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The potential of Montessori Pedagogy in the development of an Educational Chatbot: a research project

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Abstract: Recent ministerial guidelines on Innovative Learning Environments (ILE), outlined in Ministerial Decrees 65 and 66 of 2023, recognize the configuration of learning environments as a central element in the cognitive processes and social interactions that characterize inclusive teaching practices. At the international level, the OECD anticipated this perspective as early as 2008, significantly contributing to the redefinition of the ILE concept in relation to the profound changes induced by the increasing use of digital technologies in educational contexts. In subsequent contributions (OECD, 2010; 2013; 2017; 2025; INDIRE, 2014; 2016), the learning environment is progressively conceived not merely as a physical space, but as a hybrid ecosystem in which spatial, methodological, and technological dimensions interact systemically to determine the quality of educational processes. Within this framework, digital technologies and, in particular, Artificial Intelligence (AI)-based platforms, assume a structural role in making the environment adaptive and responsive to individual needs, fostering more experiential, participatory, and personalized forms of learning (Caprino et al., 2022; Kasneci et al., 2023; Fauzi et al., 2023). This approach aligns with the principles of active Montessori pedagogy, which conceives the environment as a pedagogical device capable of supporting autonomy, inclusion, and the active construction of knowledge (Montessori, 2017; Aiello, 2023). In light of these premises, this contribution presents the first phase of a broader research project aimed at creating a Virtual Tour of the *Montessori Children's House*. Specifically, the work illustrates the design and testing of an educational chatbot intended to support the learning of Montessori pedagogical principles in a university setting.

Keywords: Innovative Learning Environments (ILE); didactic chatbot; inclusion

1. Introduction

Since the early 20th century, learning spaces have assumed a central role in pedagogical reflection. The rise of the Pedagogical Activism and Puerocentrism movements led many scholars to recognize that educational environments should be intentionally designed to facilitate children's movement, exploration, and autonomy development (Nicodemo & Gomez Paloma, 2014). Within this perspective lies the experience of Don Milani, who championed workshop-based activities as a privileged educational tool (1967), as well as the thought of John Dewey with the principle

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of "learning by doing" (1938, 2014), later adopted and systematized by Maria Montessori (Aiello, 2023; Montessori, 2017). Indeed, in the Montessori Method, the educational space plays a structuring role, conceived as being "child-sized" and oriented towards fostering autonomy, self-determination, and active learning. A similar attention to learning environments emerges from the contributions of Loris Malaguzzi, who adds the role of the "third educator" to the space (Malaguzzi, 2010), recognizing its pedagogical and relational value within the educational process.

More recently, on the international stage, the Organization for Economic Co-operation and Development (OECD) has provided a significant contribution to the conceptual redefinition of Learning Environments. Starting in 2008 with the publication *Innovating to Learn, Learning to Innovate*, the OECD highlighted the circular relationship between learning and innovation, emphasizing how learning processes are simultaneously the outcome and the driver of educational innovation. In this context, the report identified three strategic areas for intervention: research on learning processes, implementing change in educational contexts, and the analysis of innovative practice case studies (OECD, 2008). Subsequently, in 2013, the OECD promoted the Innovative Learning Environments (ILE) project (OECD, 2013), aimed at the systematic study of 125 international cases, with an in-depth focus on 40 selected experiences from North America, Asia, and Europe. The analysis revealed educational models capable of overcoming the traditional teacher-centered approach, valuing interdisciplinary designs, the innovative use of digital technologies, and the construction of inclusive learning environments oriented towards promoting accessibility, active participation, and educational equity for all students (Castoldi & Pisanu, 2018).

Building on this, the most recent guidelines (OECD, 2017) reaffirm the centrality of space design as a lever for teaching innovation. In particular, the OECD and INDIRE converge in defining effective learning environments as hybrid ecosystems, where physical, social, and virtual dimensions interact dynamically and in an integrated manner (OECD, 2017; INDIRE, 2024; 2016). From this perspective, digital and emerging technologies, including Artificial Intelligence (AI) platforms, are not conceived as mere additional tools, but as pedagogical mediators capable of expanding possibilities for action, interaction, and knowledge construction, provided they are integrated within a conscious and intentional teaching design (OECD, 2017).

In this regard, the International Guidelines from the OECD (2025) outlined in the report *AI Adoption in The Education System: International Insight and Policy Considerations for Italy* confirm this vision, emphasizing the need to guide AI adoption according to four guiding principles: pedagogical intentionality and alignment; teacher centrality; precaution and educational oversight. Consistent with these recommendations, numerous recent studies (Benvenuti et al., 2023; Caprino et al., 2022; Coggi & Bellacicco, 2023; Crawford et al., 2023; De Angelis, Botes & Orlando, 2024; Fauzi et al., 2023; Kasneci et al., 2023; Kikalishvili, 2023; Lecce & Di Tore, 2025) highlight how AI-based chatbots represent promising tools for creating personalized and inclusive learning environments. They offer "tailored" tutoring for students with different profiles, special educational needs, or heterogeneous cultural backgrounds (Fauzi et al., 2023), adapting explanations, examples, and feedback to the pace and specificities of each learner (Kasneci et al., 2023; Kikalishvili, 2023). Furthermore, some studies

(Crawford et al., 2023; Benvenuti et al., 2023) emphasize that the constant availability of a digital interlocutor fosters forms of autonomous and active learning, supporting content exploration and individual in-depth study.

Based on these premises, this contribution aims to illustrate a preliminary phase of a broader research project aimed at creating a Virtual Tour of the Montessori Children's House. Specifically, the work describes the design and testing process of an educational chatbot conceived to support the learning of Montessori pedagogical principles in a university setting, outlining its theoretical and methodological framework.

2. Materials and Methods

2.1 Objective

In reference to the theoretical framework outlined, this contribution aims to illustrate a design proposal focused on the description and testing of an educational chatbot intended to support the learning of active Montessori pedagogical principles in a university setting, fostering processes of autonomy, exploration, and self-regulation in learning.
Specifically, the work aims to:

- Illustrate the methodological and technological choices adopted in designing the chatbot, trained on the principles of Montessori pedagogy.
- Define the lines of inquiry through which, in subsequent research phases, it will be possible to explore the students' interactive experience with the tool.

2.2 Participants

The research sample will consist of students enrolled in the Bachelor's Degree program for Educational Sciences (class L-19) at the University of Salerno. Specifically, the study will involve students attending the course on Special Education in Early Childhood Educational Services. The choice of the university context is functional to the research objective, as it allows for exploring students' opinions regarding interaction with the chatbot, considered as a support tool for theoretical study and pedagogical reflection within an initial training path for educators.

2.3 Data Collection Tools

A semi-structured questionnaire will be used for data collection, specifically designed to gather participants' opinions and awareness regarding the experience of interacting with a chatbot designed to study Montessori pedagogy principles.

The questionnaire, created using the Google Forms platform, consists of seven questions organized into two sections:

- The first section includes four closed-ended questions aimed at collecting socio-demographic and contextual information, such as previous educational qual-

ifications, age, and any prior experience in using chatbots, as well as the main purposes for using such tools.

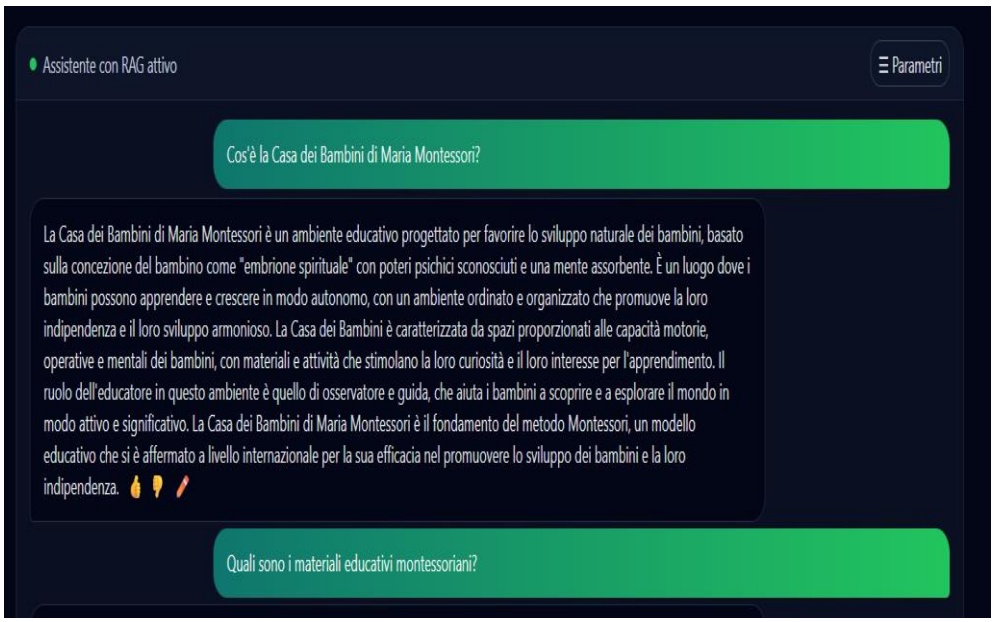
- The second section includes three open-ended questions intended to explore the digital tool interaction experience from a qualitative perspective. Specifically, the items explore:
  1. The ways in which the interaction impacted the understanding of the fundamental aspects of the Montessori method.
  2. Perceptions regarding the degree of guidance, autonomy, and opportunities for exploration compared to traditional lecture-based instruction.
  3. The educational potential attributed to the tool in a university setting, highlighting its limitations and suggestions for improvement.

2.4 Procedure: Design and Development of The Montessori Chatbot

A first prototype of an educational chatbot was developed, aimed at supporting university students in studying the principles of Montessori pedagogy, with the objective of fostering processes of autonomy, self-regulation, and active learning. The chatbot was conceived as an accessible and highly customizable conversational environment, whose dialogic infrastructure is based on the integration of the LLaMA 3.3 language model (Large Language Model Meta AI), a neural architecture capable of generating adaptive responses based on user inquiries and informational needs. Furthermore, the tool underwent a fine-tuning process using a selected corpus of scientific and educational texts related to the theories and principles of active Montessori pedagogy. This process focused particularly on the role of learning environments and educational materials (Aiello, 2023; Montessori, 2017), to ensure conceptual and pedagogical coherence during interactions (Figure 1). From an evolutionary perspective for the chatbot, the implementation of Reinforcement Learning from Human Feedback (RLHF) procedures is planned. This technique allows for the progressive optimization of the system's responses based on human evaluations, helping to improve their relevance, educational effectiveness, and adherence to the referenced pedagogical principles. Finally, the device will be integrated into a three-dimensional digital environment developed using the Unity 3D graphics engine. This integration is functional for creating immersive and interactive experiences consistent with the realization of the Montessori Children's House Virtual Tour. In an initial phase, participants will be introduced to the chatbot's general operation and the activity objectives, specifying that the tool was designed to support the study of Montessori pedagogical principles through personalized dialogic interaction. Subsequently, students will be provided with a link to access the Artificial Intelligence platform, allowing them to interact freely with the chatbot for a period of 20 to 30 minutes. This phase aims to foster processes of autonomous exploration, self-regulated learning, and active knowledge construction, aligning with the theoretical assumptions of Montessori pedagogy (Montessori, 2017). At the end of the interaction experience, students will be asked to complete a semi-structured ques-

tionnaire designed to gather their opinions and the level of awareness developed in relation to using the tool.

Figure 1: Chatbot for Active Montessori Pedagogy



2.5 Data Analysis

The data collected through the semi-structured questionnaire will be analyzed using a mixed-methods approach (Tashakkori & Teddlie, 1998), differentiated according to the nature of the questions. Responses to the closed-ended questions will undergo descriptive quantitative analysis for the exploratory purpose of understanding the sample and the experiences reported by the students. Conversely, responses to the open-ended questions will be analyzed using thematic analysis with emergent categories, following an inductive-deductive qualitative approach (Braun & Clarke, 2006). Specifically, the analysis process involves an initial phase of familiarization with the data, followed by the coding of units of meaning and the subsequent identification of recurring themes (Braun & Clarke, 2006).

3. Conclusions

The growing focus on the design of learning environments, both nationally and internationally, suggests the importance of rethinking the role of digital technologies from a pedagogically oriented, rather than merely instrumental, perspective (OECD, 2017). In this regard, AI can represent a significant lever for teaching innovation (Benvenuti et al., 2023; Caprino et al., 2022; Kasneci et al., 2023), provided its inte-

gration is intentional and consistent with theoretical frameworks (Lecce & Di Tore, 2025).

Based on the above, this contribution aimed to present a model for an educational chatbot inspired by the principles of Montessori pedagogy and conceived as an educational mediator capable of supporting autonomous and exploratory learning processes in a university setting. The combination of the ILE framework (OECD, 2017; INDIRE, 2014, 2016) and Montessori thought (Montessori, 2017) has allowed for interpreting the AI-based conversational tool not as a simple study aid, but as an integral part of a hybrid learning ecosystem (INDIRE, 2016), in which technological, methodological, and relational dimensions interact systemically.

From a design perspective, the choice of architecture based on advanced language models, fine-tuned on a targeted scientific corpus, addresses the need to ensure content coherence and reliability, as well as the educational intentionality of interactions.

The outlined experimental phase, though exploratory in nature, lays the groundwork for future empirical investigations aimed at delving deeper into students' interaction patterns with the chatbot, as well as their opinions regarding the degree of autonomy, guidance, and support provided for understanding the principles of active Montessori pedagogy, also in relation to traditional teaching methods. From this perspective, the contribution aims to fuel the scientific debate on the relationship between pedagogy and the conscious use of Artificial Intelligence, highlighting how technological innovation can find a solid and fertile theoretical reference for designing inclusive, personalized, and student-centered learning environments within the frameworks of Montessori pedagogy.

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