

Smart University Components Modeling Based on Multi-agent Systems

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Abstract—Previous research on smart universities has generally focused on specific aspects such as educational technologies, connected infrastructure, or digital services, without offering a comprehensive view of the university as an integrated system. Consequently, these approaches provide a fragmented view of the university's various components and the relationships between them. This study contributes to the literature by proposing a conceptual model based on the integration of various components of the smart university within a unified framework, structured according to the multi-agent systems approach. The framework was first established qualitatively through a review of the literature and subsequently examined quantitatively through an empirical survey. Seven domains were retained after examining their role in everyday academic and institutional activity: learner, teacher, pedagogy, classroom, administration, alumni, and extracurricular clubs. Each domain is represented as an agent following a common template adapted from existing work in smart city modelling, and the Smart Learner is detailed to show how inputs, internal states, and actions can be organized within this structure. A questionnaire distributed to learners, teachers, and administrative staff was used to examine whether these components reflect how stakeholders perceive the functioning of their institution. The questionnaire was used as a validation tool to assess the relevance of the proposed components and to verify their importance in a real-world context. The responses place learner, teacher, and pedagogy agents at the center of university activity, while still giving consistent importance to the remaining domains. Suggestions from participants also pointed to areas that are not always visible in formal models, such as student support or orientation services. The results support the choice of components and show that the model offers a coherent view of the university as a set of connected elements rather than isolated functions.

Keywords—smart university, multi-agent model, university components, smart learner model, stakeholder perceptions

I. INTRODUCTION

The concept of the smart city expanded significantly over recent years, driven by the increasing integration of digital technologies into public services. In many domains, including energy management, water distribution, and urban infrastructure, systems were designed to monitor their environment and adapt dynamically to real-time conditions [1–5]. Within this broader transformation, universities were expected to evolve as integral components of smart city ecosystems. However, their integration remained uneven and often limited in scope. In most cases, existing efforts focused on isolated technological improvements rather than on a comprehensive understanding of the university as a fully connected and adaptive system.

Previous studies highlighted the strategic role of higher education institutions in smart city development, yet their digital transformation progressed more slowly than anticipated [6].

Smart city frameworks typically described urban environments as assemblies of interconnected components that operate independently while exchanging information to support the overall system [7, 8]. This perspective was applicable to universities, which inherently consist of multiple interacting entities, including learners, teachers, classrooms, and administrative units. Despite this structural similarity, the majority of research on smart universities examined these elements in isolation. For example, significant attention was given to online learning platforms due to their contribution to accessibility and educational continuity [9, 10], while distance learning solutions were explored as flexible alternatives in various contexts [11]. Similarly, Internet of Things (IoT) applications demonstrated their effectiveness in optimizing resource management within campuses, particularly in terms of energy efficiency and space utilization [12–14]. Additional studies investigated user adoption and stakeholder expectations, emphasizing their influence on the evolution of smart campus environments [15].

Although these contributions provided valuable insights, they remained fragmented and failed to capture the interdependencies between university components. Existing approaches primarily described individual aspects of the system without addressing how these elements interacted or influenced one another within a unified structure. Even studies that identified key components of smart universities offered limited explanation regarding their operational relationships. As a result, the university was rarely conceptualized as a cohesive system, making it difficult to understand its global behavior. This limitation revealed a clear gap in the literature, namely the absence of models capable of representing the smart university as a structured and holistic system composed of interconnected components.

To address this limitation, this study proposed a conceptual model based on a Multi-Agent System (MAS) approach, in which each major component of the university was represented as an autonomous agent. The model incorporated core domains of university functioning, including the Smart Learner, Smart Teacher, Smart Pedagogy, Smart Administration, and Smart Classroom, as well as complementary components such as Smart Alumni and Smart Extracurricular Clubs. In order to provide a structured

representation, these components were organized into three main dimensions: the human dimension, which included actors directly involved in the learning process, such as the Smart Learner, Smart Teacher, Smart Pedagogy, and Smart Alumni; the administrative dimension, which encompassed coordination and management functions represented by the Smart Administration; and the environmental dimension, which referred to the physical and contextual elements supporting the educational experience, such as the Smart Classroom and Smart Extracurricular Clubs.

Within this framework, the notion of “smart” referred to the capacity of system components to exhibit adaptive and intelligent behavior, including learning, anticipation, and dynamic interaction with their environment [16]. At this conceptual stage, these characteristics were not quantitatively measured but were conceptually qualified through the functional structure and behavior of each agent, including inputs, outputs, interfaces, parameters, internal states, and actions. More specifically, adaptation referred to the ability of agents to adjust their actions according to contextual information, such as learner needs, pedagogical objectives, classroom conditions, or administrative constraints. Learning referred to the capacity to update internal states and parameters based on previous interactions, feedback, performance, or accumulated experience. Anticipation referred to proactive behavior supported by contextual information and internal states, enabling agents to recommend resources, adapt pedagogical support, or prepare administrative actions before issues arise. Dynamic interaction referred to the continuous exchange of information between agents through defined input and output interfaces. To ensure alignment between the SMART framework characteristics and their qualification in the proposed model, each characteristic was explicitly associated with specific agent elements. More specifically, adaptation was linked to contextual inputs and agent actions, learning to the evolution of internal states and parameter updates, anticipation to proactive actions supported by contextual information, and dynamic interaction to interfaces and information exchanges between agents. This explicit association provides a structured basis for future operationalization and facilitates adaptation of the framework in similar contexts. Illustrative indicators for future measurement may include the proportion of context-based action adjustments for adaptation, the evolution of internal states and parameter updates for learning, the frequency and effectiveness of proactive actions for anticipation, and the frequency and relevance of information exchanges for dynamic interaction.

The objective of this study was therefore to structure the university as a multi-agent system by modeling its component as autonomous and interacting entities. It should be noted that the proposed model remained conceptual and did not aim to simulate dynamic agent interactions. The Smart Learner agent was presented in detail as an illustrative example, while the remaining agents were described at a higher level of abstraction.

This study made several contributions to the literature. First, it identified the key components of a smart university based on existing research and conceptual frameworks. Second, it modeled these components as autonomous agents

by defining their inputs, outputs, interfaces, parameters, internal states, and actions within a multi-agent systems perspective. Third, it demonstrated that a university could be structured as an interconnected multi-agent system, providing a unified representation that remained underexplored in previous studies. Fourth, it extended existing models by integrating additional components, particularly alumni and extracurricular activities, which were rarely considered despite their relevance. Finally, it provided empirical support for the proposed model through a questionnaire-based evaluation involving key academic stakeholders, including learners, teachers, and administrative staff.

II. LITERATURE REVIEW

Research on smart universities has evolved along multiple directions, often drawing inspiration from smart city frameworks in which systems are conceptualized as interconnected entities reacting dynamically to their environment [8]. When these perspectives were extended to the university context, they did not result in a unified or coherent modeling approach. Instead, existing contributions tended to focus on specific domains in isolation, without clearly establishing their relationships within the broader institutional structure. At the same time, recent studies emphasized the need to consider educational systems as complex environments integrating advanced technologies, particularly artificial intelligence and adaptive learning mechanisms [17–19].

A significant portion of the literature concentrated on digital learning environments, primarily examining online platforms and educational technologies for their ability to enhance flexibility and ensure continuity in teaching processes [9–11]. Some of these contributions situated education within broader smart city narratives, treating it as one component of a larger digital ecosystem [6, 11]. While these studies provided valuable insights into technological adoption and learning enhancement, they largely remained centered on the tools themselves. Their connections to administrative processes and campus-wide systems were often acknowledged but rarely analyzed in depth. More recent work further highlighted the role of AI-driven systems in enabling personalized learning and adaptive educational support, reinforcing the importance of intelligent technologies in modern educational contexts [20, 21].

In parallel, another stream of research explored the integration of Internet of Things (IoT) technologies within university campuses, focusing primarily on infrastructure-related applications such as occupancy monitoring, energy optimization, and environmental control [12–14]. Although these studies demonstrated measurable efficiency improvements, they remained largely confined to technical and operational aspects, with limited consideration of their interaction with pedagogical or administrative processes. Other contributions attempted to outline the main components of a smart university by identifying key actors, including learners, teachers, and administrators, and examining how digital technologies influence their roles [15, 22]. Similarly, survey-based studies grouped smart campus initiatives according to functional categories, but did not explicitly address the relationships

between these components or their integration into a unified system [16, 23]. Recent research also introduced multi-agent system approaches to model adaptive educational environments, highlighting their potential to support dynamic interactions and intelligent decision-making [24–26]. Nevertheless, even within these approaches, the focus often remained limited to specific applications rather than to a comprehensive representation of the university as a whole.

Overall, existing studies provided fragmented perspectives on smart university development, with each line of work addressing isolated aspects of institutional activity. The interactions between these components, and their contribution to the overall behavior of the university system, remained insufficiently explored. This limitation underscored the need for approaches capable of representing the university as an integrated and structured system composed of interdependent elements. In response to this gap, the model proposed in this study adopted a multi-agent systems perspective, in which each domain was represented as an autonomous agent contributing to the collective functioning of the university. This positioning aligned with recent research on complex systems modeling, where interactions between autonomous entities played a central role in system behavior and organization [27, 28].

III. METHODOLOGY

A. Conceptual Basis for the Smart University Agent (SUA) Model

The Smart University Agent (SUA) model was developed based on a theoretical framework that defined its conceptual foundations and guided the identification and structuring of its core components within a multi-agent systems

perspective. This framework established the basis for representing the university as a set of interacting entities, each contributing to the overall system behavior.

The model was constructed using an agent-based approach, as this paradigm enabled the representation of complex systems through decentralized and interacting components rather than through a single centralized structure. Such an approach has been widely adopted in smart city research to capture the dynamic interactions between system elements [8], and was considered particularly suitable for modeling the heterogeneous and interdependent nature of university environments.

The development of the model was guided by a structured abstraction process, in which the university was analyzed based on its functional activities rather than its formal organizational hierarchy. Core processes, including teaching, learning, administrative operations, classroom usage, and student-related activities, were first identified and used as the foundation for defining system components. This perspective ensured that the model reflected the operational reality of the university rather than a purely theoretical structure.

Instead of introducing entirely new components, this study relied on a synthesis of existing conceptualizations of smart university systems reported in the literature [16, 22, 29]. This foundation was extended by incorporating additional components, particularly alumni [30–32] and extracurricular activities [17, 33–35], which have been recognized as relevant but remain underrepresented in existing models. The selection of components was based on three main criteria: their central role in academic and institutional processes, their interactions with other system elements, and their capacity to represent the key dimensions of the university ecosystem.

Table 1. Core components of a smart university

Component	Description
Smart learner	The Smart Learner was defined as the central agent of the smart university model. This agent represented students as active participants in the learning process rather than passive recipients of information. It captured how learners constructed their academic trajectories, engaged in courses and projects, and interacted with other university components. In addition, it incorporated the ability of learners to provide feedback on teaching practices and learning conditions, thereby contributing to the continuous adaptation of the system.
Smart classroom	The Smart Classroom was defined as the environment in which teaching activities took place. It encompassed both physical spaces and digital learning environments. The agent adapted to variations in course delivery and student presence, reflecting the dynamic conditions of classroom usage. It also interacted with other components of the system, including teachers, learners, and administrative services, through the exchange of relevant information when required.
Smart teacher	The Smart Teacher was defined as an agent responsible for guiding and supporting the learning process. It was modeled as both a pedagogical facilitator and a mentor, capable of designing learning activities adapted to the pace and characteristics of each learner. The agent also adjusted its teaching strategies and coordinated with other components of the system to ensure coherence in the overall learning process.
Smart alumni	The Smart Alumni agent was defined as representing graduates and their ongoing relationship with the university after completion of their studies. It captured their role in providing professional feedback, sharing experience, and supporting networking activities. Through these interactions, the agent contributed to connecting academic training with professional contexts.
Smart extracurricular clubs	The Smart Extracurricular Clubs agent was defined as representing student activities conducted outside formal academic courses. It encompassed cultural, scientific, social, and collaborative initiatives organized by students within the university environment. These activities complemented academic learning by contributing to the development of transversal skills, including communication, teamwork, leadership, and social engagement, which were not always fully addressed through classroom-based instruction.
Smart administration	The Smart Administration agent was defined as representing the administrative functions of the university. It encompassed activities such as registration management, academic record handling, scheduling, and organizational coordination. The agent was primarily responsible for supporting operational processes and ensuring the continuity of teaching and student-related services within the system.
Smart pedagogy	The Smart Pedagogy agent was defined as representing the teaching approaches and instructional methods adopted within the institution. It captured the processes through which courses were designed, delivered, and progressively refined over time. Pedagogical decisions were influenced by multiple factors, including learner feedback, institutional objectives, and constraints related to the academic environment.

Based on this framework, seven domains were identified: learning, teaching, pedagogy, classroom environments, administration, extracurricular activities, and alumni relations. Each domain was modeled as an autonomous agent

characterized by a specific role, while remaining interconnected with other agents within the system. These components, summarized in Table 1, formed the initial set of Smart University Agents (SUAs) and provided the structural

foundation for the proposed multi-agent representation of the smart university.

Fig. 1 illustrated the interaction structure between the seven agents identified in the Smart University conceptual model. The arrows represented the existence of interactions between the main components and their integration within the overall system. For clarity, only representative interactions were shown. The figure provided a global view of the relationships between the main domains of the university ecosystem, in line with the multi-agent perspective adopted in this study.

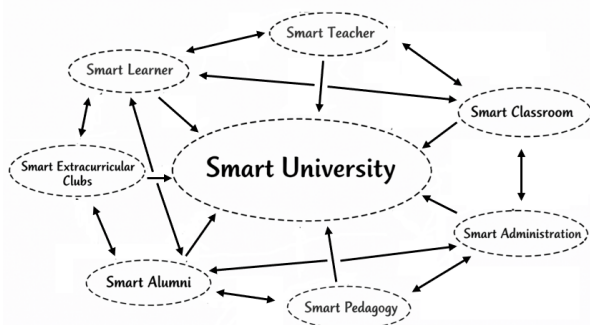


Fig. 1. Multi-agent interaction architecture of the Smart University.

B. Identification and Structuring of Agents

Based on the theoretical framework presented above, the identified components were modeled as autonomous agents. The construction of the proposed model relied on defining a unified internal structure for all agents, ensuring consistency across the system.

Each agent was described using a common Smart University Agent template, illustrated in Fig. 2. This structure was designed to capture the main elements governing agent behavior and interaction within the system:

- Inputs (C_i or E): information or events originating from the environment;
- Interfaces, input ($I = i_0 \dots i_n$) and output ($O = o_0 \dots o_n$): channels enabling communication with the environment or with other agents;
- Parameters ($P = p_0 \dots p_n$): internal variables that shape the agent's behavior;
- Internal states ($S = s_0 \dots s_n$): memory elements and contextual information maintained during operation;
- Actions ($A = a_0 \dots a_n$): operations executed according to the received inputs and internal parameters;
- Outputs (C_o or E): information produced by the agent, expressed either as control outputs ($C_o = c_{o1} \dots c_{on}$) or event outputs ($E = e_1 \dots e_n$), transmitted through the output interfaces (O).

The proposed method was based on representing each component of the Smart University as an autonomous agent within a Multi-Agent System. Each agent operated by receiving inputs from its environment or from other agents through defined interfaces. These inputs were processed using internal states and parameters, leading to the execution of specific actions. The resulting outputs were then transmitted to other components, enabling interaction and coordination across the system. This mechanism supported the overall functioning of the Smart University through continuous information exchange between agents.

To illustrate this process, a scenario involving the Smart Learner during an assessment activity was considered. In this context, the Smart Teacher agent provided an exam or assignment, which was transmitted as input to the Smart Learner through the system interface.

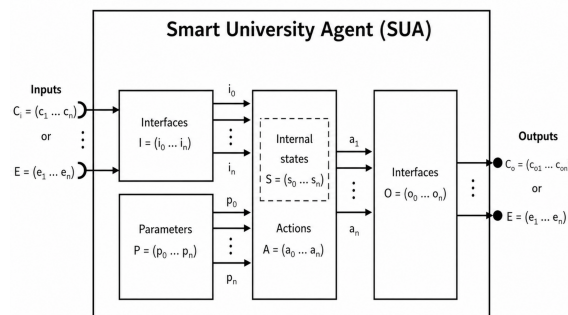


Fig. 2. Internal structure of an agent according to Lom & Pribyl [8], adapted to the university context to define the Smart University Agent (SUA).

The Smart Learner then processed this input based on its internal configuration. Its internal states included elements such as knowledge level and skill level, while its behavior was influenced by parameters related to the assessment context, including competency level, academic progress, learning style, available time, and previous experience. Based on this configuration, the learner performed the required action, namely completing the assigned task.

Once completed, the learner generated outputs in the form of submitted responses, which were transmitted through the output interface and made available to other agents. These outputs were subsequently used by the Smart Teacher to evaluate performance and provide feedback. At the same time, the Smart Pedagogy agent exploited this information to adjust learning strategies, recommend additional resources, or adapt the level of future activities.

This example demonstrated how information circulated between agents and how a single output could be shared across multiple components, enabling coordinated behavior within the system. It also highlighted the capacity of the proposed architecture to support continuous adaptation of the learning process.

This interaction structure was common to all Smart University Agents. Fig. 3 illustrated the case of the Smart Learner, showing how inputs from different components were processed internally to produce actions and outputs. The figure emphasized the diversity of interactions rather than a specific behavioral scenario. The remaining agents followed the same conceptual structure, although their detailed representations were not included due to space constraints.

The internal structure of the Smart Learner agent was detailed in Tables A1–A7 in Appendix A, which summarized its main functional elements. These tables provided a structured description of the components illustrated in Fig. 3, including inputs, outputs, parameters, internal states, and actions. They clarified the role of each element within the agent and explained the meaning of the abbreviations used in the graphical representation. This detailed presentation supported the understanding of the proposed modeling approach and highlighted how these elements contributed to the overall functioning of the agent within the university system.

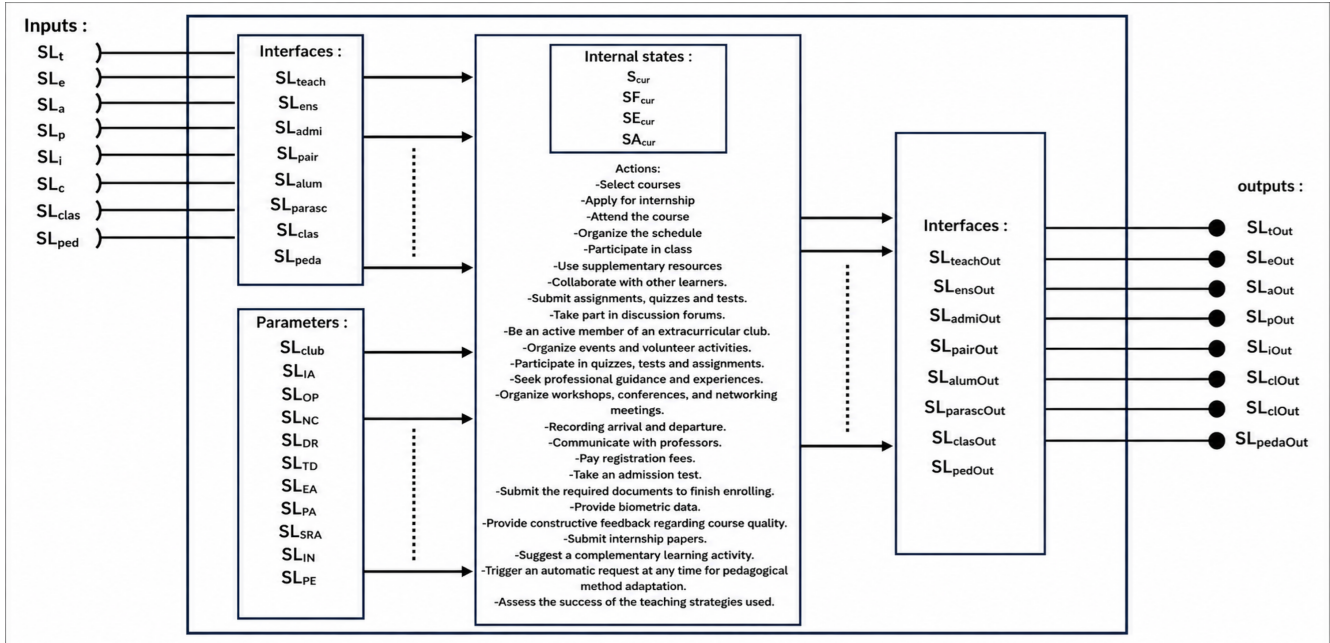


Fig. 3. Internal structure of the smart learner agent.

Fig. 4 illustrated the distribution of functional elements actions, parameters, input and output connections, interfaces, and internal states across the agents in the proposed model. The observed differences reflected the distinct operational roles of the agents rather than differences in their importance within the system.

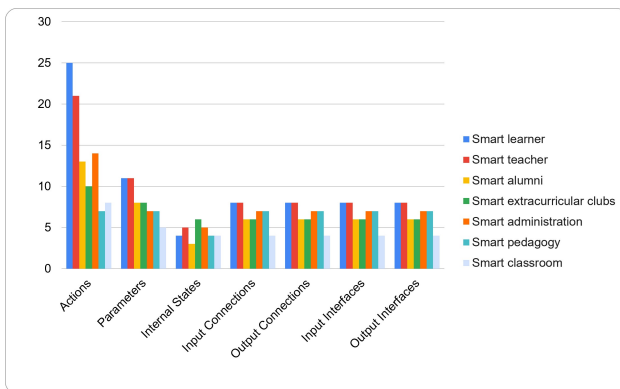


Fig. 4. Functional characterization of smart university agents.

C. Questionnaire Design and Empirical Check

A questionnaire was designed as a validation tool to examine whether the components identified in the literature were perceived as relevant by stakeholders within the university system.

The development of the questionnaire followed a structured process. First, the scope and objective of the study were defined, with the aim of assessing the perceived importance of the proposed components rather than investigating causal relationships. The questionnaire was then designed based on the components identified in the literature on smart universities. It consisted primarily of closed-ended questions to facilitate evaluation, organized into thematic sections covering respondent profiles, identification of essential components, assessment of their importance, and identification of elements considered useful but often overlooked. An additional open-ended question allowed participants to provide further comments. The

complete list of items is provided in Appendix B to ensure transparency and reproducibility.

Prior to distribution, the questionnaire was pre-tested with a small group of participants, including learners, teachers, and administrative staff. This pilot phase ensured the clarity, readability and coherence of the questions and allowed minor adjustments to improve wording and structure.

The questionnaire was subsequently administered online over a period of three weeks. Participants were recruited from the main stakeholder groups of the university system, including learners, teachers, and administrative staff, and were invited to respond voluntarily through institutional channels and direct distribution. A total of 100 valid responses were collected, providing a sufficiently diverse sample for an exploratory descriptive analysis. Participation was anonymous, and respondents were informed about the objective of the study before providing their consent. There is no universally established sample size in educational research, as it depends on the study objectives and design. According to Besekar *et al.* [36], previous studies have reported median sample sizes around 30 participants, while some studies use larger samples typically ranging between 50 and 99 participants. Building on these findings, the sample size of 100 respondents can be considered appropriate and consistent with existing practices for exploratory and descriptive studies. Moreover, the inclusion of diverse participant categories, including learners, teachers, and administrative staff, ensures the representation of multiple perspectives, thereby strengthening the reliability of the findings.

The importance of each component was assessed using a five-point Likert scale ranging from 0 (not important) to 4 (very important), allowing respondents to express their evaluation in a structured manner.

The collected data were analyzed using descriptive statistics, including frequencies, percentages, and graphical representations. This approach was consistent with the objective of the study, which was to assess the relevance of the proposed components rather than to test statistical

hypotheses or causal relationships between variables.

The results of this analysis are presented in the Results and Discussion section.

IV. RESULTS AND DISCUSSION

A. Questionnaire Results and Interpretation

A total of 100 answers were collected, and their distribution is represented in Fig. 5.

The majority of respondents were learners, followed by teachers and administrative staff. This distribution reflects the typical composition of university stakeholders and provides a balanced perspective on how different groups perceive the proposed components.

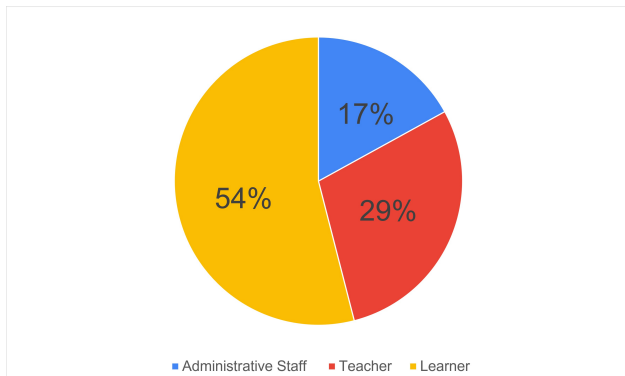


Fig. 5. Distribution of respondents by category (learners, teachers, and administrative staff).

The relevance scores for the seven agents were presented in Fig. 6. The Smart Teacher, Smart Learner, and Smart Pedagogy components obtained the highest scores, reflecting their central role in core academic activities. The Smart Classroom and Smart Administration agents followed with slightly lower but still consistent values, indicating their importance in supporting institutional operations. In contrast, the Smart Alumni and Smart Extracurricular components received more moderate scores, although the difference remained limited, suggesting that their relevance was recognized by respondents.

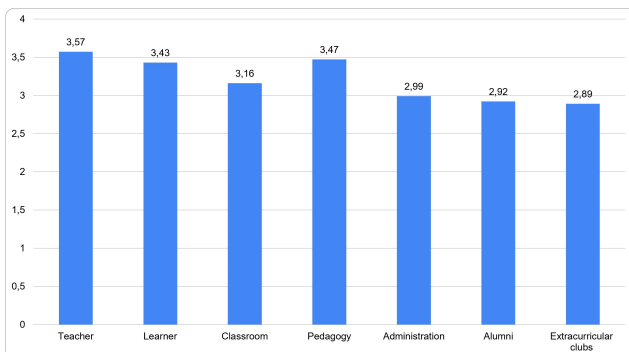


Fig. 6. Average importance score (0–4) for each smart university agent (SUA).

This distribution aligned with the functional structure of universities, where teaching and learning processes constitute the central core, while administrative and classroom-related elements provide essential organizational support. Alumni and extracurricular activities, although less directly involved in daily academic routines, contributed to broader aspects of

the university ecosystem, including external engagement and student development. Overall, the results remained consistent with the expected roles of these components within the system.

Fig. 7 highlighted the components that respondents considered useful but not sufficiently visible. The Smart Alumni and Smart Extracurricular Clubs were the most frequently cited. Both are associated with activities that extend beyond the core academic cycle, suggesting that participants perceived the university as more than a purely instructional environment.

This observation was consistent with the intent of the proposed model, which aimed to integrate domains that are often overlooked in formal representations of academic systems. Although these components are less visible within traditional structures, they were still recognized as contributing to learners' overall development, particularly in terms of social integration, collaboration, and connection with the professional environment.

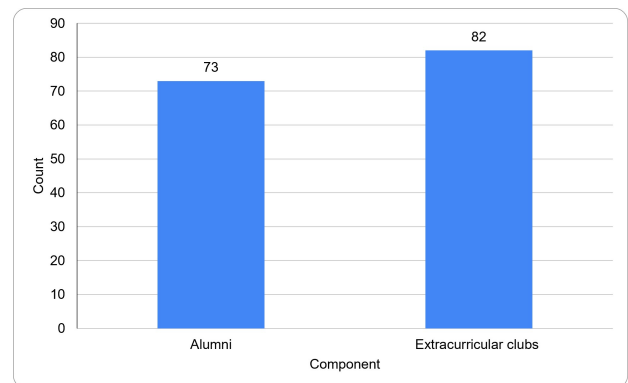


Fig. 7. Frequency of components identified as “useful but often overlooked”.

Fig. 8 provided a consolidated view of the perceived importance of the agents. The radar representation revealed a relatively balanced structure, with a clear emphasis on the Smart Teacher, Smart Learner, and Smart Pedagogy components. The Smart Administration and Smart Classroom occupied intermediate positions, while the Smart Alumni and Smart Extracurricular Clubs appeared at lower levels without being marginal.

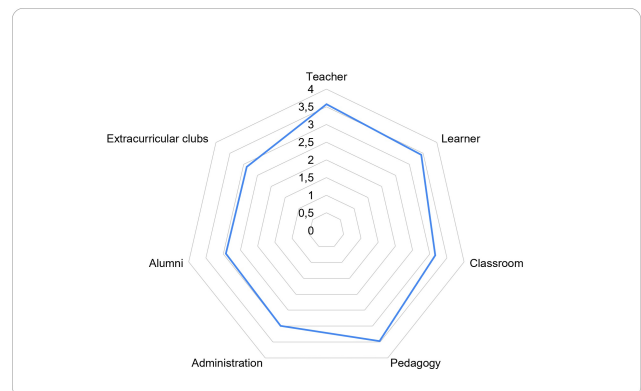


Fig. 8. Radar representation of the perceived importance of Smart University Agents (SUA).

This distribution reflected a university system in which core academic processes remained dominant, while other domains continued to play complementary roles. The overall balance observed across the agents suggested that, although

certain components were perceived as more central, all contributed to the functioning of the system. This finding supported the relevance of representing the university as a set of interconnected agents within a unified multi-agent framework.

To further examine potential differences in perception, a comparison across respondent groups was conducted based on the average importance scores assigned to each component by learners, teachers, and administrative staff.

The results revealed both a strong overall convergence and meaningful variations between groups. Teachers assigned the highest importance to the Smart Pedagogy (mean = 3.76) and Smart Teacher (mean = 3.72) components, reflecting their direct involvement in instructional processes. Learners showed a more balanced evaluation, with consistently high scores across the Smart Teacher (mean = 3.54), Smart Learner (mean = 3.50), and Smart Pedagogy (mean = 3.37), suggesting an integrated perception of the learning environment. Administrative staff reported comparatively lower overall scores but emphasized the importance of the Smart Teacher (mean = 3.41), Smart Pedagogy (mean =

3.29), and Smart Administration (mean = 3.00), highlighting their focus on organizational and operational aspects.

Across all groups, the Smart Alumni and Smart Extracurricular Clubs components received more moderate scores, although they were not disregarded, confirming their complementary role within the university ecosystem. Despite these variations, a consistent ranking emerged, with teaching, learning, and pedagogy-related components occupying central positions.

Overall, the convergence observed across respondent groups indicated a strong alignment between the proposed model and stakeholder perceptions. This consistency supported the validity of the framework and suggested that the identified agents effectively captured the main dimensions of the smart university system.

B. Comparison with Recent Works

Table 2 compared the seven agents proposed in this study with the components explicitly identified in three recent reference works, positioning the proposed model in relation to existing approaches.

Table 2. Mapping of proposed smart university agents to components reported in recent works

Reference	Learner	Teacher	Pedagogy	Classroom	Administration	Alumni	Extra-club
Mbombo & Cavus, 2021 [22]	√	√	×	×	√	×	×
Luckyardi <i>et al.</i> , 2022 [16]	√	√	×	√	√	×	×
Younus <i>et al.</i> , 2023 [29]	√	√	√	√	×	×	×
This work	√	√	√	√	√	√	√

This comparison highlighted a strong alignment with the literature regarding the core educational components, particularly the learner–teacher relationship, as well as, depending on the scope, pedagogy, classroom environments, and administrative functions. The proposed model incorporated these widely recognized elements within a unified multi-agent architecture. In addition, the integration of Smart Alumni and Smart Extracurricular Clubs extended existing approaches by introducing dimensions related to community continuity and institutional openness, which were further supported by the questionnaire results. Overall, the empirical findings provided consistent support for all components included in the model, whether commonly addressed in the literature or newly integrated.

Existing studies generally introduced these components to contextualize specific technological or functional solutions. For example, Mbombo and Cavus [22] focused on digital transformation in higher education, Luckyardi *et al.* [16] examined the role of IoT technologies in smart campuses, and Younus *et al.* [29] proposed an AI-based smart education system for adaptive learning. In these works, university components primarily served as contextual elements rather than as the foundation of a structured representation of the institution. In contrast, the present study treated these components as the central elements of the modeling process. The proposed framework organized them within a unified multi-agent system, where each component was represented as an autonomous agent characterized by inputs, outputs, internal states, parameters, and actions. This approach enabled an explicit representation of interactions and conceptualized the university as a system of interdependent entities. The inclusion of alumni and extracurricular domains further extended the scope of existing models by

incorporating dimensions related to long-term engagement and ecosystem openness.

V. CONCLUSION AND FUTURE WORK

This study proposed a conceptual representation of the smart university as a set of interacting components structured within a multi-agent system. Seven key domains—learner, teacher, pedagogy, classroom, administration, alumni, and extracurricular clubs—were identified and modeled as autonomous agents. This representation provided a coherent framework for capturing both academic and non-academic dimensions within a unified structure.

All components were defined according to a common agent architecture. The Smart Learner was presented as a detailed example to illustrate how inputs, internal states, parameters, actions, and outputs could be structured within the model. This example demonstrated the feasibility of representing university components as agents interacting within a shared system.

The questionnaire results supported the relevance of the proposed components, with teaching, learning, and pedagogy identified as central elements, while administrative, environmental, and complementary domains also contributed to the overall functioning of the system. These findings reinforced the validity of adopting a multi-agent perspective to represent the complexity and interdependence of university processes.

The proposed framework established a foundation for further developments in smart university modeling. Future work may include the simulation of agent interactions, the integration of artificial intelligence techniques to enhance adaptability and decision-making, and the evaluation of the model across different institutional contexts. Such extensions

would enable a deeper understanding of system dynamics and support the design of more responsive and intelligent university environments.

APPENDIX A

Table A1. Actions of the smart learner agent

No.	Action
1	Select their courses to individualize their academic program based on their interests and career objectives.
2	Apply for an internship to gain field exposure in their area of study and develop essential professional skills.
3	Attend the course.
4	Organize the schedule to manage time well, submit assignments and projects on time, and attend to extracurricular obligations.
5	Participate in class to promote interaction and active involvement in learning through questioning and sharing ideas with professors and classmates.
6	Use supplementary resources to maximize understanding by working with a variety of available educational material.
7	Collaborate with other learners to foster collaboration and sharing of knowledge through group projects and presentations.
8	Submit assignments, quizzes, and tests to test understanding and mastery of the concepts taught.
9	Take part in discussion forums.
10	Be an active member of an extracurricular club that offers complementary paths to learning and personal development alongside the traditional academic curriculum.
11	Organize events and volunteer activities to promote community engagement while building leadership and project management skills.
12	Participate in quizzes, tests, and assignments to assess conceptual understanding and track progress.
13	Seek professional guidance and experiences to understand the job market better and prepare for their future career.
14	Organize workshops, conferences, and networking meetings.
15	Recording arrival and departure is necessary for recording attendance at classes or events.
16	Communicate with professors.
17	Pay registration fees.
18	Take an admission test to evaluate proficiency and educational approach.
19	Submit the required documents to finish enrolling.
20	Provide biometric data.
21	Provide constructive feedback regarding course quality founded on classroom experience and learning expectations.
22	Submit internship papers: comprising the name of the learner, host firm's name, title or subject of the internship, duration of the internship, objectives, and tasks and responsibilities assigned.
23	Suggest a complementary learning activity.
24	Trigger an automatic request at any time for pedagogical method adaptation.
25	Assess the success of the teaching strategies used.

Table A2. Parameters of the smart learner agent

Code	Parameter name	Description
SLIA	Academic Interests	The fields of study or subjects that attract the learner's attention and influence their choices of courses, projects, internships, etc.
SLOP	Professional Goals	The student's career aspirations and professional objectives, which can guide their selection of courses, internships, and related activities.
SLNC	Competency Level	The degree of mastery in different academic domains, which may impact decisions regarding course or project enrollment (administrative level).
SLDR	Availability of Resources	Access to materials such as books, articles, online tools, etc., that can be used to support and enhance learning.
SLTD	Available Time	The amount of time the learner can dedicate to studies, extracurricular activities, projects, and other engagements.
SLEA	Previous Experiences	The learner's past academic experiences, including successes and failures, which may influence future decisions

SLIN	Enrollment Status	The current academic registration status of the learner.
SLPA	Academic Progress	An indicator of the learner's understanding of taught concepts, used to identify areas requiring improvement.
SLSRA	Learning Style and Pace	-If the learner prefers playful learning, they might choose fun learning activities such as role-playing, simulations, or educational games.
		-If the learner prefers written learning, they may take detailed notes, write summaries or essays to reinforce their knowledge.
		-If the learner prefers auditory learning, they may opt to listen to lectures, audio recordings, or podcasts to absorb information.
SLclub	Club Themes and Activities	Understanding the different types of clubs available (e.g., discussion groups, art clubs, science associations), as well as the specific activities organized by each.
SLPE	Type of Pedagogy Applied	The teaching methods and instructional strategies implemented in the learner's academic environment.

Table A3. Internal states of the smart learner agent

Code	Internal state name	Description
Scur	Knowledge Level	Indicates the learner's present level of theoretical knowledge.
SFcur	Skill Level	Represents the learner's practical skills and how effectively they are able to use their knowledge.
SEcur	Attitude Level	Reflects the learner's interpersonal and behavioral growth, including responsibility, cooperation, and communication.
SACur	Current Status	Represents the learner's current status and indicates in which activity they are currently involved.

Table A4. Input connections of the smart learner agent

Code	Input Connexion name	Description
SLt	Teacher Line (Input)	A communication line to receive messages from teachers through application or online platform.
SLe	Educational Line (Input)	An educational line utilized for instructional purposes.
SLa	Administration Line (Input)	A communication line to receive messages from the administration through application or online platform.
SLp	Peer Line (Input)	A communication line to receive messages from peers through an application or online platform.
SLi	Alumni Line (Input)	A communication line to receive messages from past students via an application or online platform.
SLc	Extracurricular club Line (Input)	A communication line to receive messages from extracurricular clubs through application or online platform.
SLclas	Classroom Line (Input)	A communication line to receive messages from classrooms through application or online platform.
SLped	Pedagogy Line (Input)	A communication line to receive messages from the pedagogy officer through application or online platform.

Table A5. Input interfaces of the smart learner agent

Code	Input Interface name	Description
SLteach	Teacher Interface (Input)	The interface used to receive messages from one or multiple teachers.
SLens	Teaching Interface (Input)	The interface of teaching.
SLadmi	Administration Interface (Input)	The interface used to receive messages from the administration.
SLpair	Peer Interface (Input)	The interface used to receive messages from peers.
SLalum	Alumni Interface (Input)	The interface used to receive messages from alumni.
SLparasc	Extracurricular Club Interface (Input)	The interface used to receive messages from a single or multiple extracurricular

		clubs.
SL _{clas}	Classroom Interface (Input)	The interface used to receive messages from the classes.
SL _{peda}	Pedagogical Interface (Input)	The interface used to receive messages from the pedagogy office.

Table A6. Output interfaces of the smart learner agent

Code	Output Interface name	Description
SL _{teach} Out	Teacher Interface (Output)	The interface for sending messages to teachers.
SL _{ens} Out	Teaching Interface (Output)	The interface for submitting assignments, quizzes, and assessments.
SL _{admi} Out	Administration Interface (Output)	The interface for sending messages to the administration.
SL _{pair} Out	Peer Interface (Output)	The interface for sending messages to peers.
SL _{alum} Out	Alumni Interface (Output)	The interface for sending messages to alumni.
SL _{parasc} Out	Extracurricular Club Interface (Output)	The interface for sending messages to the extracurricular clubs.
SL _{clas} Out	Classroom Interface (Output)	The interface for sending messages to the classes.
SL _{ped} Out	Pedagogical Interface (Output)	The interface for sending messages to the pedagogy officer.

Table A7. Output connections of the smart learner agent

Code	Output Connexion name	Description
SL _t Out	Teacher Line (Output)	A communication line for sending messages to teachers via application or online platform.
SL _e Out	Educational Line (Output)	A pedagogical line for sending assignments, quizzes, and assessments.
SL _a Out	Administration Line (Output)	A communication line to forward messages to the administration via application or online platform.
SL _p Out	Peer Line (Output)	A communication line for sending messages to peers via application or online platform.
SL _i Out	Alumni Line (Output)	A communication line for sending messages to alumni via application or online platform.
SL _c Out	Extracurricular club Line (Output)	A communication line for sending messages to extracurricular clubs via application or online platform.
SL _{cl} Out	Classroom Line (Output)	A communication line for sending messages to the classrooms via application or online platform.
SL _{peda} Out	Pedagogy Line (Output)	A communication line for sending messages to the pedagogy officer via application or online platform.

APPENDIX B

1. What is your role in the university?

- Student
- Teacher
- Administrative staff

2. Which of the following components do you consider essential for a smart university? (Multiple choices allowed)

- Smart Learner
- Smart Teacher
- Smart Pedagogy
- Smart Classroom
- Smart Administration
- Smart Alumni
- Smart Extracurricular Clubs

3. Please evaluate the importance of each component using the following scale: (0 = Not important, 1 = Slightly important, 2 = Moderately important, 3 = Important, 4 = Very important)

Component	0	1	2	3	4
Smart Learner	○	○	○	○	○
Smart Teacher	○	○	○	○	○
Smart Pedagogy	○	○	○	○	○
Smart Classroom	○	○	○	○	○
Smart Administration	○	○	○	○	○
Smart Alumni	○	○	○	○	○
Smart Extracurricular Clubs	○	○	○	○	○

4. Which of the following components do you consider useful but often neglected in current university systems? (Multiple choices allowed)

- Smart Alumni
- Smart Extracurricular Clubs

5. In your opinion, which components should be added or strengthened to improve a smart university? (Open-ended question)

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Ghita Hana conceptualized the study, designed the research framework, conducted the literature review, developed the conceptual model, designed the questionnaire, conducted the empirical survey, analyzed and interpreted the data, and prepared the original draft of the manuscript. Abdelmjid Saka contributed to the development of the research methodology, supervised the study, and assisted in reviewing and editing the manuscript. Mostafa Souiyate contributed to the interpretation of the research findings and critically revised the manuscript for important intellectual content. All authors discussed the results and approved the final version of the manuscript.

REFERENCES

- [1] A. Visvizi and M. D. Lytras, "Rescaling and refocusing smart cities research: From mega cities to smart villages," *Journal of Science and Technology Policy Management*, vol. 9, no. 2, pp. 134–145, 2018. doi: 10.1108/JSTPM-02-2018-0020.
- [2] M. F. Bortotti, P. Rigolin, M. E. M. Udaeta, and J. A. B. Grimoni, "Comprehensive energy analysis of vehicle-to-grid (V2G) integration with the power grid: A systemic approach incorporating integrated resource planning methodology," *Applied Sciences*, vol. 13, 11119, 2023. doi: 10.3390/app132011119
- [3] D. S. Gade, "Reinventing smart water management system through ICT and IoT driven solution for smart cities," *International Journal of Applied Engineering and Management Letters*, vol. 5, no. 2, pp. 132–151, 2021. doi: 10.47992/IJAEM.L2581.7000.0109
- [4] M. Singh and S. Ahmed, "IoT-based smart water management systems: A systematic review," *Materials Today: Proceedings*, vol. 46, part 11, pp. 5211–5218, 2021. doi: 10.1016/j.matpr.2020.08.588
- [5] A. D. Goswami and S. Chakraborty, "Road lighting standards' evolution and future development of smart street lighting based upon users' performance in view of human centric lighting: A review," *Light & Engineering*, vol. 31, no. 5, pp. 106–117, 2023. doi: 10.33383/2022-106
- [6] V. Dimitrova, N. Nikolov, and T. Gospodinov, "Education in the era of smart cities: Transformation and opportunities," in *Proc. 15th Int. Scientific and Practical Conf. Environment. Technology. Resources*, 2024, vol. 2, pp. 352–357. doi: 10.17770/etr2024vol2.8084
- [7] S. Rani and R. Kumar, "Bibliometric review of actuators: Key automation technology in a smart city framework," *Materials Today: Proceedings*, vol. 60, Part 3, pp. 1800–1807, 2022. doi: 10.1016/j.matpr.2021.12.469
- [8] M. Lom and O. Pribyl, "Smart city model based on systems theory," *International Journal of Information Management*, vol. 56, 102092, 2021. doi: 10.1016/j.ijinfomgt.2020.102092

- [9] A. E. Gourari, M. Raoufi, and M. Skouri, "Impact of using smart learning platforms in e-learning on student achievement," in *Pedagogy, Didactics and Educational Technologies: Research Experiences and Outcomes in Enhanced Learning and Teaching at Cadi Ayyad University*, Singapore: Springer Nature Singapore, 2022, pp. 127–139. doi: 10.1007/978-981-19-5137-4_11
- [10] E. S. Soegoto and M. F. Rinaldy, "Smart campus with a learning management system," in *IOP Conference Series: Materials Science and Engineering*, vol. 879, 012003, 2020. doi: 10.1088/1757-899X/879/1/012003
- [11] R. Mithun and S. Roopadarshini, "A study on distance learning: A developmental leap towards smart education in smart cities," *Journal of Digital Learning and Distance Education*, vol. 2, no. 7, pp. 645–651, 2024. doi: 10.56778/jdlde.v2i7.175
- [12] S. Azizi, G. Nair, R. Rabiee, and T. Olofsson, "Application of Internet of Things in academic buildings for space use efficiency using occupancy and booking data," *Building and Environment*, vol. 186, 107355, 2020. doi: 10.1016/j.buildenv.2020.107355
- [13] T. H. Noor, E.-S. Atlam, A. M. Almars, A. Noor, and A. S. Malki, "An IoT-based energy conservation smart classroom system," *Intelligent Automation & Soft Computing*, vol. 35, no. 3, pp. 3785–3799, 2023. doi: 10.32604/iasc.2023.032250
- [14] A. Franco, E. Crisostomi, F. Leccese, A. Mugnani, and S. Suin, "Energy savings in university buildings: The potential role of smart monitoring and IoT technologies," *Sustainability*, vol. 17, no. 1, 111, 2025. doi: 10.3390/su17010111
- [15] D. Rico-Bautista, C. D. Guerrero, C. A. Collazos, G. Maestre-Góngora, J. A. Hurtado-Alegria, Y. Medina-Cárdenas, and J. Swaminathan, "Smart university: A vision of technology adoption," *Colombian Journal of Computing*, vol. 22, no. 1, pp. 44–55, 2021. doi: 10.29375/25392115.4153
- [16] S. Luckyardi, R. Jurriyati, D. Disman, and P. D. Dirgantari, "A systematic review of the IoT in smart university: Model and contribution," *Indonesian Journal of Science and Technology*, vol. 7, no. 3, pp. 529–550, 2022. doi: 10.17509/ijost.v7i3.51476
- [17] I. Gligorea, M. Cioca, R. Oancea, A.-T. Gorski, H. Gorski, and P. Tudorache, "Adaptive learning using artificial intelligence in e-learning: A literature review," *Education Sciences*, vol. 13, no. 12, 1216, 2023. doi: 10.3390/educsci13121216
- [18] L. Y. Tan, S. Hu, D. J. Yeo, and K. H. Cheong, "Artificial intelligence-enabled adaptive learning platforms: A review," *Computers and Education: Artificial Intelligence*, vol. 9, 100429, 2025. doi: 10.1016/j.caeai.2025.100429
- [19] J. Garzón, E. Patiño, and C. Marulanda, "Systematic review of artificial intelligence in education: Trends, benefits, and challenges," *Multimodal Technologies and Interaction*, vol. 9, no. 8, 84, 2025. doi: 10.3390/mti9080084
- [20] M. Ikram, S. B. M. Hanefar, S. M. U. Saleem, and F. Zulfiqar, "Artificial intelligence in education: A systematic review of personalised learning trends and future directions," *Frontiers in Education*, vol. 11, 1782626, 2026. doi: 10.3389/feduc.2026.1782626
- [21] A. Shiwani, S. U. Hasan, and S. Kumar, "Artificial intelligence in neuroeducation: A systematic review of AI applications aligned with neuroscience principles for optimizing learning strategies," *Journal of Development and Social Sciences*, vol. 5, no. 4, pp. 578–593, 2024. doi: 10.47205/jdss.2024(5-IV)50
- [22] A. B. Mbombo and N. Cavus, "Smart university: A university in the technological age," *TEM Journal*, vol. 10, no. 1, pp. 13–17, 2021. doi: 10.18421/TEM101-02
- [23] S. Chen and Q. Li, "Smart campus and student learning engagement," *International Journal of Information and Communication Technology Education*, vol. 20, no. 1, 2024. doi: 10.4018/IJICTE.337611
- [24] A. S. Mohamedhen, A. Alfazi, N. Arfaoui, R. Ejbali, and M. F. Nanne, "Towards multi-agent system for learning object recommendation," *Heliyon*, vol. 10, no. 20, e39088, 2024. doi: 10.1016/j.heliyon.2024.e39088
- [25] J. P. López-Goyez, A. González-Briones, and Y. Demazeau, "An adaptive multi-agent architecture with reinforcement learning and generative AI for intelligent tutoring systems: A Moodle-based case study," *Applied Sciences*, vol. 16, no. 3, 1323, 2026. doi: 10.3390/app16031323
- [26] C. Dahal, J. Chen, M. Ye, and Z. Xiong, "Multi-agent systems in education: A survey from the trustworthiness perspective," *IEEE Transactions on Artificial Intelligence*, pp. 1–16, 2026. doi: 10.1109/TAI.2026.3695502
- [27] D. Maldonado, E. Cruz, J. A. Torres, P. J. Cruz, and S. D. P. G. Benitez, "Multi-agent systems: A survey about its components, framework and workflow," *IEEE Access*, vol. 12, pp. 80950–80975, 2024. doi: 10.1109/ACCESS.2024.3409051
- [28] H. Chniti, A. Hadyaoui, and L. Cheniti-Belcadhi, "Multi-intelligent agents and generative AI in learner assessment: A scoping review of research trends, challenges, and hybrid opportunities," *Procedia Computer Science*, vol. 270, pp. 3340–3351, 2025. doi: 10.1016/j.procs.2025.09.459
- [29] A. M. Younus, M. S. Abumandil, V. P. Gangwar, and S. K. Gupta, "AI-based smart education system for a smart city using an improved self-adaptive leap-frogging algorithm," in *AI-Centric Smart City Ecosystems*, CRC Press, 2022, pp. 231–245.
- [30] C. Mei, B. S. Alias, and J. B. Ahmad, "Alumni engagement in higher education institutions: A comprehensive systematic literature review (SLR)," *Environment and Social Psychology*, vol. 10, no. 12, 4398, 2025. doi: 10.59429/esp.v10i12.4398
- [31] J. Sharma, B. S. Bhatia, and S. Bali, "Technological Innovations and their impact on alumni engagement and relationship management in higher education," *International Journal of Research in Computing*, vol. 5, no. 1, pp. 57–73, 2026.
- [32] N. Nisar, A. Raza, P. N. Pathan, M. M. Sattar, and U. Memon, "Alumni-driven sustainability strategies: paving a way forward for sustainable development of public HEIs," *Journal of Applied Research in Higher Education*, vol. 17, no. 5, pp. 1626–1641, 2025. doi: 10.1108/JARHE-03-2024-0140
- [33] F. S. Nassar, A. O. Abbas, H. Al-Saify, and O. M. Ali, "The impact of extracurricular activities on developing academic standing, student satisfaction, performance, and bolstering the academic reputation of higher education institutions from the perspective of SDGs," *Journal of Lifestyle and SDGs Review*, vol. 5, no. 1, e02758, 2025. doi: 10.47172/2965-730X.SDGsReview.v5.n01.pe02758
- [34] T. T. Nguyen, L. T. H. Nguyen, C. V. Trinh, and T. T. Duong, "The role of extracurricular activities in university education: Student engagement and institutional management," *International Journal of Advanced and Applied Sciences*, vol. 12, no. 8, pp. 129–138, 2025. doi: 10.21833/ijaas.2025.08.013
- [35] N. Ribeiro, C. Malafaia, T. Neves, and I. Menezes, "The impact of extracurricular activities on university students' academic success and employability," *European Journal of Higher Education*, vol. 14, no. 3, pp. 389–409, 2024. doi: 10.1080/21568235.2023.2202874
- [36] S. Besekar, S. Jogdand, and W. Naqvi, "Sample size in educational research: A rapid synthesis," *F1000Research*, vol. 12, 1291, 2023. doi: 10.12688/f1000research.141173.1

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