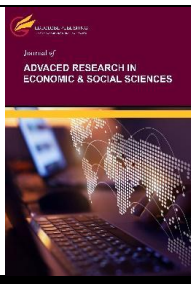
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Humanoid Robots in Education: Learning Outcomes, Engagement Models, and Acceptance Factors: A Systematic Review

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Abstract The rapid advancement of artificial intelligence (AI), robotics, and educational technologies has transformed the landscape of teaching and learning across global education systems. Among emerging innovations, humanoid robots, robots designed with human-like physical features and communicative behaviours, have attracted significant attention for their potential to act as social, cognitive, and pedagogical agents. This systematic review examined 39 empirical studies out of 954 studies after rigorous PRISMA guidelines to investigate how humanoid robots influence learning outcomes, learner engagement, and the acceptance and adoption of robotic technologies in education. Findings reveal that humanoid robots positively affect learning outcomes across academic, technical, and early childhood contexts, particularly when supported by adaptive cognitive and socio-emotional behaviours. Learner engagement, emotional, behavioural, cognitive, and social, emerges as a central mechanism linking robot interaction to improved learning, with personalization, expressivity, and interactive behaviours playing significant roles. Acceptance and adoption are shaped by pedagogical alignment, perceived usefulness, ease of use, technological reliability, ethical considerations, and institutional readiness. Synthesised within a conceptual framework, the results highlight that humanoid robots enhance learning most effectively when embedded in well-designed instructional environments and supported by trained educators and robust institutional structures. The review concludes that while humanoid robots hold strong potential to enrich educational experiences, their impact depends on thoughtful integration, contextual fit, and responsible governance. Limitations include variability in study designs, short-term implementations, and limited generalisability, underscoring the need for more longitudinal and ecologically valid research.

Keywords: Social Robotics, Human–Robot Interaction, Classroom Innovation, Technology Acceptance Models, Socio-Emotional Computing

1.0 Introduction

Advances in robotics and artificial intelligence are reshaping educational technologies and pedagogies, raising the possibility that physically embodied social agents, humanoid robots, may play an increasingly significant role in formal and informal learning environments. Unlike screen-based or purely software agents, humanoid robots can combine verbal communication with bodily gestures, gaze, motion, and proxemic behaviour, enabling face-to-face interactions that afford social, affective, and embodied learning cues (Belpaeme et al., 2018). This embodied social capacity has motivated researchers and practitioners to investigate humanoid robots as tutors, peers, classroom assistants, and mediators of engagement across age groups and subjects (Belpaeme et al., 2018; Donnermann et al., 2022). Empirical evidence suggests humanoid robots can influence multiple indicators of educational value. Several field and experimental studies report measurable gains in academic outcomes, including vocabulary acquisition, second-language learning, and domain-specific conceptual understanding, when robots are used as adaptive tutors or interactive companions (Ahmad et al., 2019; Konijn et al., 2022; Donnermann et al., 2022). For pre-school and early primary learners, humanoid platforms such as NAO have been shown to promote participation, joint attention, and gains in early literacy when robot behaviours are personalized to children's attentional and performance cues (Almousa & Alghowinem, 2022; Crompton et al., 2018). In STEM and technical learning, robots have also been used to concretize abstract concepts and facilitate active-learning sequences that improve robots scaffold problem solving, ask probing questions, and support metacognitive reflection (Donnermann et al., 2022; van Straten et al., 2022).

Social engagement appears robustly enhanced in many contexts as learners treat humanoid robots as conversational partners or peers, with implications for collaborative learning and classroom dynamics (Crompton et al., 2018; Neumann et al., 2023). Despite promising outcomes, adoption of humanoid robots in real classrooms depends on more than pedagogical promise. Teacher perceptions, institutional readiness, ethical concerns, and technological reliability are decisive factors that shape acceptance and sustained integration (Chalmers et al., 2022; Serholt et al., 2017). Teachers' willingness to adopt robots increases when they perceive a clear pedagogical fit and when training, co-design or long-term exposure demystifies the robot's role in instruction (Chalmers et al., 2022; Donnermann et al., 2022).

At the institutional level, cost, scalability, infrastructure, and policy considerations (privacy, safety, responsibility) influence decisions about deployment (Smakman et al., 2021; Serholt et al., 2017).Two broad methodological patterns temper the enthusiasm for robot-based interventions. First, many studies use small samples, short-term interventions, and laboratory or tightly controlled field settings, which constrain generalisability to diverse classrooms and longer timescales (Belpaeme et al., 2018; Woo et al., 2021). Second, the heterogeneity of designs, outcome measures, and robot behaviours complicates cross-study synthesis: learning gains are often task-specific, and the presence of novelty and short-term motivational effects is difficult to disentangle from durable learning improvements (Konijn et al., 2022; Belpaeme et al., 2018). Reviews and longitudinal field work, therefore, call for larger, ecologically valid studies that examine not only immediate achievement but also sustained learning trajectories, skill transfer, teacher workload, and ethical implications (Belpaeme et al., 2018; Chalmers et al., 2022). Given this landscape, there is a need for a focused synthesis that simultaneously examines three interrelated domains: learning outcomes, multidimensional engagement, and acceptance/adoption factors. Existing reviews document the promise of social robots and outline technical, pedagogical, and ethical challenges (Belpaeme et al., 2018; Woo et al., 2021; Smakman et al., 2021), but few syntheses centre concurrently on (a) empirical evidence for learning outcomes across age groups and subject areas, (b) the mechanisms of engagement captured as emotional, behavioural, cognitive, and social processes, and (c) the socio-technical determinants of acceptance by teachers, learners, and institutions. Addressing these linked questions is essential for theory development and for guiding practitioners toward responsible, effective deployments. This systematic review, therefore, asks three research questions: (RQ1) What is the evidence on the impact of humanoid robots on learning outcomes in educational settings? (RQ2) How do humanoid robots affect different dimensions of learner engagement (emotional, behavioural, cognitive, social)? and (RQ3) What factors influence the acceptance and adoption of humanoid robots by teachers, students, and institutions? By synthesising findings from empirical studies and field deployments, this review aims to clarify how robot behaviours and pedagogical designs interact with engagement processes to produce measurable learning effects, and to identify the technological, pedagogical, and ethical conditions necessary for sustainable adoption.

2.0 Methodology

2.1 Review Design and Justification

This study adopted a Systematic Literature Review (SLR) to synthesise empirical and conceptual evidence on the use of humanoid robots in education, with a particular focus on learning outcomes, learner engagement, and acceptance factors. An SLR approach was selected because it offers a rigorous, transparent, and replicable method for aggregating diverse research findings across fast-evolving fields such as educational robotics, human–robot interaction (HRI), cognitive psychology, learning sciences, and technology-enhanced pedagogy. Given the rapid advancements in humanoid robot design, AI capabilities, and their integration within classrooms, a structured review process was essential to capture patterns, gaps, and emerging insights. The review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines (Ahmed et al., 2025; Akinson et al., 2025; Bamiro et al., 2023; Page et al., 2021). PRISMA was used to ensure methodological rigour, reduce selection bias, and provide a clear audit trail for study identification, screening, eligibility assessment, and synthesis. The decision to adopt PRISMA was further motivated by the need for a standardised framework capable of consolidating empirical studies on humanoid robotics, a multidisciplinary space spanning engineering, education, psychology, and social sciences.

2.2 Search Procedure and Information Sources

A comprehensive and systematic search strategy was designed to capture peer-reviewed research published between 2015 and 2025, a period marked by significant advances in humanoid robot capabilities, expanded HRI research, and increased adoption of educational robots across global learning environments. Scopus served as the primary database because of its extensive indexing of high-quality research across engineering, educational technology, robotics, and behavioural sciences. To ensure broader coverage and to capture emerging or interdisciplinary studies, the search was supplemented with Google Scholar, which is valuable for identifying early-phase, cross-domain, and recently published research. The search strategy incorporated Boolean operators and phrase-matching combinations of keywords related to humanoid robots, educational robotics, learning outcomes, student engagement, acceptance models, and HRI. Typical search terms included: "humanoid robot", "social robot", "educational robotics", "robot-assisted learning", "human–robot interaction in education", "technology acceptance model and robots", and "learner engagement and robots". All retrieved records were exported into Microsoft Excel for organisation, deduplication, and preliminary screening. Additional studies were identified through backward reference tracing and forward citation searching to ensure that influential papers and recent developments not captured by initial searches were included.

2.3 Eligibility and Exclusion Criteria

Eligibility criteria were carefully defined to ensure that only studies directly addressing the research questions were incorporated into the review. Only peer-reviewed studies published in English between 2015 and 2025 were considered, reflecting the contemporary growth of humanoid robot applications in education and the recent expansion of human–robot interaction scholarship. Studies were deemed eligible if they examined the use of humanoid robots within formal or informal learning environments, assessed their impact on learning outcomes such as cognitive gains, academic performance, or skill development, explored how humanoid robots influence various dimensions of learner engagement, including emotional, behavioural, cognitive, or social aspects, or investigated acceptance, adoption, or user attitudes among teachers, students, or educational institutions. Both empirical and conceptual research, whether qualitative, quantitative, mixed-method, or experimental, were included where they offered substantial insight into at least one of the review's guiding questions. Studies were excluded when they lacked peer review, focused exclusively on technical or engineering aspects of robot development without educational implications, addressed only non-humanoid robots unless a comparison with humanoid robots was central to the analysis, or appeared as conference papers, dissertations, books, or book chapters. Research falling outside the specified publication range or not written in English was also removed. These inclusion and exclusion boundaries ensured that the final body of literature remained methodologically rigorous, conceptually coherent, and closely aligned with the objectives of the review.

2.4 Screening, Selection, and PRISMA Flow Process

The screening and selection process followed the four stages outlined in the PRISMA 2020 framework. The initial search across Scopus and Google Scholar retrieved 954 records. After consolidation, 137 duplicates were removed, leaving 817 unique articles for preliminary (title and abstract) screening.During the title/abstract screening stage, 622 studies were excluded because they did not meet the review criteria, common issues included a focus on non-humanoid robots, lack of relevance to education, learning outcomes, engagement, or acceptance. A total of 195 studies were retained for full-text assessment. During the full-text screening phase, each study was evaluated for methodological quality, conceptual alignment with the research questions, and relevance to humanoid robots in education. 156 studies were excluded at this stage due to insufficient empirical evidence, weak methodological rigour, misalignment with educational contexts, or focus on unrelated HRI domains. Ultimately, 39 studies met all inclusion criteria and were incorporated into the final synthesis. This multi-stage, transparent process ensured that the resulting evidence base was credible, thematically coherent, and sufficiently comprehensive to address the review's three research questions. A PRISMA flow diagram illustrating the identification, screening, eligibility, and inclusion stages is presented in Figure 1.

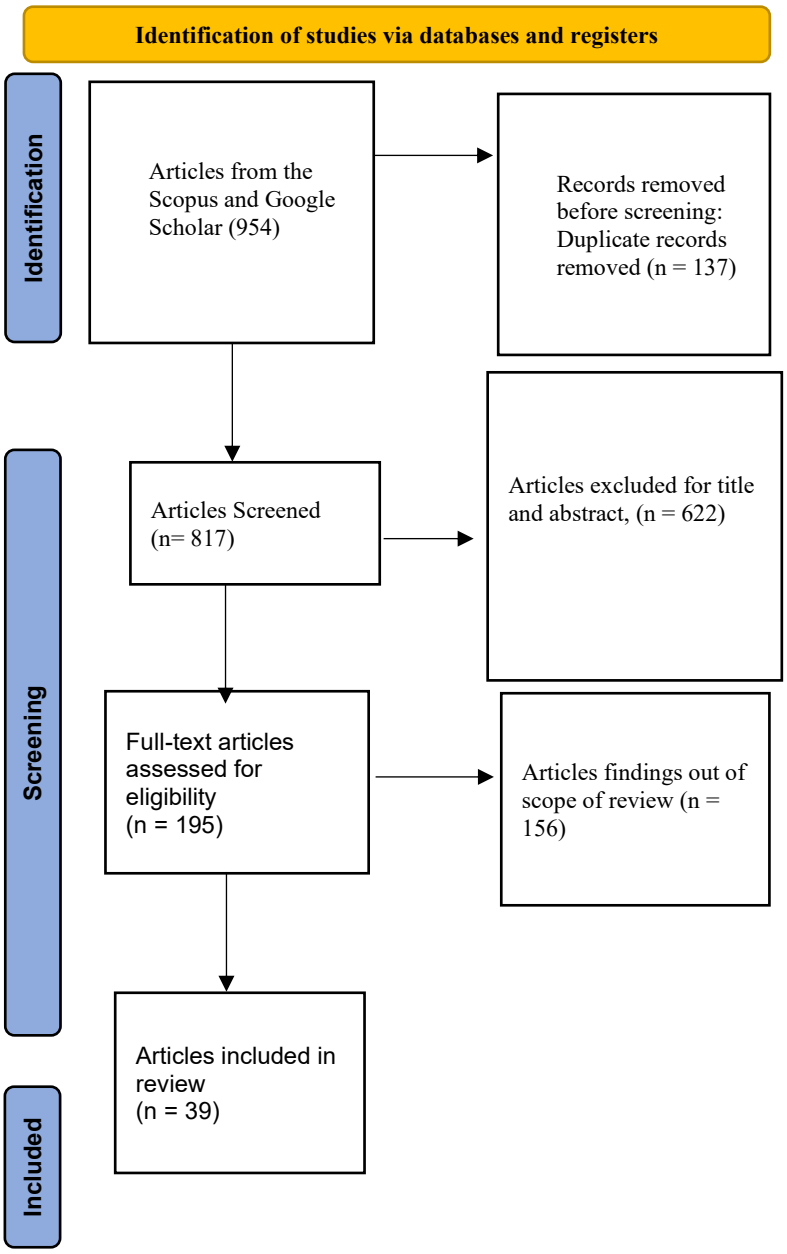


Figure. 1: PRISMA flow diagram

3.0 Data Extraction

As presented in Table 1, data extraction was conducted for all 39 studies that met the inclusion criteria, forming a structured basis for analysing learning outcomes, engagement patterns, and acceptance factors associated with humanoid robots in educational settings. A standardised data extraction template was developed to ensure consistency and comparability across studies, enabling the diverse body of evidence to be systematically organised and interpreted. The extraction framework captured essential bibliographic, methodological, and contextual information under the following categories: Authors and Year, Methodology, Country, Key Findings, and Journal of Publication. These categories were selected to align directly with the objectives of the review and to support a coherent synthesis of how different research contexts and methodological approaches contribute to understanding the role of humanoid robots in education. For each study, information on the methodology was documented to highlight the range of experimental, qualitative, quantitative, and mixed-method approaches used in humanoid-robot research. Recording the country of each study provided insights into regional variations in the adoption and use of humanoid robots across global education systems, helping identify geographic patterns in technological integration. The key findings of each article were extracted to capture evidence on learning outcomes, dimensions of learner engagement, and acceptance or adoption factors, thereby creating a unified basis for thematic comparison across the selected studies. Details about the journals of publication were also included to map the disciplinary spread of the literature, reflecting contributions from fields such as educational technology, robotics, psychology, and human–robot interaction. This systematic and well-structured extraction process ensured that the core contributions of each study were captured accurately and in a format that supported detailed analysis. By organising the literature according to methodological, contextual, and thematic dimensions, the extraction phase provided a robust foundation for synthesising evidence, identifying common patterns, and interpreting how humanoid robots influence teaching and learning dynamics across different educational environments.

S/N	Authors & Year	Methodology	Country	Key findings	Journal
1	Ekström and Pareto (2022)	Qualitative	Sweden	Teachers alternated between viewing the robot as a social actor and as a didactic tool; perceptions shifted over the co-design process; discussions centered on activity purpose, curriculum fit, child-robot collaboration, and social norms.	Education and information technologies
2	Mishra et al. (2021)	Qualitative	Norway	Presents an integrated framework (technological, pedagogical, efficacy, ethical) for school-based humanoid robot deployment and offers guidance for application and evaluation; highlights the need to center education in long-term national robotics strategies.	Electronics
3	Chalmers et al. (2022)	Qualitative	Australia	Teachers reported perceived benefits and challenges, identified pedagogical practices that supported student engagement, and located curricular fit for robots; study supports constructivist inquiry approaches and practical deployment across curriculum.	Education and Information Technologies
4	Algerafi et al. (2023)	Quantitative	China	Students showed strong intention to adopt AI-based robots; perceived usefulness and ease of use significantly predicted acceptance;	Ieee Access
5	Smakman et al. (2021)	Quantitative	The Netherlands	Identified five stakeholder attitude profiles; acceptance influenced by demographics and moral concerns; provided practical guidelines for responsible implementation of humanoid robots.	Robotics
6	Lei et al. (2022)	Quantitative	USA	Usefulness is the strongest predictor of adoption; ease of use and social norms improve perceived usefulness; perceived risk reduces ease of use	International Journal of Social Robotics
7	Donnermann et al. (2022)	Mixed-Method	Germany	Robotic tutor improved exam grades and motivation; increased intrinsic engagement; adaptivity offered no additional benefits	Frontiers in Robotics and AI
8	Konijn et al. (2022)	Qualitative	The Netherlands	Robots improved language learning gains, engagement, and enjoyment more than tablets; robot behavior style interacted with students' ability level.	International Journal of Social Robotics
9	Ahmad et al. (2019)	Qualitative	UK	Emotion-and-memory model sustained social engagement; positive emotional feedback significantly improved vocabulary learning	Adaptive Behavior
10	Cruz-Ramírez et al. (2022)	Qualitative	Mexico	NAO used as motivational active-learning tool; validated didactical sequence for Newton–Raphson; teacher reflective practice important for integration.	International Journal on Interactive Design and Manufacturing
11	Alhashmi et al. (2021)	Qualitative	UAE	Students appreciated robots; teachers cautious; voice malleability and small-group use influenced acceptability; need for adaptive behavior and better deployment processes.	Journal of Information Technology Education: Research
12	Almousa and Alghowinem (2022)	Mixed-Method	USA	Personalized interaction increased learning gains and engagement;	User Modeling and User-Adapted Interaction

13	Basori (2020)	Mixed-Method	Saudi Arabia	The positive reception by children and parents suggests that acceptability is influenced by fun, interactivity, and tangible engagement features	Indonesian Journal of Electrical Engineering and Computer Science
14	Crompton et al. (2018)	Qualitative	USA	NAO afforded language, cognitive and social–emotional learning opportunities	British Journal of Educational Technology
15	Imbernón Cuadrado et al. (2016)	Qualitative	Spain	Architecture supports personalized affective pedagogical support.	Frontiers in computational neuroscience
16	de Souza Jeronimo et al. (2022)	Qualitative	Brazil	Application feasible on both robots; embodiment and expressivity influenced children's preferences and perceived usability.	Journal of Intelligent & Robotic Systems
17	Levinson et al. (2021)	Qualitative	USA	Puppet-like robot and humanoid NAO improve learning outcomes.	International Journal of Social Robotics
18	Lopez-Caudana et al. (2022)	Qualitative	Mexico	NAO-assisted PE increased attention span and motivation relative to traditional PE.	International Journal on Interactive Design and Manufacturing
19	Molenaar et al. (2021)	Qualitative	The Netherlands	Identify voice-generation technology limitations as a factor that constrains both effectiveness and acceptance of the prosody-based robot	Multimodal Technologies and Interaction
20	Neumann et al. (2023)	Qualitative	Australia	Most children engaged (83%), 60% talked to robot; successful engagement/instruction with individual differences; thoughtful introduction recommended.	European Early Childhood Education Research Journal
21	Peretti et al. (2023)	Qualitative	UK	Robot behavior seen as more acceptable due to programming attribution.	Infant and Child Development
22	Ponce et al. (2022)	Qualitative	Mexico	Robotic improved attention, motivation, proactivity, and retention across STEM and PE contexts.	Sensors
23	So and Lee (2023)	Qualitative	Hong Kong	NAO built positive relationships and produced observable learning evidence	Cogent Education
24	Flanagan et al. (2023)	Qualitative	USA	Age and children's intuitive theories of agency are important determinants for how readily different technologies, including humanoid robots, are accepted	Developmental psychology
25	Ioannou et al. (2015)	Qualitative	Cyprus	The development of a coding scheme for verbal and non-verbal behaviours are important for institutional adoption and assessment of robot interactions	TechTrends
26	Manzi et al. (2022)	Qualitative	UK	The design of humanoid robots should consider the target age.	Frontiers in psychology
27	Okanda and Taniguchi (2022)	Qualitative	Japan	Children do not hesitate to answer robot questions and may not distinguish the robot from human interlocutors	Infant and Child Development
28	Stower et al. (2022)	Qualitative	Sweden	Tolerance for technical imperfections moderate acceptance	Interaction Studies
29	Straten et al. (2020)	Qualitative	The Netherlands	Transparency about robot's machine nature decreased animacy, anthropomorphism, social presence and trust	ACM Transactions on Human-Robot Interaction
30	van Straten et al. (2022)	Qualitative	The Netherlands	Robot question-asking increases children's trust and belief in the robot's cognitive perspective-taking	Computers in Human Behavior
31	Tilden et al.	Mixed-Method	Norway	Students found robot entertaining and	Technology,

	(2025)			mastery-enhancing for math/programming	Knowledge and Learning
32	Zemljak (2025)	Qualitative	Slovenia	Predominantly negative teacher attitudes and low self-reported readiness to integrate humanoid robots	Center for Educational Policy Studies Journal
33	Tarrés-Puertas et al. (2023)	Qualitative	Spain	Robots useful for playful STEM teaching; increased girls' interest in science/engineering	Sensors
34	Chen et al. (2025)	Qualitative	China	Novelty-seeking and self-efficacy shape perceived usefulness/ease of use; perceived usefulness/ease predict attitudes and behavioral intention to use humanoid robots.	Acta Psychologica
35	Serholt et al. (2017)	Qualitative	Sweden, UK, Portugal	Teachers raised privacy, role, child-effect and responsibility concerns; advocated reflective, responsible design and policy considerations for classroom robot adoption	Ai & Society
36	Khanlari (2016)	Qualitative	Canada	Teachers perceived robotics positively for lifelong learning skills but reported barriers to integration and specific support needs for adoption	European Journal of Engineering Education
37	Alcorn et al. (2019)	Qualitative	UK	Educators saw robots as engaging and predictable for autistic learners but warned about reduced human interaction and need for evidence of skill generalization; cautious receptivity with nuanced concerns for adoption.	Frontiers in Robotics and AI
38	LeTendre and Gray (2024)	Qualitative	USA	Pepper exposure motivated students and provoked complex student beliefs about robots;	Journal of Computer Assisted Learning
39	Nagy et al. (2024)	Qualitative	Hungary	Effective HRI is essential for NAO's success; factors like expressivity and responsiveness affect engagement and adoption	Acta Polytechnica Hungarica

Table 1: Data extraction table.

1 Temporal Distribution of Included Studies

The temporal distribution of the studies included in this systematic review reveals a steady and expanding scholarly interest in humanoid robots within educational settings. As presented in Figure 2, research on humanoid robots, particularly in relation to learning outcomes, engagement mechanisms, and acceptance factors, has grown consistently over the past decade, with notable peaks in recent years. The year 2022 recorded the highest number of publications (n = 14), marking a significant surge in academic attention. This peak corresponds with the widespread integration of social and humanoid robots in experimental classroom settings, driven by advancements in artificial intelligence, natural language processing, and adaptive learning systems. Studies published in 2022 frequently investigated how humanoid robots influence student engagement, personalized instruction, and classroom interaction patterns. The second-largest cluster of publications appears in 2023 (n = 6), reflecting continued scholarly momentum following the technological gains made in 2021 and 2022. Research from this year often shifted from exploratory deployments toward more structured evaluations of robot-assisted learning, including empirical assessments of robot-led tutoring, socio-emotional support, and student motivation. Earlier contributions also played a foundational role in shaping the field. The year 2021 contributed five studies, many of which examined user acceptance, teacher perceptions, and early-stage prototypes of humanoid robots in education. These studies built critical knowledge on usability, classroom adaptation challenges, and the social dynamics surrounding human–robot interaction. Moderate research activity was observed in 2020 (n = 2) and 2019 (n = 2), reflecting the early adoption phase during which educational technologists and roboticists began testing humanoid robots as learning companions or teaching assistants. Earlier foundational works include publications from 2018 (n = 1), 2017 (n = 1), 2016 (n = 2), and 2015 (n = 1). Although fewer in number, these studies were essential in establishing baseline insights into robot design considerations, cognitive load implications, and the pedagogical potential of social robotics. More recent years continue to demonstrate sustained interest. The year 2024 contributed two studies, reflecting a shift toward more refined evaluation frameworks and long-term classroom implementations. Similarly, 2025 (n = 3) indicates that the field remains active, with researchers exploring more advanced humanoid features such as emotional adaptation, autonomous feedback mechanisms, and culturally responsive robot

behaviours. Overall, more than 75% of the included studies were published between 2021 and 2025, highlighting the rapidly growing relevance of humanoid robots in contemporary education. This upward trajectory underscores increasing global interest in understanding not only whether humanoid robots improve learning outcomes but also how learners, teachers, and institutions engage with and accept these emerging technologies. Consequently, the current review is both timely and positioned within an expanding and highly dynamic research landscape.

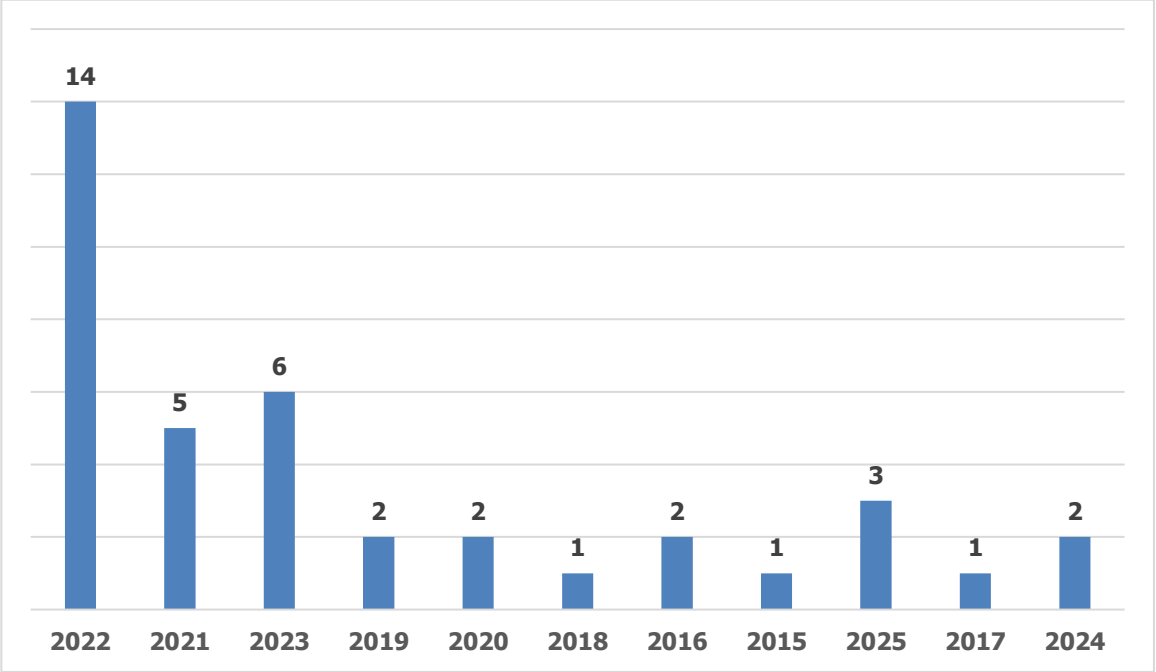


Figure 2: Distribution of Included Studies

3.2 Methodological Distribution of Included Studies

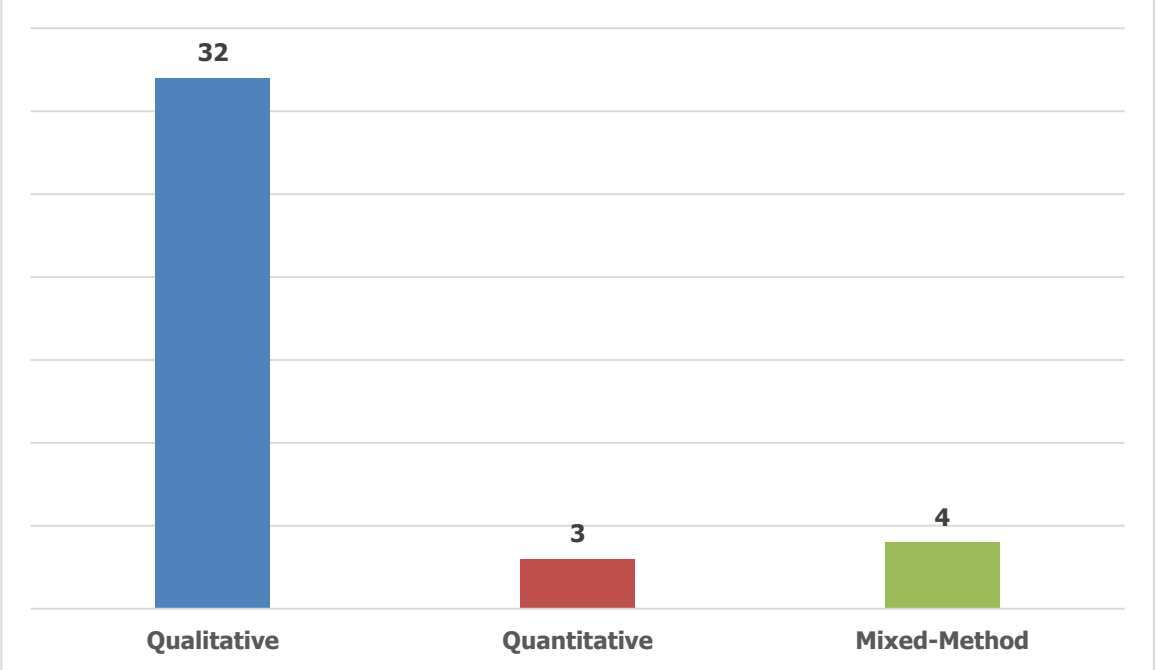


Figure 3: Methodology Analysis

As presented in Figure 3, the methodological distribution of the reviewed studies provides a clear understanding of how researchers have examined humanoid robots in education across learning outcomes, engagement models, and acceptance factors. The analysis shows a strong predominance of qualitative research designs (n = 32), highlighting that much of the existing scholarship has focused on capturing the nuanced, context-dependent nature of human–robot interaction in educational settings. These qualitative studies commonly employed interviews, observations, classroom interaction analyses, and thematic coding to explore how students and teachers perceive, respond to, and engage with humanoid robots during instructional activities. Their focus on lived experience and interactional dynamics reflects the complexity of studying social robots within real-world learning environments. A smaller proportion of the literature adopted quantitative designs (n = 3). These studies typically relied on structured surveys, controlled experiments, or statistical measures to assess variables such

as learning gains, engagement levels, acceptance scores, task performance, or behavioral changes associated with robot-assisted instruction. Although fewer in number, these studies play an important role in offering measurable evidence on the effectiveness of humanoid robots, helping to validate claims about their impact on learning outcomes and student motivation. Meanwhile, mixed-methods studies (n = 4) demonstrate researchers' efforts to integrate both qualitative depth and quantitative rigor. These studies provided comprehensive analyses by examining learner perceptions and behaviors alongside empirical performance data. Such methodological integration is especially valuable in humanoid robot research, where cognitive, emotional, behavioral, and social dimensions often intersect. Mixed-methods approaches helped triangulate findings, offering richer insights into key themes such as user acceptance, robot pedagogical roles, and engagement patterns across different instructional contexts. Overall, the methodological landscape of this review shows a field that is still developing but deeply exploratory. The dominance of qualitative studies reflects a scholarly emphasis on understanding interactional processes and acceptance dynamics, while the presence of quantitative and mixed-methods research strengthens the empirical foundation necessary for assessing educational effectiveness. Together, these methodological approaches provide a multidimensional understanding of how humanoid robots function as learning partners, engagement tools, and instructional agents in modern educational environments.

3.3 Geographical Distribution of Included Studies

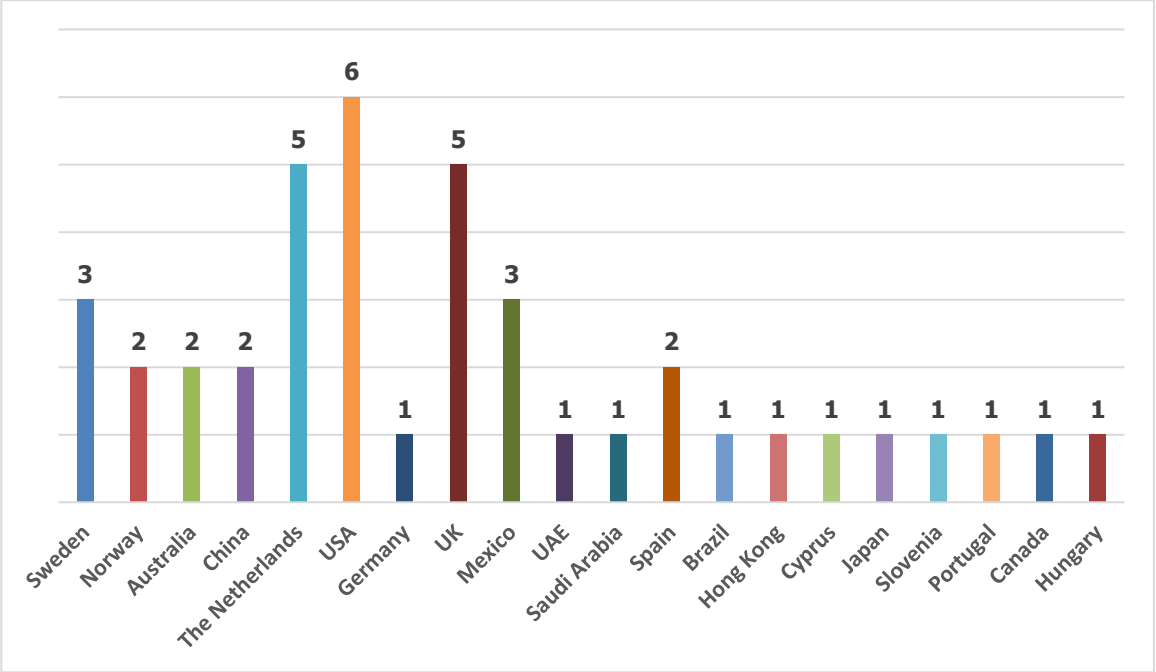


Figure 4: Geographical Distribution of Studies

The geographical distribution of the studies included in this review demonstrates a broad and growing global engagement with humanoid robots in education. As illustrated in Figure 4, the reviewed studies span multiple continents, reflecting worldwide interest in how humanoid robots influence learning outcomes, student engagement, and stakeholder acceptance within diverse educational environments. The United States emerged as the leading contributor with six studies, highlighting the country's strong research culture in educational technology, social robotics, and human–robot interaction. Much of this research explores robot-assisted learning, engagement mechanisms, and classroom integration challenges within technologically advanced learning ecosystems. The Netherlands and the United Kingdom each contributed five studies, indicating significant and sustained scholarly activity in Europe. These countries have long-standing expertise in human–robot interaction and educational innovation, which has supported a wide body of research examining robot-led tutoring, socio-emotional support, and student acceptance dynamics.Several other European countries also featured prominently. Sweden contributed three studies, while Spain, Norway, and Mexico each produced two. These contributions reflect active regional interest in exploring both the pedagogical benefits of humanoid robots and the human factors influencing their adoption in classrooms. Other European contributors, including Germany, Portugal, Hungary, Cyprus, and Slovenia, each added one study, demonstrating a geographically diverse but cohesive body of European research. Asian contributions were also notable. China produced two studies, reflecting ongoing national investment in educational robotics and AI-enhanced learning environments. Hong Kong and Japan each contributed one study, underscoring the region's long-standing interest in robotics as a tool for interactive and collaborative learning. In the Middle East, Saudi Arabia and the UAE each contributed one study, reflecting growing regional engagement with educational digitalization and emerging technologies. These studies often explored themes such as student motivation, robot acceptance, and the feasibility of robot-assisted instruction in rapidly modernizing education systems. Contributions from the Americas and Oceania also enrich the global landscape. Brazil added one study, providing important insights from a Latin American perspective, while Australia contributed two studies, reflecting its active exploration of innovative learning tools and robotics-enhanced pedagogy. Canada contributed one study, adding further depth to North American perspectives on robot-supported educational delivery. Overall, the geographical spread of the reviewed literature highlights a well-distributed and internationally representative body of research. The strong

participation from Europe, North America, and Asia, and emerging contributions from the Middle East, Oceania, and Latin America, demonstrates that the integration of humanoid robots into education is a global phenomenon. This diversity strengthens the generalizability of the findings and underscores widespread recognition of humanoid robots as promising tools for enhancing learning outcomes, engagement processes, and acceptance within contemporary educational systems.

4.0 Discussion of Findings

RQ1: What is the evidence on the impact of humanoid robots on learning outcomes in educational settings?

Across the reviewed studies, the evidence consistently shows that humanoid robots can positively influence learning outcomes in educational settings, although the extent and nature of this impact vary across contexts, age groups, and pedagogical designs. A central pattern emerging from the literature is that humanoid robots tend to enhance learning not merely through their physical form but through the instructional, emotional, and adaptive interactions they support. Studies that integrate robots into structured lessons with clear learning goals report some of the most robust gains, highlighting the importance of thoughtful pedagogical design in shaping learning effects. A number of experimental and quasi-experimental studies demonstrate direct and measurable improvements in academic performance when humanoid robots are used as tutors or learning companions. For instance, Donnermann et al. (2022) found that students who interacted with an adaptive robotic tutor achieved significantly higher exam scores and reported greater subjective knowledge gains than peers in non-robotic conditions, showing that the robot's presence alone supported academic success over the semester. Similarly, Konijn et al. (2022) observed substantially higher second-language learning gains among children taught by a humanoid robot compared with tablet-based instruction, demonstrating the distinctive effectiveness of robot-mediated interaction for early language development. Reinforcing this, Ahmad et al. (2019) showed that a NAO robot equipped with an emotion-and-memory model could produce sustained social engagement and significantly enhance vocabulary learning, indicating that socially responsive robot behaviour contributes meaningfully to learning outcomes. These results collectively suggest that robot adaptivity, whether cognitive or socio-emotional, can strengthen learning when implemented effectively. While the strongest evidence of impact comes from structured academic tasks, studies in STEM, engineering, and technical education also report positive learning effects linked to motivation and conceptual understanding. Cruz-Ramírez et al. (2022) showed that humanoid robots supported students' grasp of numerical methods and complex mathematical procedures by functioning as active-learning elements within an engineered learning trajectory. Tarrés-Puertas et al. (2023) similarly observed that the playful and intuitive nature of educational robots enhanced students' engagement with scientific concepts and contributed to measurable learning impacts over a one-year period. These outcomes indicate that robots can enrich technical learning environments by making abstract concepts more interactive and accessible. Evidence from early childhood and informal learning settings further supports the educational value of humanoid robots. Almousa and Alghowinem (2022) demonstrated that a personalized NAO tutor improved preschoolers' knowledge gains by adapting to their attention and performance states. Crompton et al. (2018) reported that robots provided opportunities for development across language, cognitive, and socio-emotional domains in preschool classrooms, even though learning was not quantified experimentally. Likewise, studies by Neumann et al. (2023) and So and Lee (2023) showed that robot-guided activities such as drawing or measurement tasks elicited high participation, interaction, and observable signs of learning among young children. These studies suggest that robot-mediated learning may be especially powerful in early childhood contexts, where engagement and social presence play vital roles in knowledge acquisition. Some studies highlight that the benefits of humanoid robots extend beyond academic performance to encompass competencies such as motivation, attention, self-confidence, and lifelong learning skills. Lopez-Caudana et al. (2022) found that robot-assisted physical education resulted in higher attention and motivation compared with traditional instruction. Tilden et al. (2025) reported that students gained short-term mastery experiences and confidence in mathematics and programming tasks, while Khanlari (2016) noted that teachers perceived robotics activities to improve teamwork, communication, and problem-solving skills. Although these outcomes are not always measured through formal assessments, they represent important learning-relevant gains that contribute to broader educational development. Despite the predominantly positive evidence, several studies emphasize that learning outcomes depend strongly on implementation quality, teacher mediation, and contextual alignment. Ekström and Pareto (2022) and Chalmers et al. (2022) both show that teachers' evolving perceptions and sustained positive appraisals influence how robots are integrated into lessons, which in turn shapes their educational impact. In some cases, the robot's morphology appears less critical than the pedagogical design itself. Levinson et al. (2021) demonstrated that children achieved comparable learning gains with both a low-cost puppet-like robot and the humanoid NAO, suggesting that humanoid form alone does not guarantee superior outcomes. Additionally, the work of Manzi et al. (2022) indicates that age-related differences in anthropomorphism influence how children attribute mental states to robots, which may affect engagement and, therefore, learning indirectly. Overall, the evidence indicates that humanoid robots meaningfully enhance learning outcomes when embedded in well-designed instructional environments supported by teacher facilitation, emotional responsiveness, and adaptive pedagogical strategies. The positive effects appear most pronounced when robots are deployed as interactive partners rather than static tools, and when their behaviour, whether cognitive, emotional, or social, is aligned with learners' needs. However, the findings also show that robots are not a standalone solution; their impact depends on curricular integration, design quality, and the broader learning ecology in which they operate.

RQ2: How do humanoid robots affect different dimensions of learner engagement (emotional, behavioural, cognitive,

social)?

The evidence across the reviewed studies shows that humanoid robots exert multidimensional effects on learner engagement, influencing emotional, behavioural, cognitive, and social dimensions in ways that often overlap and reinforce each other. A recurring pattern is that humanoid robots function simultaneously as social actors and instructional tools, and this duality shapes how learners respond to them. Ekström and Pareto (2022) demonstrate that teachers naturally oscillate between viewing the robot as a peer-like social participant and a didactic instrument, a shift that results in fluctuating emphasis on social, emotional, and task-oriented engagement depending on the classroom context. This dynamic interplay between pedagogical design and social interaction underlies much of the variability observed in engagement outcomes across studies. Emotionally, humanoid robots regularly elicit curiosity, enjoyment, and positive affect, especially when they display social or affective behaviours. Several studies highlight how robot-delivered emotional cues directly shape engagement. Ahmad et al. (2019) show that positive emotional feedback strengthens children's willingness to interact and sustains engagement across repeated sessions. Similarly, Konijn et al. (2022) find that children experience greater enjoyment and emotional involvement during storytelling with a robot than with a tablet, demonstrating that even minimal social expressivity can heighten emotional engagement. Adaptive or personalized behaviours further amplify this effect; Almousa and Alghowinem (2022) reveal that personalization based on gaze, correctness, or hesitation increases attraction to the learning tasks, while Imbernón Cuadrado et al. (2016) show that effective emotion identification enables robots to provide affective support that enhances emotional and cognitive engagement. Across playful and informal settings, such as those described by Basori (2020), Ioannou et al. (2015), and So and Lee (2023), children responded with excitement, empathy, and friendliness, indicating that humanoid robots can evoke rich emotional interactions that support learning readiness. Behavioural engagement also emerges as a robust area of impact. Many studies report increased attention, on-task behaviour, and active participation when humanoid robots are integrated into instruction. Konijn et al. (2022), Cruz-Ramírez et al. (2022), and Crompton et al. (2018) all document heightened behavioural involvement ranging from focused task execution to turn-taking and cooperative participation. In physical education and technical subjects, robots appear to act as motivational catalysts; Lopez-Caudana et al. (2022) show improved attention and motivation in robot-assisted PE classes, while Tarrés-Puertas et al. (2023) and Ponce et al. (2022) report increased behavioural engagement in STEM contexts. Notably, long-term deployments such as Chalmers et al. (2022) and LeTendre and Gray (2024) indicate that novelty-driven engagement does not necessarily fade quickly; instead, robots can sustain behavioural participation when embedded meaningfully within inquiry-based or project-based learning environments. Cognitive engagement tends to be strengthened when robots pose questions, provide scaffolding, or support metacognitive processes. Donnermann et al. (2022) show that university students experienced sustained cognitive engagement and intrinsic motivation during exam preparation with a robotic tutor. van Straten et al. (2022) further illustrate that specific communicative strategies shape cognitive involvement: robot question-asking enhanced children's trust in the robot's cognitive perspective-taking, thereby increasing deeper mental engagement. Studies involving adaptive learning, such as those by Almousa and Alghowinem (2022), demonstrate that personalization encourages learners to think, reflect, and respond more actively, revealing the cognitive potential of adaptive HRI design. Even when morphology is simplified, as shown in the comparison by Levinson et al. (2021), cognitively meaningful engagement can be sustained, suggesting that cognitive engagement depends more on pedagogical and interaction design than on high-fidelity humanoid embodiment. Social engagement is perhaps the most consistently enhanced dimension across studies, as humanoid robots often function as conversational partners or peer-like companions. Crompton et al. (2018), Neumann et al. (2023), and So and Lee (2023) all provide evidence of children initiating conversations, maintaining eye contact, cooperating, and treating the robot as a social partner. Ekström and Pareto (2022) and Chalmers et al. (2022) observe that classroom norms evolve to include the robot as a social participant, reshaping group dynamics and supporting collaborative engagement. Social engagement also emerges in settings involving special needs learners; Alcorn et al. (2019) report that autistic pupils respond positively to the predictability and consistency of humanoid robots, although they warn that robots may simultaneously reduce opportunities for human interaction. Studies examining embodiment preferences, such as de Souza Jeronimo et al. (2022), show that features like motion, expressivity, and design shape learners' willingness to socially interact, while Nagy et al. (2024) highlight expressivity and responsiveness as key HRI factors that influence social and emotional involvement. At the same time, the literature acknowledges variability and limitations in engagement outcomes. Neumann et al. (2023) note that while most children engaged socially and behaviourally, a small group remained disengaged, suggesting individual differences in robot acceptance. Tilden et al. (2025) show that lack of tailored feedback or limited expressivity can hinder engagement despite overall enjoyment. Some studies, such as Alcorn et al. (2019), raise caution about over-reliance on robots for social engagement, particularly for vulnerable learner groups. Despite these nuances, the overall evidence converges on the conclusion that humanoid robots positively influence emotional, behavioural, cognitive, and social dimensions of engagement, particularly when their design and behaviours align with pedagogical goals and learner needs. In summary, humanoid robots act as multifaceted engagement tools that can simultaneously stimulate emotion, sustain attention, prompt cognitive effort, and facilitate social interaction. Their effectiveness stems not only from their humanoid form but from their interactive behaviours, personalization capacities, and integration into meaningful learning activities. The literature indicates that, when appropriately implemented, humanoid robots can substantially enrich the engagement landscape of educational environments across age groups, subjects, and learning contexts.

RQ3: What factors influence the acceptance and adoption of humanoid robots by teachers, students, and institutions?

Across the reviewed literature, acceptance and adoption of humanoid robots in education are shaped by an intricate interplay of technological, pedagogical, ethical, contextual, and human–robot interaction factors. A central theme is that acceptance cannot be reduced to the appeal or novelty of the robot alone; instead, teachers, students, and institutions evaluate humanoid robots through the lenses of usefulness, ease of use, curricular relevance, ethical soundness, and the practical realities of classroom operation. Ekström and Pareto (2022) illustrate this complexity by showing that teachers' acceptance evolved as they gained hands-on experience and a clearer understanding of the robot's pedagogical role. Initially shaped by concerns about classroom norms, curricular alignment, and the robot's purpose, teacher acceptance expanded with prolonged exposure and co-design involvement, highlighting that familiarity, training, and contextual fit play central roles in shaping teacher openness. Pedagogical alignment and perceived usefulness emerge as particularly influential determinants of both teacher and institutional adoption. Mishra et al. (2021) emphasize four interconnected acceptance dimensions; technology readiness, pedagogical fit, demonstrated efficacy, and ethical considerations, arguing that successful institutional adoption requires evidence that robots genuinely add value to learning. This aligns with findings from Chalmers et al. (2022) and Cruz-Ramírez et al. (2022), where teachers were more willing to integrate robots when they observed real learning benefits, when the robot supported established pedagogical practices, and when its use was feasible within classroom constraints. These studies underscore that teacher professional development, curriculum-aligned lesson designs, and institutional support structures are essential for sustained adoption. From the learner perspective, perceived usefulness and ease of use are dominant predictors of acceptance, consistent with Technology Acceptance Model (TAM) frameworks. Algerafi et al. (2023), Lei et al. (2022), and Chen et al. (2025) collectively show that students' adoption intentions are driven by expectations of practical educational benefits, intuitive operation, and confidence in their ability to meaningfully interact with the robots. Novelty-seeking traits, self-efficacy, and social support from peers or instructors further strengthen acceptance. Children's acceptance, illustrated in studies such as Ahmad et al. (2019), Basori (2020), and Okanda and Taniguchi (2022), is influenced by robot expressiveness, positive feedback, embodiment, perceived friendliness, and interactive features. Developmental factors also matter; Flanagan et al. (2023) and Peretti et al. (2023) show that children's moral judgements, attributions of agency, and understanding of intentionality affect their comfort with and trust in humanoid robots, implying that age-appropriate design is essential for acceptance. Technological maturity, reliability, and design features also play decisive roles in adoption. Teachers in Alhashmi et al. (2021), Molenaar et al. (2021), and Tilden et al. (2025) point to issues such as voice-generation limitations, lack of expressive capabilities, constrained responsiveness, and the need for tailored feedback as practical barriers that undermine trust in robots as classroom partners. At the institutional level, cost, scalability, and ease of deployment—highlighted by Levinson et al. (2021), strongly influence whether robots are considered viable for broader adoption. Studies conducted during the COVID-19 period, such as de Souza Jeronimo et al. (2022), also reveal how operational conditions and infrastructural constraints can shape feasibility and acceptance, underscoring the importance of supportive environments for robot integration. Ethical, cultural, and policy considerations further moderate acceptance. Smakman et al. (2021) and Serholt et al. (2017) stress that moral attitudes, privacy concerns, role definition, and safety expectations influence whether stakeholders view robots as appropriate educational tools. Teachers express worries about responsibility for robot actions, potential effects on children's social development, and the need for transparent governance and ethical frameworks. These concerns are particularly prominent in special education contexts: Alcorn et al. (2019) show that while robots can be highly engaging for autistic learners, educators emphasize the need for clear evidence of skill generalization and warn against over-dependence on robot-mediated interaction. Transparency-related findings (Straten et al. 2020), which reveal that excessive disclosure about robotic limitations can reduce children's trust, illustrate the delicate balance institutions must strike in crafting policy and communication strategies that foster responsible but still effective adoption. Institutional readiness, teacher training, and role clarity consistently emerge as decisive enabling factors. Studies such as Crompton et al. (2018), Khanlari (2016), and Zemljak (2025) reveal that teachers frequently feel unprepared to operate or integrate robots without explicit training, technical support, and pedagogical models. Where institutions lack capacity, adoption intentions remain low even when teachers or students personally view the robots positively. Long-term deployments, as seen in LeTendre and Gray (2024), show that robots place additional planning and reflection demands on teachers, signalling that acceptance is tied to workload and institutional expectations. Finally, HRI-specific considerations such as expressivity, interactivity, embodiment, and responsiveness, discussed in Nagy et al. (2024), Manzi et al. (2022), and So and Lee (2023)—shape how intuitively stakeholders interact with humanoid robots, further influencing acceptance. Overall, the literature demonstrates that acceptance and adoption of humanoid robots in education are determined by a convergence of usability, usefulness, pedagogical integration, ethical safeguards, technical reliability, teacher readiness, contextual fit, and developmental appropriateness. Adoption is strongest when robots demonstrably support learning goals, when educators are trained and supported, when operational and ethical concerns are addressed, and when robot design aligns with learner needs and institutional ecosystems.

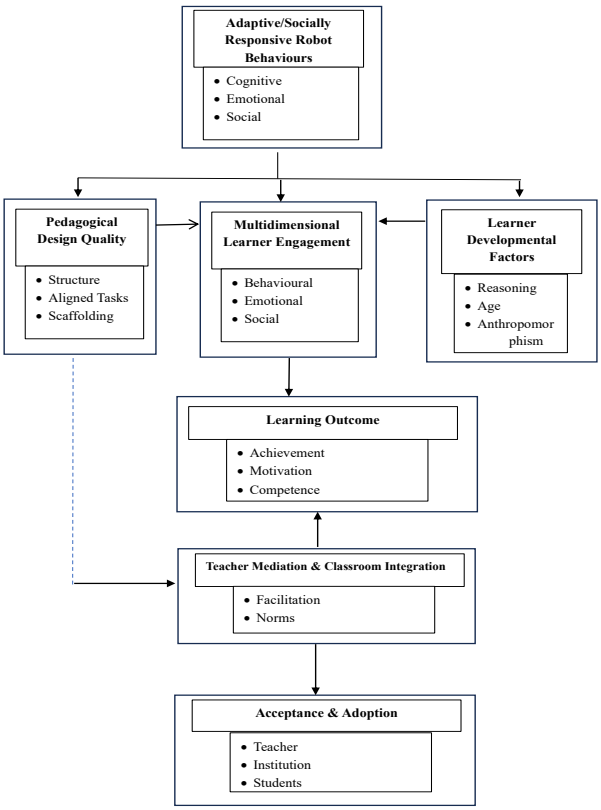


Figure 5: Conceptual Framework by author

The conceptual framework, Figure 5, illustrates how humanoid robots influence learning outcomes through a set of interdependent pedagogical, interactional, and contextual processes reflected across the reviewed studies. Central to the framework is the role of adaptive and socially responsive robot behaviours, which include cognitive scaffolding, emotional expressivity, and social presence. Evidence shows that these behaviours directly stimulate learner engagement and, in turn, shape learning outcomes. For instance, Donnermann et al. (2022) and Konijn et al. (2022) demonstrate that adaptive tutoring and socially interactive storytelling result in higher exam performance and language learning gains, while Ahmad et al. (2019) shows that emotionally responsive robots can strengthen children's engagement and vocabulary acquisition. These findings indicate that robot behaviour does not operate in isolation but directly feeds into how learners think, feel, and interact within educational settings. Pedagogical design quality serves as a foundational determinant of robot effectiveness and interacts closely with robot behaviours to shape engagement. Studies such as Cruz-Ramírez et al. (2022) and Tarrés-Puertas et al. (2023) emphasize that robots enhance conceptual understanding most effectively when they are embedded in well-structured instructional sequences and active-learning trajectories. The importance of pedagogical alignment is further reinforced by Ekström and Pareto (2022) and Chalmers et al. (2022), who show that teachers' perceptions of curricular integration and feasibility shape how robots are positioned in classroom practice. This connection between design quality and engagement also reflects Levinson et al.'s (2021) observation that morphological sophistication does not determine learning gains; rather, the pedagogical context and interaction design are what sustain meaningful cognitive engagement.At the core of the framework is multidimensional learner engagement, encompassing emotional, behavioural, cognitive, and social dimensions. The reviewed studies show a reciprocal relationship between robot behaviours and engagement. Emotional engagement is enhanced when robots display positive affect or adapt to learner cues, as observed in Almousa and Alghowinem (2022), Imbernón Cuadrado et al. (2016), and Basori (2020). Behavioural engagement increases through heightened attention and participation, particularly in STEM and physical education contexts (Lopez-Caudana et al., 2022; Ponce et al., 2022). Cognitive engagement strengthens when robots prompt reflection, pose questions, and support metacognition, as demonstrated by van Straten et al. (2022) and Donnermann et al. (2022). Social engagement is reinforced through conversational, cooperative, and peer-like interactions, consistent with evidence from Crompton et al. (2018), Neumann et al. (2023), and So and Lee (2023). These engagement dimensions collectively mediate the relationship between robot behaviours and learning outcomes, illustrating why engagement is the central mechanism in the framework. The framework highlights that learning outcomes—including academic achievement, conceptual understanding, motivation, and broader competencies—emerge as the cumulative effect of robot adaptivity, high-quality pedagogy, and sustained engagement. The positive results reported by Tarrés-Puertas et al. (2023), Cruz-Ramírez et al. (2022), and Almousa and Alghowinem (2022), as well as the development of skills such as confidence and teamwork observed by Tilden et al. (2025) and Khanlari (2016), support a multifaceted interpretation of "learning outcomes." The findings collectively suggest that robots contribute most effectively when they function as interactive partners that respond to learner needs and are embedded within coherent instructional environments.Teacher mediation and classroom integration form a critical moderating layer. The work of Ekström and Pareto (2022) illustrates how teachers' shifting perceptions—seeing the robot sometimes as a peer and

sometimes as an instructional tool—shape classroom norms and influence how learners respond socially and behaviourally. Chalmers et al. (2022) similarly show that long-term robot integration strengthens teacher acceptance and improves engagement patterns. Teacher mediation thus not only influences how robots are implemented but also directly impacts learner engagement and indirectly affects learning outcomes. A further moderating influence arises from learner developmental factors, including age-related differences in anthropomorphism, moral reasoning, and attributions of intentionality. Manzi et al. (2022) demonstrates that younger children assign more mental states to robots, which affects engagement strength, while findings from Flanagan et al. (2023) and Peretti et al. (2023) show that children's moral and cognitive judgments shape comfort, trust, and acceptance. These developmental differences influence both engagement and acceptance, reinforcing the need for age-appropriate robot design. The lower portion of the framework reflects that acceptance and adoption are shaped by the combined influence of robot performance, pedagogical alignment, teacher readiness, ethical considerations, and institutional support. Studies such as Mishra et al. (2021), Chalmers et al. (2022), and Cruz-Ramírez et al. (2022) show that acceptance is strongest when robots are demonstrably useful and fit within existing instructional structures. From the learner perspective, perceived usefulness and ease of use—highlighted by Algerafi et al. (2023), Lei et al. (2022), and Chen et al. (2025)—reinforce the role of cognitive and emotional expectations in adoption decisions. Ethical concerns noted by Serholt et al. (2017), Smakman et al. (2021), and Alcorn et al. (2019) reveal that trust, privacy, and developmental impacts also shape how institutions and teachers conceptualize the role of humanoid robots. Finally, technical limitations identified by Alhashmi et al. (2021), Molenaar et al. (2021), and Tilden et al. (2025) demonstrate that reliability and expressivity are essential for sustained adoption. Acceptance thus emerges as both an outcome of successful implementation and a prerequisite for long-term integration. Taken together, the framework depicts humanoid robots as influential learning partners whose impact depends on the dynamic interplay between robot behaviours, pedagogical design, learner engagement, teacher mediation, developmental characteristics, and acceptance conditions. The literature demonstrates that positive learning outcomes arise when these components align, reinforcing the view that humanoid robots are effective not because of their form alone but because of their integration within supportive pedagogical and institutional ecosystems.

5.0 Conclusion

This systematic review synthesised findings from 39 empirical studies to examine the impact of humanoid robots on learning outcomes, learner engagement, and stakeholder acceptance within educational settings. The evidence demonstrates that humanoid robots can meaningfully enhance learning outcomes when implemented within well-designed pedagogical environments and supported by adaptive, socially responsive robot behaviours. Across academic, technical, and early childhood contexts, robots consistently contributed to improvements in knowledge acquisition, motivation, conceptual understanding, and broader learning-related competencies. The review further shows that humanoid robots exert multidimensional effects on emotional, behavioural, cognitive, and social engagement, with engagement functioning as a central mechanism through which robots influence learning. However, these effects depend strongly on interaction quality, personalization, teacher facilitation, and contextual alignment. Acceptance and adoption were found to be shaped by technological reliability, pedagogical fit, ethical considerations, ease of use, and institutional readiness, reflecting the complex sociotechnical ecosystem in which humanoid robots operate. Overall, the findings indicate that humanoid robots hold significant promise for enhancing educational experiences, but their effectiveness depends on thoughtful integration, stakeholder preparedness, and alignment with curriculum and learner needs.

6.0 Study Implications

The findings have important theoretical, pedagogical, and institutional implications. The conceptual synthesis indicates that the impact of humanoid robots is best understood through the interplay of adaptive robot behaviours, learner engagement, and pedagogical design. This reinforces the need for educational technology frameworks that account not only for tool functionality but for the relational and social dynamics that emerge during human–robot interaction. For educators and instructional designers, the results highlight the importance of embedding robots within structured, curriculum-aligned activities, ensuring that robot behaviours—whether cognitive scaffolding, emotional support, or personalized feedback—are matched to learning goals. Practically, teachers must be supported through training, professional development, and co-design processes to effectively integrate robots into classroom routines. At the institutional level, successful adoption depends on providing adequate infrastructural support, ensuring technological reliability, and establishing clear ethical guidelines regarding data privacy, learner well-being, and role expectations. For policymakers, the findings suggest a need for governance frameworks that balance innovation with responsible use, especially in early childhood and special education contexts. Overall, the study underscores that the educational value of humanoid robots is contingent on coordinated decision-making across the classroom, institutional, and policy levels.

7.0 Limitations

Although the review offers a comprehensive synthesis, several limitations must be acknowledged. First, the review relies on 39 studies, limiting the generalisability of findings across diverse educational systems. Publication bias may be present, as positive results are more likely to be reported than unsuccessful or neutral robot deployments. These limitations suggest the need for more longitudinal, classroom-based, and methodologically rigorous research to validate and extend current conclusions.

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