Multi-Agent Systems and Artificial Intelligence supporting students throughout academic life

Yasmim Rosa[1], **Milene Serrano**[1], **Maurício Serrano**[1]

[1]Faculdade de Ciências e Tecnologias em Engenharia (FCTE) – UnB
CEP 72444-240 – Campus Gama – Gama – Brasília – DF – Brasil

yasmim.rosa@aluno.unb.br, {mileneserrano, serrano}@unb.br

Abstract. *This paper describes an organizational model of metaversity, and the ongoing implementation of a Multi-Agent System with Artificial Intelligence. The goal is to explore a more student-centered approach, supporting them throughout their academic life. This proposal becomes a complementary means to traditional teaching, engaging students in a friendly and attentive environment. Similar approaches are discussed. Reflections are made about the contributions, weaknesses, and future work of the approach. This approach relies on the Agent-Group-Role Model, MaDkit, and Large Language Models.*

Resumo. *Esse artigo descreve uma modelagem organizacional de metaversidade, e a implementação do Sistema Multi-Agentes com Inteligência Artificial. O intuito é explorar uma abordagem mais centrada no estudante, amparando-o ao longo da vida acadêmica. Essa proposta torna-se um meio complementar ao ensino tradicional, procurando engajar o aluno em um ambiente mais amigável e atencioso às suas necessidades. Abordagens similares são conferidas. Reflexões são reportadas sobre as contribuições, fragilidades, e perpectivas da abordagem. Essa abordagem apoia-se em Agent-Group-Role Model, MaDkit, e Large Language Models.*

1. Introduction

In modern societies, young people are exposed to various stimuli and gamified, interactive and dynamic environments [Shanmugasundaram and Tamilarasu 2023]. However, in many universities, teaching is still very traditional, based on the teacher as the main authority and static materials that do not attract students' attention. Even learning platforms with more attractive resources, such as Moodle-oriented learning environments [Olugbade et al. 2023], do not compare to modern visual materials available on video platforms (e.g. YouTube) or assisted language learning approaches [Loewen et al. 2019].

Since students have specific skills and learn in different ways throughout their academic life, it is necessary to innovate teaching and learning approaches. The purpose of this ongoing work is to represent lifelong learners and their companions within metaversity. This proposal is based on the original idea documented in Nóbrega et al. (2024), and agrees on evolutions oriented toward the Multi-agent Systems (MAS) and Artificial Intelligence (AI) (e.g., Large Language Models (LLMs) [Ross et al. 2025]).

This paper is organized in Sections: Related Work (Section 2), Theoretical Foundations (Section 3), Modeling and Implementation of Metaversity (Section 4), Discussion (Section 5), and Conclusion (Section 6).

DOI: 10.5753/wdescentraie.2025.15922

2. Related Work

Related work that inspired this project includes research conducted by Northwestern's CCL [NET-LOGO 2025], which seeks to teach using playful resources (e.g., more didactic platforms [SoftwareTools 2025]).

Kaledio et al. (2024) argue that the advantage of AI in education is its ability to provide immediate and constructive feedback to students, allowing them to understand their strengths and weaknesses in real time. This feature, when combined with the architecture of MAS, can further enhance the learning process.

In Afzaal et al. (2023), the authors propose a "transformer-based approach", which models students' knowledge of various course concepts, guided by their performance in various evaluated tasks. Then, this modeling is combined with the learning support materials offered by a course, generating exercises in a personalized way.

3. Theoretical Foundations

Three key concepts support this work: MAS, AI and Agent-Group-Role (AGR) Model.

A software agent can be understood as a computational entity capable of acting independently on behalf of its user or owner. In a MAS, agents act collectively through message exchange to achieve a set of goals [Wooldridge 2009]. For Selker (1994), agents are entities that simulate a human relationship. They model complex real-world scenarios with distributed and decentralized information and control.

AI is a branch of science dedicated to the development of systems capable of performing complex tasks that require human intelligence and autonomous decision making [Minh et al. 2022]. The implementation of intelligent agents in e-learning architectures, as proposed by Nadrljanski et al. (2018), allows to achieve systems tailored to the needs of each student. This approach aligns with the current demand for educational environments that transcend the traditional model and offer truly personalized experiences.

Considering the AALAADIN Model proposed by Ferber and Gutknecht (1998) and Gutknecht (2001), Agents, Groups, and Roles (AGR) is an Organizational Model. The groups have roles and agents that play these roles. There are several initiatives centered on the AGR model [Seddari et al. 2017] [Abrami et al. 2002] [Parunak and Odell 2001] [Peng and Peng 2005] [Chebout et al. 2023]. They clarify how agents interact with each other and define the term "Cheese Boards Diagram".

4. Proposal of a Metaversity to Lifelong Learners

The proposal of a metaversity to Lifelong Learners is detailed considering: modeling level based on AGR Model, Personal Online Datastore, and LLMs, as well as the implementation level with MAS and AI support.

4.1. Modeling Level

In our proposal, we have a conceptual modeling considering a student named Eve; a structure specified using "Cheese Board" and possible roles that software agents can play in an educational context (see Figure 1). This modeling focuses on both approaches to data

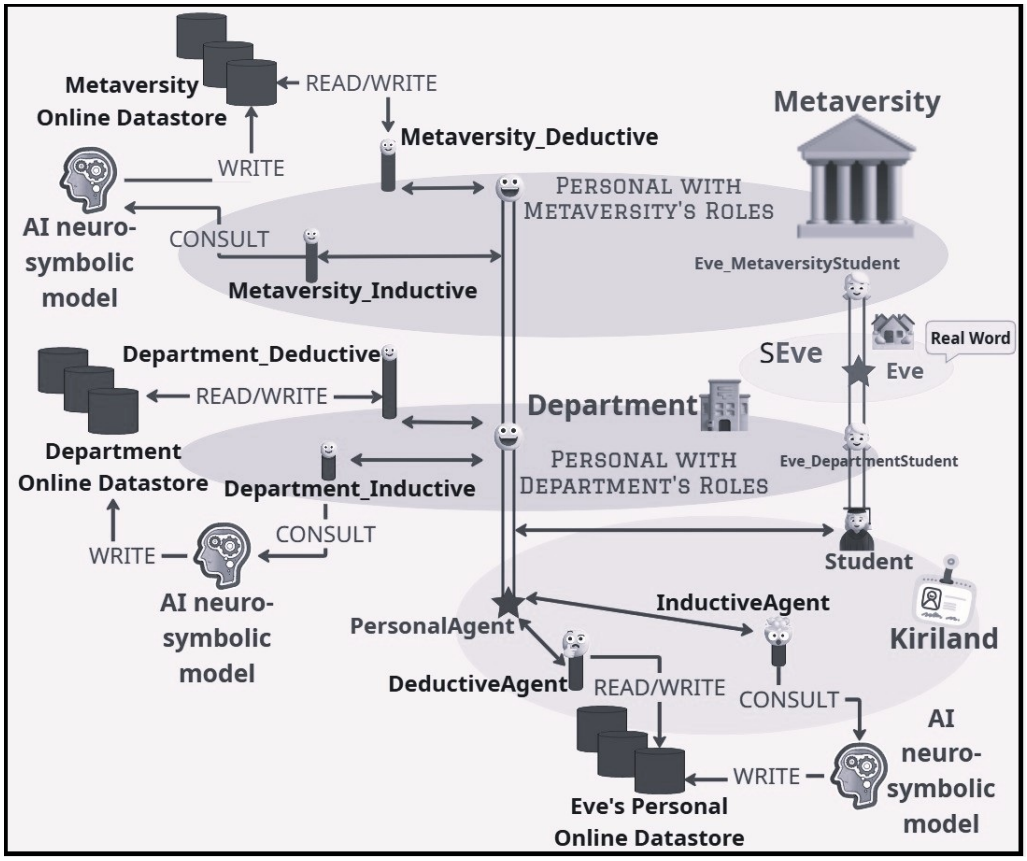

Figure 1. Organizational Model based on AGR Model

collection (Short-term and Long-term) [Kompan et al. 2019]. PersonalAgent is transversal to the "Cheese Boards". This agent is capable of playing different roles. When the agent is on the "Cheese Board kiriland", it is an expert in Eve's academic information.

The PersonalAgent can navigate to other elements of the educational network, such as Department, assuming even more specialized roles. This allows this agent to learn about resolutions, minutes, rules, and guidelines specific to this Department. This model can be extended to other elements of an educational network, such as research laboratories. This self-authored approach is oriented to the General Data Protection Regulation [GDPR 2018], evidencing a Responsible AI-based proposal.

4.2. Implementation Level

To obtain a proof-of-concept, the MaDkit [MaDkitTool 2025] was used to implement MAS with a logic involving: (i) knowledge bases specified in JSON files, and downloaded from Solid PODs (Social Linked Data PODs) [Silva et al. 2024], to infer knowledge from information provided by students and agencies within the metaversity (e.g., departments), each with its own dedicated PODs; and (ii) LLMs that apply deep learning algorithms to understand and generate natural language text. We use the Gemini-2.0-flash model, available in the GoogleAPIs database `(https://cloud.google.com/vertex-ai/generative-ai/docs/models/gemini/2-0-flash?hl=pt-br)`, but other AI neuro-symbolic model could be addressed. A parser was programmed to convert Gemini's return into a string, making the response more understandable to Eve.

Figure 2 illustrates: (a) the deductive approach and (b) the inductive approach. It includes four essential intelligent entities: StudentAgent, PersonalAgent, DeductiveAgent, and InductiveAgent. These agents are dedicated to each student in metaversity, providing a typical MAS, distributed, asynchronous, reactive, and cognitive.

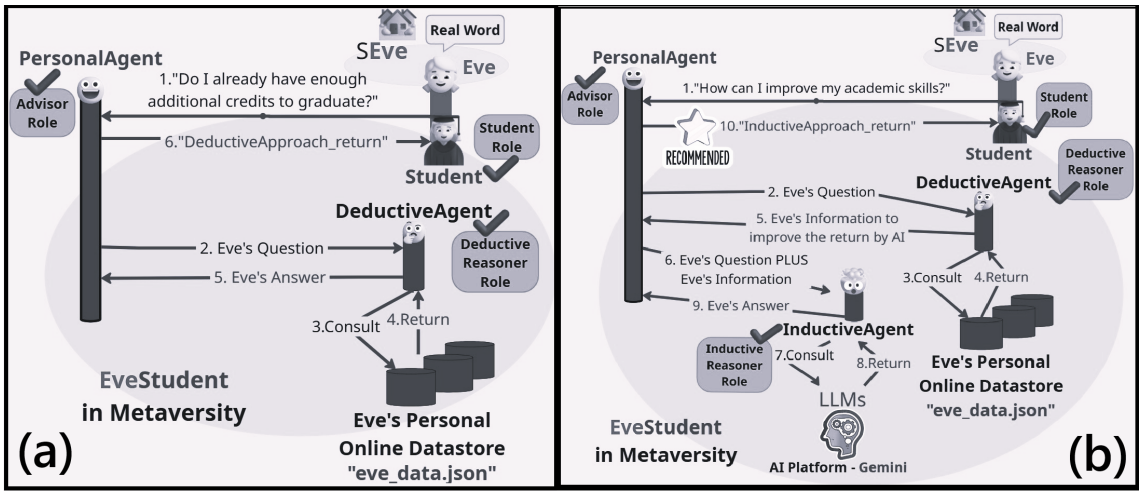

Figure 2. Use Scenario of Deductive and Inductive Approaches for Student Eve

The PersonalAgent holds the role of Advisor and assists Eve in metaversity. Once a message is received, if the content begins with “EVE HISTORY”, the DeductiveAgent is invoked, and it accesses Eve’s POD academic data (indices, mentions, workload dedication, courses history, observations, and statistics), structured in a JSON file (“eve-data.json”). If the content begins with ”AI RECOMMENDATION”, the InductiveAgent is invoked, and it uses Gemini to recommend academic improvement opportunities. To avoid sending Eve’s information to Gemini, the agent filters personal data.

5. Discussion

The integration of AI into education represents transformations in the contemporary educational landscape, allowing personalized learning experiences that meet the individual needs of students [Kaledio et al. 2024]. The development of e-learning systems faces numerous challenges, including the transition from traditional e-learning to a more user-centered, interactive, and collaborative model. The use of agent technology represents an essential approach to address these challenges [Nadrljanski et al. 2018].

In order to clarify how deduction and induction will be used with Symbolic AI, Machine Learning, and Generative AI, we focus on the metaversity services. For example, if the question is about internships, the idea is to have a trained/specialized AI in that context, aiming for precise answers. In this case, Symbolic AI or Machine Learning will be used. The same will happen for other services that commonly raise questions among students, such as academic performance, monitoring, tutoring, among others. However, the student’s questions are expected in various contexts, including unforeseen contexts. In these other contexts, not specialized through already provided services, Generative AI with LLMs will be used.

We also have concerns about the security and privacy of sensitive data observed in the study and look at ways to mitigate them throughout bibliographic research on Smart

Contracts [Bartoletti et al. 2025] and Self-Sovereign Identity [Akli and Chougdali 2025]. In this sense, the DeductiveAgent plays the role of the DeductiveReasoner. This agent reasons by following a deductive approach, capable of inferring information considering the knowledge base structured in a JSON file, available from dedicated POD. Solid POD has a file storage structure organized into directories, with an emphasis on the ability to make files publicly or privately accessible, as well as share them via links. This sharing can involve different permissions: View, Edit, Append, or Control. If desired, files can be added as bookmarks, verifiable credentials, and even a contact list can be maintained. In this contact list, for example, students could specify with whom they would like to share their files, maintaining the privacy of their data according to their preferences. These more advanced features have not been explored yet. Only student data specified in the JSON file were made available in the student's POD public directory, making it possible to obtain student academic information. The actual integration between the proposed application and features of Solid POD is currently underway in our deductive approach solution.

6. Final Considerations

This paper reveals efforts to improve student learning throughout their academic lives, using MAS with AI in a metaversity. We reported some related work, AGR-based modeling, and the implementation of a MAS, highlighting the distribution of responsibilities among agents. In future work, there are architectures to improve agents' cognition based on behavior [Bellifemine et al. 2007] or BDI Model (Belief-Desire-Intention Model) [Pokahr et al. 2014] [BDI4JADE 2021]. The authors are working in this direction. We are also applying traditional AI to improve deductive agents.

References

Abrami, G., Barreteau, O., and Cernesson, F. (2002). An Agent Group Role based modelling framework for participative water management support. In *International Environmental Modelling and Software Society IEMSs* , volume 3, Lugano , Switzerland. IEMSs .

Afzaal, M., Nouri, J., and Aayesha, A. (2023). A transformer-based approach for the automatic generation of concept-wise exercises to provide personalized learning support to students. In Viberg, O., Jivet, I., Muñoz-Merino, P., Perifanou, M., and Papathoma, T., editors, *Responsive and Sustainable Educational Futures*, pages 16–31, Cham. Springer Nature Switzerland.

Akli, A. and Chougdali, K. (2025). Iota-assisted self-sovereign identity framework for decentralized authentication and secure data sharing. *IEEE Access*, 13:80191–80205.

Bartoletti, M., Benetollo, L., Bugliesi, M., Crafa, S., Sasso, G. D., Pettinau, R., Pinna, A., Piras, M., Rossi, S., Salis, S., Spanò, A., Tkachenko, V., Tonelli, R., and Zunino, R. (2025). Smart contract languages: A comparative analysis. *Future Generation Computer Systems*, 164:107563.

BDI4JADE (2021). Bdi4jade: Bdi framework para jade v2.0. Accessed August, 2025.

Bellifemine, F. L., Caire, G., and Greenwood, D. (2007). *Developing Multi-Agent Systems with JADE (Wiley Series in Agent Technology)*. John Wiley & Sons, Inc., Hoboken, NJ, USA.

Chebout, M. S., Marir, T., and Gupta, V. (2023). Noragr: a normative agent groupe role model for organizational centered open multi-agent systems. In *2023 Third International Conference on Theoretical and Applicative Aspects of Computer Science (ICTAACS)*, pages 1–5.

Ferber, J. and Gutknecht, O. (1998). A meta-model for the analysis and design of organizations in multi-agent systems. In *Proceedings International Conference on Multi Agent Systems (Cat. No.98EX160)*, pages 128–135.

GDPR (2018). General data protection regulation. `https://gdpr-info.eu/`.

Gutknecht, O. (2001). *Proposition d'un modèle organisationnel générique de systèmes multi-agents et examen de ses conséquences formelles, implémentatoires et méthologiques*. Theses, Université Montpellier II - Sciences et Techniques du Languedoc.

Kaledio, P., Robert, A., and Frank, L. (2024). The impact of artificial intelligence on students' learning experience. *SSRN Electronic Journal*.

Kompan, M., Kassak, O., and Bielikova, M. (2019). The short-term user modeling for predictive applications. *Journal on Data Semantics*, 8.

Loewen, S., Crowther, D., Isbell, D. R., Kim, K. M., Maloney, J., Miller, Z. F., and Rawal, H. (2019). Mobile-assisted language learning: A duolingo case study. *ReCALL*, 31(3):293–311.

MaDkitTool (2025). Madkit tool. Accessed August, 2025.

Minh, D., Wang, H. X., Li, Y. F., and Nguyen, T. N. (2022). Explainable artificial intelligence: a comprehensive review. *Artif. Intell. Rev.*, 55(5):3503–3568.

Nadrljanski, M., Vukić, , and Nadrljanski, D. (2018). Multi-agent systems in e-learning. In *2018 41st International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO)*, pages 0990–0995.

NET-LOGO (2025). Net-logo. Accessed August, 2025.

Nóbrega, G., Pains, A., and Cruz, F. (2024). Uma sociedade de companions inteligentes na metaversidade para incrementar a aprendizagem ao longo da vida. In *Anais do XXXV Simpósio Brasileiro de Informática na Educação*, pages 3085–3096, Porto Alegre, RS, Brasil. SBC.

Olugbade, D., Ojo, O. A., and Tolorunleke, A. E. (2023). Challenges and limitations of moodle lms in handling large-scale projects: West-african universities lecturers' perspective. *Journal of Educational Technology and Instruction*, 2(2):47–66.

Parunak, H. V. D. and Odell, J. (2001). Representing social structures in uml. In *Proceedings of the Fifth International Conference on Autonomous Agents*, AGENTS '01, page 100–101, New York, NY, USA. Association for Computing Machinery.

Peng, Z.-P. and Peng, H. (2005). An improved agent/group/role meta-model for building multti-agen systems. In *2005 International Conference on Machine Learning and Cybernetics*, volume 1, pages 287–292.

Pokahr, A., Braubach, L., Haubeck, C., and Ladiges, J. (2014). Programming bdi agents with pure java. In Müller, J. P., Weyrich, M., and Bazzan, A. L. C., editors, *Multiagent System Technologies*, pages 216–233, Cham. Springer International Publishing.

Ross, E., Kansal, Y., Renzella, J., Vassar, A., and Taylor, A. (2025). Supervised fine-tuning llms to behave as pedagogical agents in programming education.

Seddari, N., Belaoued, M., and Bougueroua, S. (2017). Agent/group/role organizational model to simulate an industrial control system. *World Academy of Science, Engineering and Technology, International Journal of Social, Behavioral, Educational, Economic, Business and Industrial Engineering*, 11(10):2376–2385.

Selker, T. (1994). Coach: a teaching agent that learns. *Commun. ACM*, 37(7):92–99.

Shanmugasundaram, M. and Tamilarasu, A. (2023). The impact of digital technology, social media, and artificial intelligence on cognitive functions: a review. *Frontiers in Cognition*, Volume 2 - 2023.

Silva, O., Souza, T., Duda, J., Barros, B., and Nóbrega, G. (2024). Você decide quem pod: empoderando a/o estudante de computação quanto à propriedade de seus dados. In *Anais do IV Simpósio Brasileiro de Educação em Computação*, pages 367–374, Porto Alegre, RS, Brasil. SBC.

SoftwareTools (2025). Software tools. Accessed August, 2025.

Wooldridge, M. (2009). *An Introduction to MultiAgent Systems*. Wiley Publishing, 2nd edition.