Skill Development Through Artificial Cognitive Systems and Social Robotics applied at Tech-Education

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Abstract

The focus of this research is to demonstrate how a platform composed of systems of artificial cognitive agents and social robotics can interact, teach and learn with students and teachers, through a pedagogical practice and methodological integration of the psychological concepts of Howard Gardner Theory of Multiple Intelligences (Gardner 1983), educational foundations of Paulo Freire's Dialectical methodology (Freire 1967), and JCR-Licklider's about Man-Machine Symbiosis (Licklider 1960).

The objective of this article is to present the cognitive methodological concept of the project developed, from the theoretical foundations, to the selection criteria for the models presented in the current discussions, taking as reference the works from: Mike Ligthart (Ligthart 2020), Tony Belpaeme (Belpaeme et al. 2018), Kim Baraka (Baraka and Veloso 2018), Cristina Gena (Gena et al. 2022), Alessandra Sciutti (Sciutti et al. 2018) and, Séverin Lemaignan (Lemaignan et al. 2017).

Platform Composed of Systems of Artificial Cognitive Agents and Social Robotics

The challenges of technological education (STEAM and CTE) are present across the globe (Kang 2019), (Kuz, Falco, and Giandini 2018). Our motivation is contained in the desire to use the integration between technologies and methodologies to positively impact learning and the development of skills in the classroom (Sciutti et al. 2018).

This proposal aims to organize, standardize and structure the concept of technological education aimed at the vocational and professional segment within learning environments in a location close to the reality of students and teachers (Blikstein 2013).

With the aim of carrying out practices and objectives to respond to the following arguments:

1. What's the problem?

"Lack of evolution in Technological Learning"; As the demand for quality education in technological disciplines grows, Intelligent Tutorial Systems (ITS) (Nwana 1990) emerge as an alternative to provide learning activities that better meet the cognitive needs of students. But the challenge goes beyond providing feedback on performance, it is necessary to work on the education of concepts focused on individuals (Doncieux et al. 2022).

The traditional, one-size-fits-all educational model often fails to adequately engage and support students. The essence of this approach lies in the recognition that students are not uniform in their abilities, strengths or learning styles.

2. How to solve this problem?

Proposal for a platform with an artificial cognitive system: Using the concept of storytelling based on the path of multiple intelligences (Ligthart 2020).

The concept of storytelling, as a pedagogical tool, offers a multifaceted path to engaging students of diverse intelligences, as theorized by (Gardner 1983).

However, the developed system transcends the limits of conventional didactics, presenting educational content in narrative form, thus taking advantage of linguistic, logical-mathematical, spatial, kinesthetic, musical, interpersonal, intrapersonal, naturalistic and existential intelligences.

3. What technologies and methodologies will be used?

Emphasize the importance of the cognitive aspect through a physical robot (Breazeal et al. 2017) with an Artificial Cognitive System (Soar Architecture) creating a symbiotic interface inserted in an interactive digital book (Proprietary WebApp) uniting humans, machines and software interconnected through this knowledge development environment with content, technical information and challenges, as well as homework to explore individual and collective aspects to help them improve their technical skills in the best way by abstract concepts (Cangelosi and Asada 2022).

The adoption of social robotics technology was motivated by the understanding that the technological education scenario is not covered in an adequate and viable way by solutions that actually seek integration with students, which is why social robotics (Junior 2021), demonstrates significant advantage in this symbiotic threshold of integration between machine and human, hardware, software and cognitive modeling (Licklider 1960), (Newell 1994).

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Figure 1: Block diagram to demonstrate the platform concept, with the Soar architecture at the center of collecting data from all actors, the Raspberry as the host, the WebApp as the Interactive Book interface and the Social Robot performing real-world functions.

As shown in figure 1, the Interactive Book will be responsible for collecting data on all students' actions, and at the same time being a bridge for students' interaction with the Robot; It is in this cycle that the teacher will be able to receive feedback informing about each student's performance.

Main Fundamentals and Selection Criteria

1. Technological Education: With a professional bias towards qualifying professionals for industry and the workforce, based on Paulo Freire's critical methodology of dialectical education (Freire 1967), where our intention will be to create dynamic content, which allows students to consume content constructed from the environment around them, but which is motivated to solve problems based on constructive conflicts;

2. Artificial Cognitive Systems: There are several cognitive architectures available for use, like ACT-R, CLARION, LIDA, and others, in this project was selected the Soar Architecture, due to some important elements such as: high level of reliability, large development community active for over 40 years and maintained by the Michigan University, versions available in Java and compatible with API's used in this project in C, C++ and Python. (Laird et al. 2017), (Mohan 2021);

3. Learning Psychology: deepening the field analysis based on Howard Gardner's theory of multiple intelligences (Gardner 1983);

4. Social Robotics: bringing a purely educational approach, as seen in the work of (Belpaeme et al. 2018), (Cangelosi and Schlesinger 2015) but highlighting the importance of making a short-term impact on technological and professional schools in regions with fewer resources.

Didactic Platform and Social Robot

For the development of this project layer, it was important to define the creation of an educational robot focusing on low-cost components.

Initially, the prerequisites were defined to ensure that this robot could be classified with the minimum capacity for social interaction.

Features Available Through the WebApp Interface

Access to the Interactive Book Teachers and students can access the teaching content through the WebApp interface. The primary objective of this software is to serve as an aid in the development of skills.

Students, on the other hand, can consume this content and navigate personalized learning paths within their storytelling journey. As students progress along their knowledge trajectory, the system collects valuable data, as illustrated in Figure 2:

1. Dedication Level: This metric measures the time spent on a page to gauge the student's level of dedication to an activity. For instance, if a student spends less than 30 seconds on a page, they receive a score of 0; if they stay between 30 seconds and 4 minutes, they score 1; and if they remain on the page for over 4 minutes, they also score 1.

2. Level of Commitment: This assesses students' engagement with the challenges presented in classes. The system analyzes the number of attempts students make on random questionnaires until they answer correctly. If a student answers a question correctly on the first attempt, they receive a score of 1. However, if they take multiple attempts or choose to "skip" a question, indicating reduced motivation, they score 0, and an alert is sent to the teacher.

3. Level of Participation in Group Activities: Teachers can propose collaborative challenges, and the system monitors individual student interactivity within these activities. Each group task aims to enhance social engagement, and the system scores each student with 1 when both students successfully complete their assigned tasks.

4. Research Capacity: In certain cases, teachers may enable this feature, allowing students to search for information and solutions to unsolved problems. The teacher can score students who meet this challenge with a 1.

5. Main Difficulties: The system identifies content areas where students encounter the most challenges. Teachers can view evaluations on a scale from 0 to 10 to better understand student struggles.

6. Big Five Performance: Teachers can enable this module to gain insights into students' personalities based on the Big Five personality traits: extraversion, agreeableness, openness, conscientiousness, and neuroticism. This information is collected through a framework of questions (De Raad 2000).

7. DISC Profile Test: By enabling the behavioral profile analysis module, teachers can gain insights into students' dominant characteristics based on the DISC framework (Dominance, Influence, Stability, and Conformity) (Gerber et al. 2011).

8. Type of Intelligence Dashboard: This module allows teachers to track students' progress in relation to multiple intelligences, as per the theory of multiple intelligences (Gardner 1983).

9. Total Attempts and Objective Success Rate: Teachers can access a timeline-based view of students' technical progression over time, considering their maximum capacity and current position on their learning journey.

10. Class Attendance: This module provides a simple count of student attendance according to the academic class schedule, presented in a monthly timeline graph format.

Please note that for items 6, 7, and 8, specific frameworks are used for these tests, which are modeled in the artificial cognitive system to understand students' evolution within these aspects. Detailed modeling information can be found in our dissertation, as referenced by (Souza 2023).

It's important to clarify that the Interactive Book is intended for student interaction, while the teacher profile is exclusively for accessing the dashboard system.

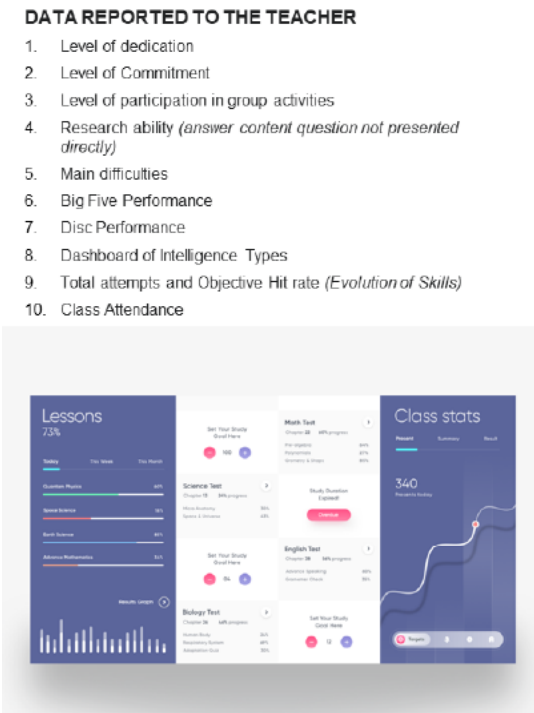

Figure 2: The system's dashboard will only be accessible through the teacher's login so that only he and his managers can access the reports issued by students.

SOAR Cognitive Architecture

Soar Architecture (Laird 2012), despite having been developed with the purpose of being a general problem solver, is a formidable option when it comes to solving the challenge of understanding and developing human skill levels. It stands out for several reasons:

By employing the SOAR Architecture as the middleware and developing a user-friendly WebApp, the project ensures a robust software infrastructure for controlling the social robot's behavior, facilitating communication, and providing an intuitive interface for users (Laird et al. 2017). This software ecosystem enhances the overall functionality and usability of the robot, enabling effective engagement and interaction with learners in educational settings.

Soar architecture provides a solid foundation for developing artificial cognitive systems that can learn and develop skills over time, making goal-based decisions and modeling human cognition. It is especially suitable when the objective is to teach machines to perform tasks in a similar way to humans.

Cognitive Agents

The cognitive agents that will be featured collectively form the backbone of the platform, ensuring a personalized and adaptive learning experience for students while monitoring their progress, emotions and interactions to provide valuable insights for students and educators (Gena et al. 2022), (Neumann and Baumann 2021).

Below is an explanation of the Functions and Relationship between Agents as can be seen in figure 3.

Agent 1: Student Profile Collector

The main function of this agent is to gather comprehensive information about the student's profile. It assesses the student's affinity levels with each of the nine types of intelligence proposed by Gardner's theory. The agent operates within a three-tier model. In the first layer, it evaluates the student's level of affinity with each type of intelligence. The second layer analyzes decision-making processes in real time to adapt the student's intelligence type. Finally, the third layer provides a dashboard that displays student affinity levels within each intelligence type.

Agent 2: Student backlog manager

This agent is responsible for answering questions that aim to identify the student's type of intelligence.

Agent 3: Storytelling Coordinator

The Storytelling Coordinator is another agent who operates within a three-tier structure. The first layer selects the next lesson based on the previous one and the user's interactions with the proposed type of intelligence. In the second layer, it evaluates the possibility of alternative paths, considering the potential development of a new type of intelligence or capitalizing on a solid foundation with high affinity. In the final step, it compares the previously presented content, the next content and the affinity level to determine the next "lesson".

Agent 4: Controller of Emotion and Expression

This agent is responsible for controlling the robot's emotions and expressions, specifically focusing on the robot's eyes, LED-RGB belt and arms (when not involved in component collection operations).

Agent 5: Navigation Controller

The Navigation Controller plays a crucial role in managing the robot's movements. It helps control the robot's navigation, whether it is following a specific path, operating by coordinates or integrating autonomously with the ROS (Robot Operating System) platform.

Data Collection and Analysis

Data collection for the research will involve multiple methods and sources. These include:

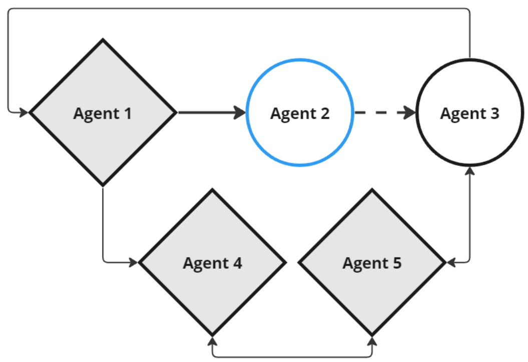

Figure 3: It presents the flow of communication between agents, Agent 1 is responsible for making decisions, while the others provide status information and execute actions according to student feedback.

1. User Interaction Logs: Logs will be recorded during user interactions with the robot and the WebApp. These logs will capture user commands, robot responses, and system events, enabling a detailed analysis of user-robot interactions.
2. Performance Metrics: Quantitative data will be collected through performance metrics such as completion time, accuracy, and task success rates. These metrics will provide objective measures of the robot's performance and progress over time.
3. Observations: Researchers will observe the robot's interactions, behaviors, and responses during experiments and real-world scenarios. Detailed notes and recordings will be made to capture relevant information.
4. Surveys and Questionnaires: Participants, such as teachers and students, will be given surveys and questionnaires to gather their feedback, opinions, and experiences regarding the robot and its impact on their learning and engagement.
5. Interviews: In-depth interviews will be conducted with educators, experts in the field, and stakeholders involved in the project to gain insights into their perspectives, challenges, and recommendations.

Detailed information about logs, survey forms and others questions and templates can be found in our dissertation, as referenced by (Souza 2023).

Experiment

In the following scenario, let us consider that the teacher intends to convey the fundamental concept of the constant of “Pi” to the students. It is well established that the irrational number 3.14159... plays a crucial role in basic mathematics, particularly in defining cylindrical measurements, circumferences, and other geometric concepts.

The challenge of this class is for students to understand, through the platform and using the ”Interactive Book” with the theoretical content about Pi. They will learn to calculate the radius and, with the teacher's guidance, program the robot's movements to perform specific tasks, such as advancing 1 meter, turning 90 degrees and repeating this process to complete a closed square.

Throughout this lesson, students will not only gain a theoretical understanding, but also apply this knowledge in practice, improving their understanding of one of the fundamental principles of mathematics. The platform will be leveraged to its full potential, collecting valuable data, inferring cognitive concepts and providing insights to educational administrators, teachers and even parents, contributing to a holistic educational experience.

To evaluate the effectiveness and performance of cognitive agents and their integration into social robotics, an extensive experimental study was designed. The experiment involves a series of interactions between cognitive agents and human participants in a professional educational environment.

Performance Evaluation

To evaluate the performance of cognitive agents, several metrics were employed to measure different aspects of their behavior and impact on participants. These metrics include task completion rates, response accuracy, user satisfaction scores, and learning outcomes.

Analysis of Interactions

The analysis of the collected data focused on examining the interactions between cognitive agents and participants. The agents' behavior was analyzed in terms of engagement, adaptability and social intelligence, as well as the participants' responses, including their level of engagement, attention and satisfaction.

Furthermore, the adaptability of the agents to the individual needs and preferences of the participants was considered. This analysis involved assessing the agents' ability to personalize the learning experience by adapting their responses and explanations based on participants' prior knowledge, learning style, and areas of interest.

Conclusion

The information presented considers the development progress of this research project, focusing on the main aspects of artificial cognitive systems and social robotics. it is possible to understand the importance of structural memory (symbolic and episodic available in the Soar Architecture) to facilitate the storage and retrieval of information, as well as the integration of cognitive capabilities through the Student Profile Coordination agents, Backlog Coordinator, Storytelling Coordinator , Robot Emotions and Expressions Coordinator and Navigation Coordinator.

A relevant novelty of this approach is that it brings together what can be considered a multi-agent system for an environment that has not used multi-agents together in the past. Educational environments often employ a robot, or a webapp, or some form of “smart” software, but all three have not been found in a single architecture, as proposed in this work.

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