. They allow students to engage with scientific concepts independently, resulting in a deep and clear understanding of complex concepts, which are often difficult to comprehend. Their higher-order cognitive skills are particularly important predictors of academic success, especially in STEM (Science, Technology, Engineering, and Mathematics). The social and emotional expertise of a humanoid robot results in the strengthening of academic performance. Generally, particularly young learners, face problems like fear, lack of experience, underconfidence, and being afraid of public speaking when they are interacting with teachers, professors, and peers. In this case, humanoid robots create a comfortable environment where they can enthusiastically interact. Moreover, they praise students and increase student motivation. Often, they provide additional information to maintain a trend of curiosity among students. Overall, humanoid robots have a positive influence on academic performance by increasing student engagement, supporting personalized learning, fostering active participation, and improving student motivation across the educational industry.

VI. HUMAN-ROBOT INTERACTION (HRI)

Human-Robot Interaction means the communication and collaboration between us humans and these robots. In the educational sector, HRI plays an important role in determining the benefits of humanoid robots as a tool in learning. The type of interaction between humans and humanoid robots can affect the overall classroom experience, as these humanoid robots are made to represent human-like behaviour through actions and speech. One of the most outstanding effects of human-robot interaction in the science education sector is the advancement of effective communication between students and robots. These robots can give answers to questions, provide elaborate explanations, and give proper responses to verbal commands, which creates a 2 way interaction that supports interactive learning, which also helps clarify doubts at an instant and enhances participation during classroom activities.

Human-Robot Interaction also contributes to increasing student confidence, since a few students might feel some hesitation to ask about their queries in front of other students, mainly due to the fear of judgment or fear of making mistakes, but the interaction with robots often helps to reduce this anxiety, since for students, these robots are non-judgmental. As a result of this, students are more willing to get assistance and explore more advanced scientific concepts in depth. One more significant impact of these HR practices is that they help establish trust and a positive attitude towards technologies.

On top of that, these HRIs support collaborative learning by

Numerous robot-assisted tasks require cooperation, communication, and problem-solving. It is through these experiences that the students acquire enhanced communication skills and critical thinking skills that are significant in scientific investigation and training within the scientific field. These human-like characteristics of humanoid robots also create a sense of social presence. This also renders learning experiences more individualized and personalized, and this makes the students feel acknowledged. The HRI, however, relies on human behaviour being learned and responded to by the robot.

Altogether, the interaction of humanoid robots influences science education greatly, as it requires communication and cooperation. HRI can also provide a supportive learning environment through the effective implementation of these robots that enhance the learning experience of students.

VII. BENEFITS OF HUMANOID ROBOTS IN SCIENCE EDUCATION

Humanoid robots have a number of advantages in science education, including the ability to structure interactive, engaging, and learner-centered learning spaces. Their human-like appearance, have a sense of communication, and can carry out educational duties, which makes them a powerful tool in transforming the processes of teaching and learning.

Since educational institutes are increasingly integrating advanced technology with the classroom to create a digital classroom, humanoid robots are becoming less of a commodity and more of a valuable tool to improve the performance of science education and shape the spirit of the 21st century. Humanoid robots help in increasing student engagement and interactivity. They simplified complex science concepts and evoke a learner-driven learning context. Humanoid robots have been of great significance in supporting Inquiry-Based Learning (IBL), which is an education method that focuses on exploration, questioning, experimentation, and problem-solving.

This interactive guidance helps students develop scientific reasoning skills along with rational thinking while actively constructing valuable knowledge rather than passively receiving information. As a result, learners gain a deeper understanding of scientific concepts and complex processes. They can provide personalised outputs. They often simplify topics and lead to better conceptual understanding. They have a feature that provides an immediate response, helping people who lack patience. They help in the development of critical problem-solving skills. Increased collaboration and communication among peers result in reduced anxiety and stress, and help in better public speaking. They help in the better education of STEM and robotics. Also, they improve knowledge retention.

VIII. CHALLENGES AND LIMITATIONS

8.1 Technical Challenges

Despite the popularity of humanoid robots, there are multiple technical challenges that limit their effectiveness and acceptance. The most common concern is about the efficiency of their hardware and software. Humanoid robots are composed of a complex mechanism of sensors, cameras, microphones, and artificial intelligence algorithms to efficiently interact with students. Unexpected technical issues such as sensor inaccuracies, connectivity issues, software bugs, or mechanical failures can disrupt classroom activities and reduce learning effectiveness.

Another significant challenge is natural language processing and communication. Often, robots struggle with different accents, complex terminologies, and unexpected interactions. This struggle leads to incorrect responses and misconceptions in a particular topic for students. The results show a reduction in students' trust in the technology. Humanoid robots require certain technological infrastructure, which includes stable internet connectivity, sufficient power supply, regular software updates, and compatible classroom technology. Schools with limited technology face difficulties in the implementation of humanoid robots. Robots are not capable of dealing with several questions at once like a human teacher. They usually experience problems controlling classroom behavior. Additional concerns are maintenance and technical support. Calibration, troubleshooting, software maintenance, and hardware repairs are time-consuming issues. Schools might not have qualified staff to handle these technical requirements, leading to significant issues over time.

8.2 Financial Challenges

As the high cost of the humanoid robots is among the most significant challenges to their use in the science field, the acquisition of the humanoid robots takes considerably huge financial resources since they are endowed with high technology and modernities like AI, sensors, and cameras. Also, the schools will have to invest money in having a suitable software system and a reliable network connection.

Maintenance is another major expense, since these humanoid robots require software updates, battery replacements, and technical support so that the robots function effectively; hence, the schools may also need to provide training for teachers, which further adds to the overall cost of implementation. Financial limitations also weigh on world schools and education centres in developing locations, where the limited budget makes it challenging to make the robot system adjust to such locations. It results in unequal access to learning resources and increases the divide between resource-abundant schools and under-resourced schools.

Moreover, the robotics industry is evolving quite fast, and the systems that are currently being operated will be outdated in the near future, which will again result in further expensive upgrades or replacements. Because of this, a humanoid robot system has been shunned by many schools despite its advantages in education.

Overall, while humanoid robots do have the potential to provide improvements in the science education sector, their high maintenance and training costs remain a very significant barrier to implementation. Although these expenses may be minimized by means of government funding, alliances, and technological discoveries will be needed to make robot-assisted learning more easily accessible.

8.3 Educational Challenges

Even though humanoid robots help open new innovative possibilities in the field of science education, they have their limitations at some point, in the form of certain educational requirements. Most of the time, it takes expertise from technicians to use this type of sophisticated technology.

In some cases, students are more engrossed in the interaction with the robot instead of learning, and that is not the primary objective. The other issue that was frequently involved is the connection between robot-assisted activities and learning outcomes, as well as the educational standards. Humanoid robots should be programmed and designed so as to support certain instructional objectives, scientific topics, and pedagogical strategies. Unless there are some plans in the classroom activities, working with robots can become a frivolity instead of a significant and productive educational tool, and productive learning will be low. The role of humanoid robots can also be influenced by differences in the learning speed of students and their abilities. Although there might be those students who could find the robot-based teaching style to be interesting and encouraging, other students might be content with the conventional method of

teaching or experience significant difficulties in communication with technological devices. Consequently, teachers have to make sure that robot-based learning can support most of the needs of learners and lead to quality learning. Human teachers are able to tailor their explanations and emotions as well as change their approaches according to the understanding of students and classroom situations. In contrast, robots tend to work in pre-defined programming that could limit their capability to respond to unexpected and unfamiliar queries, misconceptions, or misinterpretations in complex learning situations.

8.4 Ethical Challenges

The application of humanoid robots in science education attracts numerous ethical issues that must be addressed. The issue of data privacy is one of the primary concerns, as most humanoid robots are equipped with cameras, speakers, and other types of sensors, which aid in communicating with students. This may also include collecting personal information, making it important that student data is stored safely and used responsibly. Another ethical issue is the chance that the students will become overly dependent on robots for learning. While robots can provide valuable educational support, they should provide help rather than replace teachers. Humanoid robots play a very important role in providing emotional support and social interactions that robots can obviously not fully replicate. Inclusiveness and accessibility also present ethical concerns, since humanoid robots are expensive, not all schools can afford them, which further leads to unequal access to advanced educational technologies. This may widen the educational gap further between well-funded and under-resourced education centers.

Additionally, there are a few concerns about prejudice in artificial intelligence. If the algorithm that is used by humanoid robots is not carefully designed, they may give inaccurate or prejudiced answers, which could affect the students' learning experiences. Overall, ethical challenges such as data privacy, overdependence on technology, and other issues must be addressed to ensure that the humanoid robots are used responsibly and with credibility in the science education sector.

IX. CONCLUSION

Humanoid robots have been coming out as a valuable tool in the science education sector, and have been offering quite unique and innovative ways to improve teaching and enhance the learning experience for students. Their ability to explain scientific concepts visually, making them more comprehensive and promoting student engagement, makes them an effective tool in the teaching field. Through interactive communication and Human Robot Interaction (HRI), these robots encourage active participation, collaboration, and the development of thinking and reasoning as well as problem-solving skills, thereby improving the overall learning experience.

Despite these advantages, the successful implementation of humanoid robots into the education sector is accompanied by a lot of challenges and hardships. The high maintenance and teacher training requirements, technical limitations and the data privacy and equitable access problems will be carefully considered. These issues highlight that humanoid robots cannot be regarded as replacements for teachers, but as a supportive educational tool to contribute to the teaching process.

With future advancements in artificial intelligence and robotics, humanoid robots will likely become more affordable and more accessible. They can change and transform science education with proper policies and constant research, which can make learning more inclusive and student-centered. Therefore, science education of the future is in the effective integration of human knowledge with robotic advancements to support training the students to meet the requirements of the fast-growing, technology-driven world.

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