Connecting AI, Embodied Learning and Student Engagement: A Didactic–Pedagogical Perspective for Secondary Schools

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Abstract
Among the most powerful predictors of learning effectiveness in secondary schools is student engagement. This paper explores the synergistic value of artificial intelligence (AI) and embodiment to increase such engagement. We conducted an experimental study that involved the use of the Nao robot for the development of digital and logical skills, integrated with motor activities oriented to promote embodied processes in Physical Science lessons. Data collection included the administration of the Student Engagement Scale (SES) and a qualitative analysis of student responses. The evidence shows a significant increase in engagement in both cases, with distinct profiles: AI mainly favours the emotional and cognitive components; embodiment predominantly affects the behavioural one. These results suggest that a combination of AI and embodiment could be an innovative strategy to foster more dynamic and engaging learning.

Keywords: *School, Student, Pedagogical Perspective*

Introduction

In recent years, student engagement has become a central topic in educational research because it is closely linked to students' academic success and emotional well-being. According to Fredricks, Blumenfeld and Paris (2004), engagement comprises three main dimensions: emotional, cognitive, and behavioral. Supporting these three dimensions in secondary school proves challenging: students must contend with fluctuating motivation, increasingly complex curricula, and a steadily rising demand for autonomy. Recent studies suggest that applying artificial intelligence (AI) in educational contexts can positively influence engagement and create more dynamic, personalized learning experiences (Ava, 2022). Conversely, the concept of embodiment, which involves learning through physical and bodily interaction, is attracting attention for its potential to activate students' cognitive and behavioral engagement, especially in motor disciplines (Rossi & De Luca, 2023).

The introduction of artificial intelligence (AI) into education has also opened new prospects for enhancing engagement, particularly through interactive tools such as social robots. Recent studies, including those by Belpaeme et al. (2018), show that humanoid robots can interact with students in engaging ways, facilitating the learning of abstract concepts. In parallel, embodiment—learning grounded in physical experience—has been recognized as a powerful tool for stimulating cognitive and behavioral engagement, especially in motor science teaching activities (Gallese, 2011).

The purpose of this study is to investigate how the integration of AI and embodiment can strengthen student engagement in secondary schools by offering activities that combine cognitive and physical components to activate learners on multiple levels. In addition, to enrich our understanding of engagement processes, we adopted a qualitative approach using student focus groups, complemented by quantitative measurements with the Student Engagement Scale (SES). Integrating these methods makes it possible to analyze both the quantitative and observable aspects of engagement and the students' subjective, lived experiences.

1. Methodology: Participants, Evaluation Tools, Instructional Protocol

The study included 60 secondary-school students (ages 14–16) who were randomly split into two groups: an AI group (30) and an embodiment group (30). Each group followed a custom five-week learning program. Students in the AI group took part in interactive sessions with the Nao robot; those in the embodiment group did motor-science activities that emphasized working together through movement.

Student engagement was assessed with the validated Student Engagement Scale (SES), which captures three engagement dimensions: emotional, cognitive, and behavioral. The scale was administered at the beginning and again at the end of the study to detect changes in engagement over time. In addition, focus groups were conducted with a subset of students to gather in-depth qualitative data about their learning experiences. This qualitative component enabled us to probe students' perceptions of working with the Nao robot and of the movement-based activities, and to gain deeper insight into their motivations, emotions, and challenges during the learning process.

Participants in the AI and Embodiment groups attended five weekly sessions of one hour each, with specific activities designed to stimulate engagement according to the approach used. The teaching activities for both groups were delivered by trained teachers, with the aim of maintaining a high degree of standardisation between the two approaches.

2. Teaching with the Nao Robot and AI

The AI team engaged in educational sessions featuring the Nao humanoid robot, an advanced artificial-intelligence system capable of real-time interaction with students. Nao is engineered to interpret voice and visual cues, execute complex motions, and adapt to varied situations, which makes it an effective pedagogical aid. The activities were structured to stimulate curiosity and encourage active student participation.

- *Teaching Activity 1 (AI): Introduction to the Nao robot and its operation*
  During this activity, students had the opportunity to explore the robot and watch Nao perform movements and respond to voice commands. After a short presentation on how AI works, the students were guided into direct interaction with the robot, teaching it simple movements and phrases. This phase was crucial in facil-itating an open and collaborative learning environment, encouraging students to interact with technology that may seem complex. The aim was to familiarise the stu-dents with the robot and to stimulate initial

interest through an interactive activity. This initial approach generated enthusiasm and curiosity, creating a positive and in-clusive learning environment.

- *Teaching Activity 2 (AI): programming exercises*

In this activity, students were introduced to a visual programming language that allowed them to program Nao's movements and vocal responses. Using a drag-and-drop interface, students created sequences of commands for the robot to perform specific actions, such as dancing or answering questions. This activity not only taught the basics of programming, but also encouraged teamwork as students had to work together to design the sequences. The aim is to develop logical and problem-solving skills through programming, allowing students to see the results of their ac-tions in real time. This approach made programming more accessible and less ab-stract, helping students to understand how instructions can be translated into concrete actions.

- *Teaching Activity 3 (AI): problem solving with Nao*

During this activity, Nao posed mathematical and scientific questions to the students, who had to solve them using the information they had learned in the pre-vious activities. Nao not only acted as a virtual teacher, but also provided immediate feedback, encouraging students to reflect on their answers and discuss the solutions in groups. The aim is to increase cognitive engagement and collaborative learning by encouraging students to work together to solve problems. Interacting with the robot stimulated critical thinking as students were encouraged to justify their answers and consider different strategies to overcome the challenges presented.

3. Teaching Embodiment in Motor Sciences

The Embodiment group participated in physical education sessions designed to support learning through movement. These activities emphasised exercises that foster not only physical health but also social interaction and cognitive development, making learning more engaging and dynamic.

- *Teaching Activity 1 (EMBODIMENT): group games and collaborative activities*

Students took part in obstacle courses and team games where they had to work together to complete challenges. Each activity required a combination of physical and communication skills, encouraging students to work together and support each other to achieve goals. The aim is to encourage collaboration and behavioural engagement through movement. The creation of a cooperative learning environment helped to improve interpersonal relationships between the students and strengthen their sense of belonging to the group.

- *Teaching Activity 2 (EMBODIMENT) – Motor coordination exercises*

During the lesson, students carried out activities that demanded synchrony and movement coordination. Through dynamic games—such as ball-passing drills and short dance sequences—they worked in pairs or small groups, practicing mutual listening and non-verbal communication. The goal was to heighten body awareness in space and to sharpen attention and concentration. This physical experience enabled them to explore their own bodies and capabilities while also promoting the acquisition of new motor skills.

- *Teaching Activity 3 (EMBODIMENT): Problem-solving physical activities*

During this activity, students faced motor challenges that required them to find creative solutions to overcome physical obstacles. For example, students were divided into teams and had to design a path for an object using the materials provided to create an innovative solution.

The aim is to promote collaborative learning through physical movement, stimulating the ability to work together to solve complex problems in an active environment. This activity encouraged critical thinking and creativity and allowed students to express their ideas in a practical and engaging context.

In both proposals, the central intention was to create a lively and interactive learning context in which students not only assimilate disciplinary content but also cultivate social and operational skills that are fundamental to their personal growth. The integration of AI-based approaches and embodiment activities proved very effective in enhancing engagement, offering learners different ways of exploring and internalising knowledge.

Table 1. Our elaboration

Teaching Activity	AI Group (Nao Robot)	Embodiment Group (Physical Education)
Teaching Activity 1	Introduction to the Nao robot and interaction using voice and visual commands.	Group games and cooperative activities to encourage collaboration.
Goal	Familiarise students with the robot and stimulate curiosity and initial interest.	Stimulate behavioural engagement through movement and collaboration.
Teaching Activity 2	Introduction to programming the Nao robot using a visual language (drag and drop).	Motor coordination activities: synchronised exercises and ball games.
Goal	Develop logic and problem solving skills through programming.	Improve body awareness and concentration through physical activity.
Teaching Activity 3	Problem solving with Nao in maths and science activities.	Physical activities related to group motor problem solving.
Goal	Encourage cognitive engagement and critical thinking through the robot.	Encourage teamwork and creative problem solving.

4. Results

- *Quantitative Results*

Data collected using the Student Engagement Scale (SES) showed a significant increase in engagement in both groups. In the group, emotional engagement increased by 15% ($p<0.05$), indicating that students felt more emotionally engaged as a result of interacting with the Nao robot. Cognitive engagement also increased by 12% ($p<0.05$), suggesting that using Nao stimulated curiosity and motivation to learn new technical skills.

In the embodied group, behavioural engagement increased by 18% ($p<0.01$), suggesting that the physical activities stimulated more active participation from the students. Cognitive engagement also increased significantly by 14% ($p<0.05$), prob- ably related to experiential learning through movement.

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- *Qualitative Results*

The qualitative analysis of the data collected from the focus groups provided an in depth insight into the students' perceptions and experiences.

In the AI group, the interaction with the Nao robot was received with great enthusiasm. Students often described the experience as *“a new and fun way to learn”.* The robot's ability to interact naturally, answer questions and guide students through complex tasks was perceived as highly engaging. Many students expressed admira- tion for the robot's abilities, pointing out that it not only explained technical con- cepts, but was also able to adapt to their responses. For example, one participant said “*Nao made me feel like I was playing, but I was actually learning*”.

A recurring element in the discussions was the sense of curiosity generated by interacting with a humanoid robot. Some students reported that the use of advanced technology motivated them to ask more questions and experiment with more confi- dence, as the robot was perceived as 'non-judgmental' compared to a human teach- er. However, a less positive side emerged: some participants reported feeling over- whelmed during the more technical phases of the activities (for example, programming the robot). One participant commented: *“I was enthusiastic at first, but when I couldn't get the programme to work, I got frustrated”.* This suggests that although the robot can be an excellent initial facilitator, it is important to calibrate the difficulty of the activities according to the level of competence of the students.

Other comments suggested that the experience with the robot fostered a unique form of emotional engagement, while other students emphasised that the robot, with its voice and movements, evoked empathy and a sense of connection.

In the embodiment group, students reported mostly positive experiences, emphasising the value of learning through movement and collaboration. An emblematic phrase that emerged from the focus groups was: *“Moving helped me to understand better what we were doing”.* This suggests that physical learning had a direct impact on understanding and recalling the concepts covered. Pupils described the motor activities as 'fun' and 'stimulating', emphasising that the playful aspect of the learning activities made the experience less stressful and more memorable.

Another element that emerged was a sense of belonging and social connection. Working in groups to complete motor activities strengthened relationships between pupils and improved cooperation and communication. One participant stated: *“We had to think together and move as a team, which made me feel part of something bigger”.* This social dimension was perceived as particularly rewarding, especially for students who tended to be less participative in other contexts.

Some students commented that body movement helped them to maintain con- centration throughout the lesson, reducing monotony and feelings of fatigue. One participant commented: *“I'm usually easily distracted, but doing body activities kept me alert and engaged”.* However, some criticisms were made, particularly by students less used to physical activity or with motor difficulties. These participants reported that they sometimes felt at a disadvantage compared to their peers, suggesting the need to adapt activities to different levels of physical ability.

5. Discussion

Emerging evidence indicates that AI and embodiment represent effective and mutually complementary strategies to support student engagement, offering distinct responses to learners' cognitive, emotional and behavioural needs. The use of the Nao robot highlighted how AI can generate a personalised and interactive learning context, capable of focusing students' attention and promoting interest in complex domains such as programming and problem solving. In line with the findings of Belpaeme et al. (2018), social robots prove to be particularly effective mediators of learning due to the natural and engaging quality of their interactions. In parallel, the embodied approach exerts a marked impact on behavioural engagement, recalling the central role of physical movement in learning processes. Gallese (2011) points out that embodiment activates neural circuits of action and promotes an experience of belonging and participation, capable of reinforcing students' general involvement; physical practice also supports the development of transversal skills such as cooperation and problem solving. Among the most original aspects of the work is the prospect of making AI and embodiment work together. Although they have been examined separately here, we can imagine lessons in which social robots help to make physical activities richer and more structured: they could lead warm-ups, propose point trails or coordinate teams in cooperative competitions that require both technological input and movement. Such an approach could increase engagement and, at the same time, bring subjects such as computer science and exercise science into dialogue. Qualitative evidence underlines the need to calibrate teaching activities to the students' level of competence and interests. Without appropriate adaptation, some may feel excluded or overwhelmed, particularly when the activity requires high technical skills or specific movements. It is therefore appropriate for teachers to offer graded routes or differentiated alternatives. Our work marks an advance towards more inclusive and multidimensional teaching practices, capable of integrating emerging technologies and bodily learning to create richer and more motivating contexts. Future studies should further investigate how to combine AI and embodiment and evaluate the long-term effects on motivation and school performance.

Conclusions

Summing up the results: Artificial Intelligence works well to stimulate students' interest and cognitive processing, while embodied practices foster active participation and engaged behaviour. Bringing these two strands together-for example, using social robots such as Nao to support guided motor activities-can generate more inclusive and all-round educational experiences. The next challenge for teachers will be to translate this integration into coherent curricular sequences that develop not only disciplinary knowledge but also critical skills for the future. Further research will have to explore how to adapt these pathways to different student profiles to optimise motivation and academic achievement. In times of increasing intersection between digital technologies and the body, schools have an opportunity to rethink themselves.

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