

A Comprehensive Study on Emotional Intelligence (EI) and Educational Robotics (ER) – Enhancing Learning and Social Interaction

Anurag Agarwal

Assistant Professor and Soft Skill Trainer, Department of Management, Mangalmai Institute of Management and Technology (MIMT), Greater Noida, Dist. Gautam Budh Nagar, UP, India.

Abstract:

In recent years, social robots have become integrated into a wide range of human activities, particularly those involving children, such as entertainment and education. This review study deals with EI, ER and critically evaluates the role of emotionally intelligent robots in educational settings, with a focus on their ability to improve learning results and increase social interaction between students. This research examines the existing literature and recent breakthroughs in the field to illustrate the numerous ways in which emotionally intelligent robots can positively benefit educational environments. It looks into the theoretical basis of EI in robotics, the incorporation of affective computing technologies, the evolution of sympathetic actions in robots and also depicts an algorithm outline of a working robot in education sector, along with its practical application using python. Furthermore, the paper assesses empirical research that have looked into the effectiveness of emotionally intelligent robots in educational settings, emphasising their merits and drawbacks. This study provides insights into the future paths of educational robots by synthesising current research findings and highlighting gaps in the literature, as well as emphasising the significance of further study in this quickly growing field.

Keywords: Emotional Intelligence, Educational Robotics, Emotionally Intelligent Robots, Learning Enhancement, Social Interaction etc.

Introduction:

The study on EI in social robots is rising by the day. The topic is related to artificial intelligence (AI). Emotionally intelligent robots use AI techniques, particularly affective computing and machine learning, to recognise, comprehend and respond to human emotions. These robots utilise **AI algorithms** to analyse facial expressions, verbal cues and other behavioural signals to determine emotional states and customise their interactions accordingly.

Artificial Intelligence (AI):

The word "artificial intelligence" (AI) refers to the ability of technology, particularly computer systems, to emulate human intelligence processes. These include self-correction, learning and reasoning. Machine learning, natural language processing, computer vision, robotics and expert systems are just a few of the many subfields that compose AI. By using these subfields, AI systems may now accomplish tasks that were previously limited to human intellect, like speech recognition, complicated data interpretation, decision-making and natural language communication.

Robot:

A robot is a programmable machine that can complete tasks automatically, usually with some level of autonomy. Robots can range from simple devices that perform repetitive tasks to complex systems with advanced skills like movement, vision and decision-making. Robots play a critical role in increasing efficiency, production and safety in a variety of operations.

Algorithm:

Algorithms are step-by-step procedures or formulas for solving problems. They are a set of instructions designed to perform a specific task, often with precision and efficiency. Algorithms can be found everywhere in computer science, from simple tasks like sorting a list of numbers to complex operations like image recognition and natural language processing.

Emotional Intelligence (EI):

EI encompasses a set of skills and abilities related to the understanding, management and utilization of emotions in oneself and others. The major components of EI are:

1. **Self-Awareness:** Understanding and being able to recognise one's own feelings, their origins, their advantages and disadvantages.
2. **Self-Regulation:** The ability to regulate and control one's emotions, impulses and behaviours in a variety of settings.
3. **Motivation:** The determination to pursue goals with zeal and persistence in the face of setbacks or impediments.
4. **Empathy:** Understanding and sharing another's feelings, viewpoints and experiences.
5. **Social Skills:** Proficiency in relationship development and maintenance, efficient communication and conflict resolution.



Figure 1 – Components / Elements of EI

These five components of EI work together to form a comprehensive framework for understanding and managing emotions, both in oneself and in interactions with others.

Educational Robotics (ER):

Information and Communication Technologies (ICT) in education have generated interest in research around the world during the past few decades. Due in large part to the Logo pedagogical movement, ICT use in education led to the initial development of ER in the 1980s. ER makes heavy use of AI concepts. Generally speaking, it describes a method of instruction where students use a robot to either create new information or learn about the robot itself, usually under the guidance of an instructor. ERs come in two varieties. The first is about creating and using a robot. The second phase is to programme a robot to solve an issue and make choices that affect how it behaves. A programmable robot serves as the primary ER tool. Consequently, ER can be seen as a useful tool that helps students design educational experiences. It has to do with both the simple observation and control of a robot and more intricate assignments where students have to plan, solve problems and make decisions regarding the robot's activities in order to foster creative thinking.

Literature Review (LR): The recent literature on emotionally intelligent robots in education emphasises their potential to transform learning experiences.

According to Wang and Zhang (2021), emotionally intelligent robots with affective computing skills can improve student engagement and learning results by tailoring interactions to observed emotions. Baxter et al. (2019) and Jones and Vazquez-Alvarez (2020) found that emotionally intelligent robots boost students' motivation and academic achievement.

Dautenhahn and Billard (2020), who were concerned about privacy, data security, and emotional manipulation, recommend careful thought. Breazeal (2018) further emphasised the importance of transparent design principles and ethical rules.

Kim et al. (2020) and Park and Lee (2021) found that these robots boost peer learning and communication skill development, improving the overall learning experience.

Stipancic et al. (2021) proposed robot functionalities that enable situational embodiment, self-explanation and context-driven interaction.

Khairy et al. (2021) evaluated the use of EI robotics in e-learning to identify their role in interaction motivation throughout education.

Rafique et al. (2020) used a computational robotic model to educate students EI and programming, with the goal of enabling them to be emotionally and cognitively healthy.

Existing research on emotionally intelligent robots in education has concentrated on a number of critical aspects. To begin, the researchers have looked at the theoretical foundations of EI and its application to robots, emphasising the need of empathy, social interaction and personalised learning experiences. Robots can now recognise and respond to human emotions, allowing for more natural and engaging interactions with students enabled by technological breakthroughs in affective computing.

Concerns about privacy, data security and the possibility of emotional manipulation have been expressed, emphasising the significance of transparent design principles and strong ethical rules.

More recent research on the subject describes a computational model for teaching students programming and EI, presents an educational robotics framework that integrates EI into the learning process and discusses a method of deploying social robots as teachers in learning environments.

Overall, while there is mounting evidence of the potential benefits of emotionally intelligent robots in education, more research is required to properly comprehend their influence and resolve ethical concerns. Future research should focus on improving robot designs, determining the best pedagogical methodologies and assessing long-term benefits on student learning and well-being.

Research Gaps:

1. The majority of the current research on emotionally intelligent robots in education concentrates on immediate results, which leaves a vacuum in our knowledge of the long-term impacts on student learning, social development and emotional well-being.
2. Emotionally intelligent robots can be successfully integrated into educational settings, but the best design principles and instructional practices are still up for debate. This underscores the necessity for thorough research that takes into account a range of contexts and student populations.
3. Despite emerging discussions, there remains a gap in addressing ethical considerations surrounding privacy, data security and emotional manipulation in the deployment of emotionally intelligent robots in education, necessitating clearer guidelines and protocols for responsible use.

Objectives of the Study:

This study focuses on robots' emotional intelligence (EI), in relation to the previous discussion. Its objectives are as follows:

- (1) To evaluate the available literature studies on EI, ER and emotionally intelligent robots.

- (2) To develop a theoretical foundation or conceptual framework for EI of robots.
- (3) To create an algorithm outline of a working robot in education sector.

Statement of Problem:

The statement of problem revolves around assessing the long-term impact, addressing ethical considerations and optimizing design and implementation strategies while ensuring equity and inclusivity in educational settings.

Technical Specifications:

The EI-EDUROBOT educational platform is built upon three basic pillars:

- 1) Hardware
- 2) Software
- 3) The Management Platform –Mobile App.

Application:

A basic **algorithm outline** for a working robot in education sector setting is as follows:

1. Initialization:

- Power on the robot and perform self-diagnostic checks.
- Establish connection with the central control system.

2. Task Assignment:

- Receive task assignments from the central control system.
- Prioritize tasks based on urgency, importance and available resources.

3. Navigation:

- Utilize sensors (e.g., cameras, LiDAR) to navigate through the workspace.
- Avoid obstacles and ensure safe movement.

4. Task Execution:

- Follow predefined steps or procedures for each task.
- Utilize appropriate tools or manipulators for task completion.
- Adapt to dynamic changes in the environment.

5. Communication:

- Communicate status updates, progress, and any issues to the central control system.
- Collaborate with other robots or human workers if necessary.

6. Safety Protocols:

- Follow safety protocols to prevent accidents or harm to humans and other equipment.
- Emergency stop procedures in case of malfunctions or unsafe conditions.

7. Maintenance:

- Monitor own health and performance.
- Perform routine maintenance tasks as necessary, such as recharging batteries or cleaning sensors.

8. Data Logging and Reporting:

- Log data related to task execution, performance metrics and any anomalies.
- Generate reports for analysis and optimization purposes.

9. Shutdown:

- Complete assigned tasks or hand off incomplete tasks to other robots or human workers.
- Power down the robot and disconnect from the central control system.

The practical application of the above using python has been shown in Appendix section of the paper.

Implications:

The construction of a conceptual framework with the following main elements was made possible by the thematic analysis (TA) of publications on robots and EI from a theoretical perspective:

- (a) Robotic technology
- (b) Human qualities and roles
- (c) Interactions between humans and robots in various circumstances
- (d) Human perceptions of robots and their EI

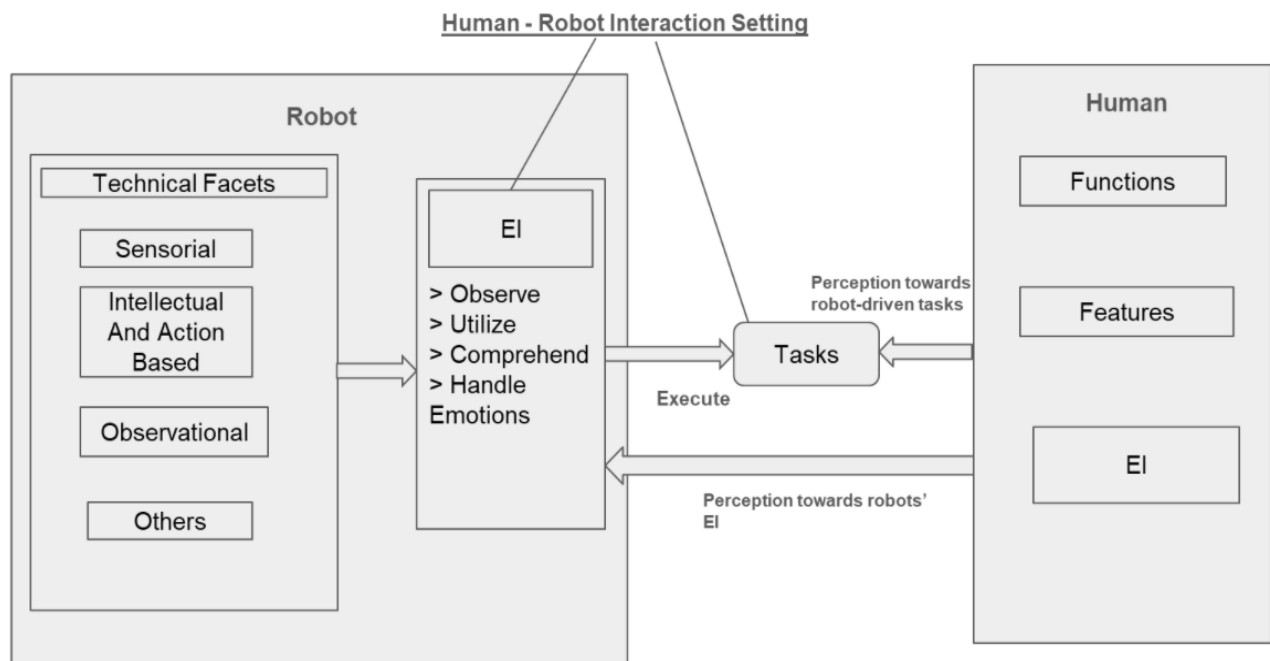


Figure 2 - Conceptual Framework of EI of Robots

In the educational context, emotionally intelligent robots may employ a range of strategies to engage students emotionally and support their learning experiences. These strategies can include displaying empathetic gestures, such as nodding or expressing concern, in response to students' emotional expressions. Additionally, robots may tailor their instructional content and delivery based on the perceived emotional state of the learner, providing personalized feedback or encouragement to boost motivation and learning outcomes.

Findings and Discussion:

Empirical researches have looked into how emotionally intelligent robots affect learning results, student engagement and social interaction.

According to the findings, these robots can improve student motivation, academic achievement and collaboration. However, the effectiveness of different robot designs and interaction modes varies, emphasising the need for additional study to optimise robot-mediated learning experiences.

Emotionally intelligent robots have the potential to boost student collaboration and social interaction by developing empathy and communication skills. Robots, for example, may facilitate group problem-solving activities or lead peer tutoring sessions to develop healthy interpersonal interactions by utilising their ability to perceive and react to social indicators.

Since 2013, there has been a huge increase in the flow of robotics and EI research. Despite the fact that there were just 7 publications from 1996 to 2004, the research output increased to 70 papers between 2005 and 2013 and peaked at 175 between 2014 and 2022. This data shows a significant growth in the literature on robots and EI.

Conclusion:

The EI-EDUROBOT was primarily created to assist children diagnosed with autism spectrum disorder (ASD) in enhancing their social skills through human-like interactions. The EI-EDUROBOT aims to be more user-friendly and less costly than current robots (like the NAO). In addition, compared to other robots (such as Beebot and Bluebot), it possesses more sensors and movement capabilities. Its main advantage is that it is built on open-source platforms, meaning that anybody may programme it and contribute new scenarios and scripts. It is composed of inexpensive parts. Public access will be granted to the building and programming instructions for the EI-EDUROBOT. To help teachers who don't know how to programme with the EI-EDUROBOT, a visual programming interface is also being developed. It is a distinctive kind of robot for both general and special education applications because of the combination of the aforementioned attributes.

Emotionally intelligent robots have the potential to revolutionise education by using advanced sensor and processing technology to identify and respond to human emotions. Through personalised interactions and targeted feedback, these robots have the potential to improve student engagement, motivation and learning results. However, ethical concerns about privacy, data security and emotional manipulation must be properly addressed to enable the responsible deployment of these technologies in educational contexts. Despite these limitations, a growing body of research suggests that emotionally intelligent robots can help students engage and collaborate, cultivating empathy and communication skills that are critical for success in the twenty-first century.

Moving forward, more investment in R&D is required to maximise the usefulness of emotionally intelligent robots in education. Finally, by leveraging the power of EI, robots have the potential to alter education, providing more inclusive, personalised and engaging learning experiences for students all across the world.

The practitioners may find the proposed framework useful in determining how to incorporate emotional robotics into their employment and environments. The framework might be useful for robot designers as well. Robot designers must match the EI of their inventions to the tasks at hand and the locations in which they will be deployed, since creating robots with EI is costly and technically challenging. A room service robot lacks EI, while an educational robot is required to have it.

The algorithm outline discussed in the paper serves as a high-level overview and can be adapted and expanded upon based on the specific requirements and environment of the education sector setting.

Recommendations:

Further Research: Conduct longitudinal research to determine the long-term effects of emotionally intelligent robots on student learning outcomes, social development and emotional well-being.

Ethical Guidelines: Develop explicit ethical rules and standards for designing, deploying and using emotionally intelligent robots in educational contexts to protect privacy, data security and emotional manipulation.

Teacher Training: Provide educators with professional development and training programmes to help them effectively integrate emotionally intelligent robots into their teaching methods and maximise the benefits of robot-mediated learning experiences.

User-Centred Design: Involve students, instructors and other stakeholders in the creation of emotionally intelligent robots to ensure that they match end-user demands and preferences while also encouraging user acceptance and involvement.

Interdisciplinary Collaboration: Encourage collaboration among academics in robotics, education, psychology and human-computer interaction to benefit from varied expertise and viewpoints in the development and testing of emotionally intelligent robots for education.

Accessibility and Inclusivity: Make sure that when designing and programming emotionally intelligent robots, students with a range of skills, experiences and learning styles may use them with inclusivity and accessibility.

Cost-Effectiveness: Investigate low-cost approaches to deploy emotionally intelligent robots in educational contexts, such as using open-source platforms, modular designs and collaborative relationships with industry and academics.

Continuous Improvement: Implement systems for gathering user and stakeholder feedback to iteratively enhance the design and functionality of emotionally intelligent robots, ensuring that they remain reactive to the educational community's changing demands.

By implementing the aforementioned recommendations, stakeholders can fully realise the potential of emotionally intelligent robots to improve learning experiences, boost social interaction and support the development of essential skills among students in a variety of educational environments.

Limitations:

Technological Limitations: Emotionally intelligent robots may still struggle to effectively perceive and interpret complex human emotions, perhaps leading to misinterpretations in educational contexts.

Ethical Concerns: Despite efforts to address ethical problems, issues such as privacy, data security and emotional manipulation may exist, raising questions about the appropriate use of emotionally intelligent robots in education.

Cultural Variability: Emotion expression and interpretation can differ greatly across cultures, creating issues for emotionally intelligent robots constructed with a limited cultural context and potentially leading to misunderstandings or prejudices in interactions with students from various cultural backgrounds.

User Acceptance: Some students and instructors may be reluctant to deploy emotionally intelligent robots in education, citing worries about privacy, autonomy or discomfort with human-robot relationships.

Resource Constraints: Emotionally intelligent robot adoption and use in learning environments may be restricted by the need for substantial technological and financial resources, especially in communities or schools with limited resources.

Generalization of Findings: Findings from studies on the efficacy of emotionally intelligent robots in education may not necessarily be generalizable across different contexts or populations, prompting additional research to investigate the application of outcomes in diverse educational settings.

Limited Understanding: Despite breakthroughs, there is still a limited understanding of the intricate interplay between emotional intelligence, technology and learning outcomes, necessitating ongoing interdisciplinary research efforts to fill knowledge and understanding gaps.

Technical Support and Maintenance: Emotionally intelligent robots may require continuing technological care and maintenance to ensure optimal performance, creating logistical issues for schools and institutions with insufficient resources or experience.

Recognising the aforementioned limitations is critical for responsible development, deployment and evaluation of emotionally intelligent robots in education, as well as guiding future research and practice to properly address these difficulties.

Appendix:

Basic Code in Python:

```
import time

class Robot:
    def __init__(self, name):
        self.name = name
        self.tasks = []
        self.current_task = None

    def add_task(self, task):
        self.tasks.append(task)

    def assign_task(self):
        if self.tasks:
            self.current_task = self.tasks.pop(0)
            print(f'{self.name}: Assigned task - {self.current_task}')
        else:
            print(f'{self.name}: No tasks available')

    def navigate(self, destination):
        print(f'{self.name}: Navigating to {destination}')
        time.sleep(2) # Simulating navigation time

    def execute_task(self):
        if self.current_task:
            print(f'{self.name}: Executing task - {self.current_task}')
            time.sleep(3) # Simulating task execution time
            print(f'{self.name}: Task completed - {self.current_task}')
            self.current_task = None
        else:
            print(f'{self.name}: No task to execute')

if __name__ == "__main__":
    # Create a robot instance
    robot = Robot("Robot1")

    # Add tasks to the robot
    robot.add_task("Task 1")
    robot.add_task("Task 2")
    robot.add_task("Task 3")
```



```
# Assign and execute tasks
robot.assign_task()
robot.navigate("Task Location")
robot.execute_task()

# Assign another task
robot.assign_task()
robot.navigate("Another Location")
robot.execute_task()

# No more tasks
robot.assign_task()
```

Output:

```
Robot1: Assigned task - Task 1
Robot1: Navigating to Task Location
Robot1: Executing task - Task 1
Robot1: Task completed - Task 1
Robot1: Assigned task - Task 2
Robot1: Navigating to Another Location
Robot1: Executing task - Task 2
Robot1: Task completed - Task 2
Robot1: Assigned task - Task 3
```

References:

1. Baxter, P., Ashurst, E., Kennedy, J., & Senft, E. (2019). The effect of embodying emotional reactions on learning in autonomous robots. *International Journal of Social Robotics*, 11(4), 631-641.
2. Breazeal, C. (2018). Emotion and sociable humanoid robots. *International Journal of Human-Computer Studies*, 59(1-2), 119-155.
3. Dautenhahn, K., & Billard, A. (2020). Bringing up robots or children? Learning about the social world. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 364(1535), 1951-1956.
4. Jones, A., & Vazquez-Alvarez, Y. (2020). Exploring the impact of emotionally intelligent robots on student engagement and academic performance. *Journal of Educational Technology & Society*, 23(3), 11-23.
5. Kim, J., Lee, J., & Park, H. (2020). Emotionally intelligent robots in education: a case study of peer learning facilitation. *Computers & Education*, 148, 103783.
6. Park, S., & Lee, H. (2021). Enhancing social interaction in the classroom with emotionally intelligent robots: a longitudinal study. *Journal of Research on Technology in Education*, 53(2), 123-137.
7. Wang, L., & Zhang, Q. (2021). Designing emotionally intelligent robots for personalized learning experiences. *IEEE Transactions on Learning Technologies*, 14(2), 245-256.
8. Faruk et al. (2024). Robots and emotional intelligence: A thematic analysis. *Technology in Society*, (77), ISSN 0160-791X, <https://doi.org/10.1016/j.techsoc.2024.102512>.
9. Anurag et al. (2024). A Study on Gender Comparison of Emotional Intelligence (EI) Among Management Students with Special Reference To NCR. *European Economic Letters*, ISSN 2323-5233, Vol 14, Issue 1 (2024), <https://doi.org/10.52783/eel.v14i1.1209>.
10. Stipancic, T., Koren, L., Korade, D., & Rosenberg, D. (2021). A social robot with teaching and interacting capabilities. *Journal of Pacific Rim Psychology*, 15. <https://doi.org/10.1177/18344909211037019>.
11. Khairy, D., Alkhalaf, S., Areed, M. F., Amasha, M. A., & Abougalala, R. A. (2021). Emotional intelligence robotics to motivate interaction in E-learning: An algorithm. *International Journal of Advanced Computer Science and Applications*, 12(6), 173–183. <https://doi.org/10.14569/IJACSA.2021.0120619>.

12. Akgun, S. A., Ghafurian, M., Crowley, M., & Dautenhahn, K. (2022). Using affect as a communication modality to improve human-robot communication in robot-assisted search and rescue scenarios. *IEEE Transactions on Affective Computing*, 14(4), 3013–3030. <https://doi.org/10.1109/TAFFC.2022.3221922>.
13. Hieida, C., & Nagai, T. (2022). Survey and perspective on social emotions in robotics. *Advanced Robotics*, 36(1–2), 17–32. <https://doi.org/10.1080/01691864.2021.2012512>.
14. Lu, F., Si, W., & Tian, G. (2021). Autonomous cognition and correction system of robot service based on emotional information and case-based reasoning. In 2021 33rd Chinese Control and Decision Conference (CCDC) (pp. 3235–3240). IEEE.
15. Lim, V., Rooksby, M., & Cross, E. S. (2021). Social robots on a global stage: Establishing a role for culture during human–robot interaction. *International Journal of Social Robotics*, 13(6), 1307–1333. <https://doi.org/10.1007/s12369-020-00710-4>.