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How to link educational purposes and immersive video games development? An ontological approach proposal

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ABSTRACT

Video games offer a interesting approach for enhancing educational experiences across various domains. Whether repurposing existing games, such as Sim City for teaching budget management, or developing dedicated serious games, they enrich the spectrum of educational resources available.

Nevertheless, creating immersive gaming and learning environments presents challenges. The absence of consensus on comprehensive tools or models poses an initial hurdle. Furthermore, designing such experiences entails intricate considerations, including multidisciplinary collaboration and the inherent complexity of open nature of learning experiences.

Our proposed ontology addresses these challenges by integrating concepts from education, immersive game design, and virtual environments. This integration facilitates the alignment of learning objectives with game-design elements, leveraging the multi-agent systems paradigm for coherence.

Serving as a semantic hub, our ontology enhances communication among interdisciplinary teams by employing clearly defined terms. Additionally, it provides a robust conceptual framework to navigate the complexity inherent in educational game development.

We assess the efficacy of our ontology by instantiating it with several existing games or game engine. This instantiation validates its expressiveness and completeness, while logical consistency is confirmed through inference engine verification. Through these efforts, our ontology emerges as a valuable tool for advancing the design and development of educational video games.

Keywords: Knowledge-Driven Approach, Generic Ontology, Education Video Games, Immersive Video Games, Multi-Agent Paradigm.

1. INTRODUCTION

In addition to its prominent position in modern cultural discourse, video games also offer an interesting approach to enhancing the quality of education on multiple fronts, such as improving decision-making skills, fostering collaboration, and providing learners with a more rewarding sense of progression [1] [2]. Furthermore, the diverse forms these games can take, ranging from simulator-style games to more playful investigative experiences, represent new educational tools with applicability across all age groups. However, as some authors have noted [3], the diverted use of video games for education has its limitations, particularly concerning adaptation to learning objectives. One solution is to develop games based on specific learning objectives.

Thus, the development of educational video games requires the collaboration of multidisciplinary teams (pedagogical engineers, teachers, game designers, developers, etc.). During the operational phase of the game, teachers continue their work by leveraging the game, such as monitoring learners' progress or providing guidance to those encountering difficulties. Additionally, during the design phase, these teachers oversee the didactic scope of the developed game and ensure that the pedagogical objectives align with the gameplay.

This brings us to several challenges in the development of this type of game. Firstly, it is essential to accurately define the learning objectives to be achieved, including the knowledge and skills to be conveyed. Secondly, engaging and enjoyable gameplay mechanisms must be designed based on these learning objectives. This design phase involves the multidisciplinary teams mentioned earlier, highlighting the need for tools that facilitate synergy among them, particularly in the form of a common modeling tool, such as an ontology [4].

However, in the current scientific literature, there are few generic models and ontologies that intersect these domains and offer a holistic approach. While some ontologies address video games, education, and learning representation separately, few articles propose models for educational games, often lacking coverage of essential game components or educational aspects, sometimes neglecting user modeling. Yet, representing all components and actors in play is essential for elucidating and leveraging relationships among these different elements. The ultimate goal is to propose a generic model that facilitates the development of immersive and educational games.

Our proposal entails an ontology written in OWL, describing and relating all significant concepts involved in the development of an educational game. In addition to concepts pertaining to the immersive world of video games and learning objectives, this ontology enables the correlation of these elements through the lens of the multi-agent paradigm and the explication of the educational objectives the game system must achieve.

2. RELATED WORKS

An ontology is a formal model representing a shared and common conceptualization of a specific knowledge domain. Its purpose is to explicitly define the concepts, entities, relations, and axioms that underlie this domain, thereby establishing a formal semantic structure for the representation and comprehension of domain knowledge.

In knowledge-based approaches, ontologies serve as reference computational models, interconnecting all concepts, especially when multiple domains are involved. As such, the use of an ontology offers numerous advantages [3] [5] [6]:

1. It enables system interoperability based on this model.
2. It facilitates knowledge sharing among all stakeholders involved in development, particularly in multidisciplinary team settings.
3. It enhances the logical robustness of the model through verification with logical inferences.

Specifically, within the context of multi-agent systems (MAS), ontologies provide reinforcement in several aspects [7]:

1. They enable the modeling of agents, the environment, and organization as a coherent whole.
2. They facilitate the structuring of knowledge, objectives, and reasoning of agents in alignment with the rest of the system.
3. They ease the modeling, development, and verification of MAS.

This necessitates clarifying the relationship between MAS and our objective of linking video games and educational objectives. Immersive video games are based on a virtual world populated with objects and non-player characters (NPCs) with which the player interacts. This entity structure can be likened to an MAS where the environment is the virtual world, containing objects (a term shared in the MAS domain) and NPCs (agents with which the player interacts). The player character can thus be viewed as an embodied agent immersed in this environment. Moreover, immersive video games and MAS share similar characteristics [8] [9]:

1. Autonomous and goal-directed behaviors (proactivity).
2. System dynamics based on interaction and communication.
3. The pursuit of emergent behaviors.

Furthermore, models and ontologies from the MAS domain, and more broadly, works from the MAS field, enrich the models of video games, which are already scarce. Finally, it becomes interesting to consider what video games can bring to education.

Indeed, these contributions are beneficial for all parties involved. According to C. Russell and J. Shepherd [10], the benefits of immersive role-playing game learning environments extend to both learners and teachers. The authors propose criteria for evaluating these benefits.

For learners, educational video games should enable/provide:

1. Immersion.
2. Engagement in the role.
3. Anonymity.
4. Synchronous and asynchronous communications.
5. Group and individual reflections.

For teachers, the criteria conditioning the benefits are:

1. Facilitating pedagogical monitoring by providing a means to have both a global and more precise view.
2. Enhancing the speed of teacher feedback, thanks to the previous point.
3. Structuring pedagogical activities.

Increasing the range of pedagogical resources available to teachers, with an innovative and engaging type of resource.

Before continuing our study on video games, it is important to clarify the meaning of the adjective "immersive." It is possible to qualify as "immersive" video games that establish and rely on a diegesis. These games offer players a plausible fictional universe with which the player can interact [11]. Immersive video games are designed to provide the user with a sense of presence and engagement. In contrast, non-immersive video games (such as Minesweeper or a simple quiz game) have limited interaction and provide no sense of immersion. We choose to focus this work on immersive games precisely because this immersion facilitates engagement [10] [11].

The development of immersive educational games could be facilitated by using a platform or a generic reference model with a holistic approach. Furthermore, this model should meet the targeted success criteria. However, despite several proposals in the current scientific literature, these do not validate all these requirements. First, we will review articles dealing with the modeling of educational video games. Second, we will explore articles dealing with the modeling of each of the involved domains.

In the current literature, there are a few models addressing educational video games. Notably, Notari, Hieshelr, and King [12] propose an ontology delineating various educational software, including educational video games. However, this ontology is posterior to our research, as it treats educational video games as available pedagogical resources without addressing their components explicitly. Similarly, some works [13] delineate the types of ontologies relevant to educational video games.

Closer to our research focus, several articles address the modeling of educational video games [14] [15] [16], proposing ontologies emphasizing generality, adaptation, and educational aspects. However, these proposals remain limited in certain aspects. Specifically, these ontologies do not offer an explicit representation of user profiles (both learners and teachers), which could limit personalization of the game and learning. Additionally, these ontologies are heavily focused on the gaming experience while neglecting the modeling of the game's diegesis. This omission appears to hinder the proposal of a comprehensive design model, which would ensure the coherence of all designed components.

Furthermore, another set of interesting works [17] [18] [19] [20] concerns the modeling of concepts related to narrative video games with educational purposes. The proposed models cover a wide range of targeted criteria, including adaptation, engagement, and motivation. However, these ontologies are not generic as they are limited to narrative games. Moreover, they lack a component for representing elements of an immersive video game (environment or objects).

As observed, current literature offers few works suitable for a holistic approach to modeling all components of an immersive educational game system. However, there are several seminal works addressing individual major concepts composing such systems.

In the domain of video games itself, there exist several ontologies covering the diegetic components of video games, as well as those dealing with the relationship between the player and the game.

For the first category, A. O. R. Franco et al. [21] propose a modeling of all diegetic elements composing a role-playing game: from the played character to objects, quests, and scenarios. These works are interesting as role-playing games aim to immerse the player in a fictional universe, aligning with our goal of modeling immersive games. However, the proposed ontology addresses very few non-diegetic elements.

For the second category, the authors of "The Video Game Ontology" [23] have addressed concepts related to the "object" video game, focusing on non-diegetic elements such as the representation of achievements, the player, game sessions, or real-money purchases. While these elements are relevant to address, they only encompass a subset of what is necessary for our proposal. This is also the case for the "Game Ontology Project" [24] [25], which offers a reading of the video game through four main concepts: Rules, Interfaces, Entity Manipulations, and Goals. This project covers the main non-diegetic elements that constitute a video game.
Finally, other works, such as the thesis of M.S. Debus [22], propose a "hybrid" vocabulary by addressing certain diegetic and non-diegetic aspects of video games, such as entities, goals, space, and time.

By aggregating the vocabularies from these ontologies, it is possible to have an overview of diegetic and non-diegetic elements constituting an immersive video game. Notably, key concepts emerge, including entities, time, space, and goals, which are common points with multi-agent modeling [28], as they also address these concepts. However, in our particular case of immersive and educational video games, there is a need to clarify the types of objectives that our game system aims to achieve.

This leads us to question the modeling and ontologies dealing with teaching concepts, specifically the representation of learning objectives.

The works of R. Vas [27] propose an ontology where learning tasks are composed based on competencies linked to knowledge areas, which in turn group theorems, basic concepts, and examples. This is a very interesting modeling of learning competencies and tasks. However, it seems challenging to exploit as it lacks a notion of learning goal that intersects easily with the already specified goal concepts. Furthermore, the representation of all tasks does not offer a distinction that would allow us to directly link it to other concepts from video games and the multi-agent paradigm.

Bloom's taxonomy [28] [29] is another modeling in the field of education, aiming to classify learning objectives along two dimensions: the type of knowledge and the cognitive process required. This classification is an important reference, focusing on the goals to be achieved. This facilitates its integration with other ontology concepts. We will revisit its integration in the section addressing our proposal.

We have just reviewed a set of works relevant to the modeling of immersive and educational video games. It is evident that there is no consensus for modeling educational video games, and some of these models are not generic, focusing on a specific type of game. Among the models addressing educational games in a generic manner, current proposals have limitations regarding holistic aspects, often omitting user representation or immersion elements.

Subsequently, examining more specialized works, we noticed the existence of several ontologies, solely within the domain of video games, addressing both diegetic and non-diegetic elements that compose video games. These ontologies share common terms, facilitating their reuse and aggregation.

Furthermore, in the domain of knowledge and learning objective modeling, Bloom's taxonomy emerged as a reference. We also observed that Bloom's taxonomy integrates more seamlessly with goal and task representations from reference ontologies of video games and multi-agent systems.

In summary, research conducted in these specific domains offers promising perspectives for modeling immersive and educational video games. However, a significant gap remains apparent: the lack of a unifying ontology capable of linking these disparate works to ensure logical and semantic coherence at all levels. It is precisely to address this need that we present our proposal, which consists of an ontology serving as a comprehensive conceptual framework for the design of immersive video games for educational purposes.

3. ONTOLOGY PROPOSAL

To construct this ontology, we adhere to a classical methodology such as the one proposed by METHONTOLOGY [30]. Although there are several methodologies available, the maturity of the latter has already been demonstrated [31]. This methodology is based on four main phases: specification (where use cases and overall expected use are defined), conceptualization (where important concepts of the model are selected and organized), formalization (involving the transformation of the conceptual model into a formal model), and integration (where the previous model is implemented in a computer-understandable language). In our case, integration will be done using OWL with the Protégé tool [32].

The ontology we present, named "DIG Ontology" (for "Didactic and Immersive Game Development"), aims to provide a conceptual framework facilitating knowledge sharing and the design of immersive video games for educational purposes. This conceptual framework has been decided in accordance with the success criteria outlined in the previous section. The main themes of the concepts addressed are therefore as follows, as shown in the figure 1: Education, specifically knowledge and learning objectives to be achieved,Video games and their non-diegetic components, Immersive virtual worlds, corresponding to the diegetic elements of video games, which will be observed through the multi-agent paradigm.

As previously mentioned, immersive video games and their fictional worlds are a type of multi-agent systems. Therefore, we incorporate the main concepts of the multi-agent paradigm into the DIG ontology. To do this, we rely on the integration of the reference ontology "MOBMAS" [26]. We thus propose to integrate at least the following concepts:

Objects: encompassing all entities of the system and present in the environment. These entities have attributes and can undergo actions that cause them to evolve.

Agents: corresponding to the objects of the system that can undertake actions oriented towards themselves or, more generally, towards other objects in the environment.

Organizations: representing a dynamic group of agents with a common role.

Environment: corresponding to the abstract entity containing the objects, resources, and agents of the system.
Events: significant occurrences in the environment to which an agent can react.

Agent Goals: representing a set of world states that the agent wishes to achieve. These goals can be hierarchically organized in the form of a tree.

System Tasks: specifying the final objectives of the system. Agent goals are constructed to achieve the accomplishment of these system tasks.

Actions: the atomic unit of work that the agent can perform. These actions aim to modify the environment, creating system dynamics.

Furthermore, in the context of immersive video games and virtual worlds, some concepts retain a nearly unchanged meaning. This is the case for concepts such as Environment, Action, or Object. Other concepts receive additional or more precise meanings.

Drawing from previous references [21][22][23], the following concepts and their definitions emerge:

Characters (sometimes **Entity**): encompassing all active entities of the system, corresponding to the concept of Agent. In our specific framework, two subclasses of agents can be delineated: player characters and non-player characters.

States: representing a generic state property attributable to characters. This can be a numeric state (e.g., hit points) or boolean (e.g., representing whether the player is asleep).

Missions: the objectives that the player must achieve within the fictional universe. They should echo the learning objectives and can be assimilated to the Objectives of a particular type of agent, namely player characters.

Objectives: corresponding to the role-tasks of all agents within the game. They determine the gameplay mechanics to be implemented.

Game Rules: the freedoms and constraints that condition possible actions and thus govern the game through its environment.

So far, we have explored the elements necessary for building the ludic components of the model. It remains to determine how to model the knowledge and learning objectives targeted. As we highlighted in the "Related Works" section, Bloom's taxonomy [28] classifies learning objectives along two dimensions: Firstly, a cognitive process corresponding to a verb. Secondly, a type of knowledge corresponding to a noun among the hierarchy of Bloom’s taxonomy.

A **learning objective** is thus composed of a verb (the cognitive process) and a noun (the type of knowledge). Thus, to express the objective "I want learners to know the Pythagorean theorem," it can be decomposed into "Remember the Pythagorean theorem." With "Remember" representing the cognitive process and "the Pythagorean theorem" corresponding to "knowledge of theory." Mastery of this theory can then be increased by moving to a higher-level process, such as "Understand the Pythagorean theorem."

By integrating these concepts into the DIG ontology, we have shown how to represent learning objectives, but the question arises of how to relate them to elements of the game.

To address this, we propose defining complementary cognitive processes that lead to the objective. Thus, we obtain:

For learners to "*Remember*," the immersive game must "*Unearth*," i.e., it must anchor the fact in long-term memory.
For learners to "*Understand*," the game must "*Explain*," i.e., it must explain the knowledge from multiple aspects.

For "*Apply*," it is necessary to "*Immerse*," i.e., to put the knowledge into a situation for the learner to implement.

For "*Analyze*," it is necessary to "*Breakdown*," i.e., to decompose the knowledge to help the learner identify its components and relationships.

For "*Evaluate*," it is necessary to "*Deem*," i.e., to judge the knowledge so the learner can position it relative to criteria (relevance, reliability, credibility) and their own ideas.

For "*Create*," it is necessary to "*Summarize/Combine*," i.e., to encourage synthesis of knowledge so the learner can combine it with existing knowledge to derive new insights.

Thus, by proposing these complementary verbs, we suggest grouping them under the concept of **Pedagogical Experience**. This refers to what the pedagogical source (in our case, the teacher and immersive video game) must achieve to address the pedagogical objective.

In the specific context of our immersive video game, we then propose specifying the definition of these Pedagogical Experiences, resulting in **Immersive Pedagogical Experiences**. We define the latter as follows:

Unearth: Existence within the universe / Articulation in a spatio-temporal situation.

Explain: Introduce an explicit/implicit storyline. For example, through a dialogue with an NPC or in a cinematic.

Immerse: Provide a problem to solve related to this knowledge. For example, by giving a quest.

Breakdown: It is possible to break down the problem into more specific sub-problems to solve. This decomposition must be related to the targeted knowledge.

Deem: Provide feedback on the player's choices to solve the sub-objectives related to the quest to be accomplished, for example in the form of a score.

Summarize/Combine: Provide the player with a synthesis of what they have accomplished, or offer a new objective requiring synthesis, for example in the form of a summary, a final cinematic, or a more challenging challenge combining everything seen.

To complete the relationship between these didactic concepts and the rest of the previously discussed concepts, we now define that **System-tasks** aims to produce **Immersive Pedagogical Experiences**. Taking the previous example of learning the Pythagorean theorem, if we want learners to be able to use the Pythagorean theorem, the ontology proposes the following breakdown:

Apply the Pythagorean theorem -> **Immerse** -> Ex. An NPC gives a quest where the player has to reinforce a wall against enemy invasion. They have to find the right beam.

To Apply the Pythagorean theorem, it is necessary to:
Understand the Pythagorean theorem -> **Explain** -> Ex. An NPC talks to the player to explain the principle of the Pythagorean theorem, using the environment.

To Understand the Pythagorean theorem, it is necessary to:
Remember the Pythagorean theorem -> **Unearth** -> Ex. A cutscene introduces the Pythagorean theorem and how it can be utilized.

As we have just seen, the ontology we propose aims to provide a conceptual and semantic framework facilitating the development of immersive educational video games. This ontology is generic and follows a holistic approach, covering concepts from all involved fields. It could be jointly used by educational and game development teams to design this innovative type of educational resources. To achieve this, we propose employing a cyclical utilization method, based on the refinement of a specific ontology founded on DIG, as shown in the figure 2.

In the "Related Works" section, we outlined the criteria for evaluating the benefits brought by immersive educational video games. For a game to bring these benefits, the structure/model on which it is based must allow it. To promote immersion, the ontology provides vocabulary for representing environments populated with objects and characters. Engagement is brought about precisely by immersion and clear objectives. Playing a game through an avatar (PlayerCharacter) allows the learner to feel more anonymous, encouraging experimentation and testing without fear of failure, thus echoing the facilitation of individual reflections. The ontology also proposes modeling learners, such as teachers, allowing them to have PlayerCharacters that could have mailboxes or discussions via a chat, facilitating communications and hence group reflections. Finally, by implementing a visualization dashboard of objectives accomplished by each learner, for teachers, the game facilitates pedagogical monitoring. Moreover, this dashboard, also built from the ontology (especially through Bloom's taxonomy), ensures the structuring of pedagogical activities. Ultimately, immersive educational games developed based on this ontology help expand the range of available educational resources.

4. EXPERIMENTAL EVALUATION

These endeavors have been undertaken with the aim of providing a functional foundation facilitating the development of immersive and educational games. At this stage, the ontology's evaluation already involves several assessments: automated validation through the reasoners offered by the Protégé tool, as well as validation through comparison with other ontologies, since the DIG ontology integrates several of them.

Furthermore, we propose to evaluate it through several distinct use cases. We propose to apply it to the description of several different cases: 1- The case of the video game "Paper Please," which at first glance does not have an educational purpose but can be assimilated to a "light-simulation" of customs post management. 2- The case of the serious game "UrgSim," whose objective is to train healthcare professionals in emergency care through simulation.

The video game "Paper Please" is, according to its authors [33], an adventure and simulation game where the player, "as an Immigration Inspector, must control the flow of people wishing to enter the territory." The game's environment is straightforward, as the player cannot move, and the environment mainly consists of the immigration inspector's office and a secondary view at the top of the screen (see screenshot), showing an overview of the checkpoint with borders and waiting individuals.

The main system-task is therefore to "immerse the player as an immigration service inspector (with the tasks assigned to him/her)." Although this goal is not an end in itself (here, this immersion serves more as a pretext to experience a political fiction and question the player's morality), it identifies the two types of roles found in the game: the inspector, embodied by the player; and the individuals wishing to migrate, virtual characters controlled by the game. With these two roles, the objectives of each are easily distinguishable. The inspector must control each passage by checking various documents, which are interactive objects that can help the player perform his/her mission. Decision-making is simple and symbolized by an environmental object: the immigration service's validation or rejection stamp.

Although the game's objective is not purely didactic, it is possible to model learning objectives within this game. Indeed, the main gameplay loop is based on a "Knowledge of criteria for determining appropriate procedures," which involves verifying the set of criteria determining entry or denial of entry to the territory. It is also possible to observe, in the game, the evolution of the cognitive process since it offers the player an object (the manual) to remember the procedure to follow. Then, on the first pass, the player is guided by the game's tutorial, which explains the steps to follow step by step (understand process). Finally, in the following days, the player must apply the appropriate procedure to progress in the game.

The serious game "UrgSim" proposes to embody an emergency physician [34]. Its authors describe it as a computer-assisted training tool for learning emergency care management. It is therefore an immersive educational game.

The agents in the game are the player character, who takes on the role of the learner, and the patients who are virtual characters. It is noteworthy here that the teacher is not represented in the game, which may be due precisely to the lack of a generic model that takes them into account. This game offers two phases of care: diagnosis and treatment.

In the first phase, the game environment is the virtual patient's room, represented in 3 dimensions. The two characters (the doctor and the patient) are visible on the screen, and this phase focuses on diagnosis, where the player can ask the patient questions about his/her condition to determine the ailments. In this phase of the game, the interaction takes place through a dialogue window (questions/answers).

In the second phase of the game, the environment evolves to the ambulance. This time, the goal shifts to the application of emergency care. In the ambulance are several objects that allow for patient care.

This system-task can be broken down into two agent-tasks, linked to learning objectives, which the ontology allows to describe as follows: The main system-task could be "Allow the learner to take care of emergency situations." This system-task can be related to the main learning objective: "Apply appropriate emergency care." Here, "appropriate emergency care" can be categorized as a "Knowledge of specific methods," depending on the diagnosis, which itself can be represented as "Knowledge of criteria for determining appropriate procedures." Just as we have decomposed the system-task, it is possible to decompose these agent-tasks again to a finer granularity level, to reach the atomic actions that the learner/player must perform. The figure 3 shows this instantiation in the ontology.

The software "RPG Maker" enables the development of two-dimensional role-playing games with a retro style [35]. The definition of the main game elements is done in what the software authors have called the "Database," composed by many tabs. Let's verify if the DIG ontology allows modeling all these elements.

The first tab, "Actor," allows defining player characters. This corresponds to the concept of PlayerCharacter, which is a child of the Character class, which are themselves a type of agents. It is possible to see that this window allows assigning values to the states of each of the PlayerCharacters planned in the game. The "Classes" tab is specific to the "RPG" genre and allows defining the evolution of states and skills that each "class" of character can use. These "classes" can be likened to organizations in that they group together a set of characters with common states. The "Skills" tab is also specific to the "RPG" genre and defines the actions usable by characters during combat. The following tabs "Items," "Armor," and "Weapons" represent objects whose categorization and use are specific to the genre. The "Enemies" are a specific type of NonPlayerCharacter, and this tab precisely allows adjusting each action usable by this character. The tab also allows adjusting the various statistics (or statuses) of each enemy. The "Troops" tab allows defining groups of enemies with the common objective of defeating the player in combat, which corresponds to the definition of organizations specific to each combat. The "State" tab maintains the same terminology but allows defining specific states: booleans. Graphic environments can be defined via the "Tilesets" tab. These environments are then drawn in another window using these "tilesets," on which the objects and characters are placed. The "Animation" tab allows drawing graphical special effects, while the following tabs allow adjusting the gameRules of the game.

In this section, we implemented our ontology proposal using two games, as well as a game engine, as case studies. First, we described how the ontology was adapted to represent the concepts and relations specific to each game and software. We experimented with the use of the ontology on two games of different nature (one educational and one not), as well as with software specifically dedicated to role-playing game creation. These results underscore the generality and completeness of our ontological approach in the domain of immersive educational games, providing a solid conceptual framework for the design and development of immersive games for learning.

5. CONCLUSIONS

The utilization of immersive educational video games represents an engaging opportunity to support the pedagogical resources available for teaching [1] [10]. However, the diverted use of an existing video game to match pedagogical needs remains limited [3]. Therefore, the solution remains to develop dedicated immersive educational video games, but the solutions proposed in current literature remain limited in terms of covering all the necessary multidisciplinary vocabulary and in terms of generality.

Our proposal consists of an ontology providing a conceptual and semantic framework facilitating the development of this type of game. The latter facilitates communication between multidisciplinary teams, enables the normalization of data produced by such games, and facilitates the structuring of game components. Furthermore, its implementation in OWL allows checking the logic of the involved concepts, in addition to being able to be used to study games or other existing solutions through its prism.

To evaluate our ontology, we confronted it with different use cases, including an educational game, a non-educational game, and a game engine. It will be interesting to push these experiments further, notably by applying it in real development projects. Furthermore, this ontology constitutes a foundation that needs to be extended according to more specific needs.

We aim to continue developing the DIG ontology through the development of an educational game for university students, as part of a MOOC. Additionally, we would like to make it available to experts in each of the involved domains to continue its extension.

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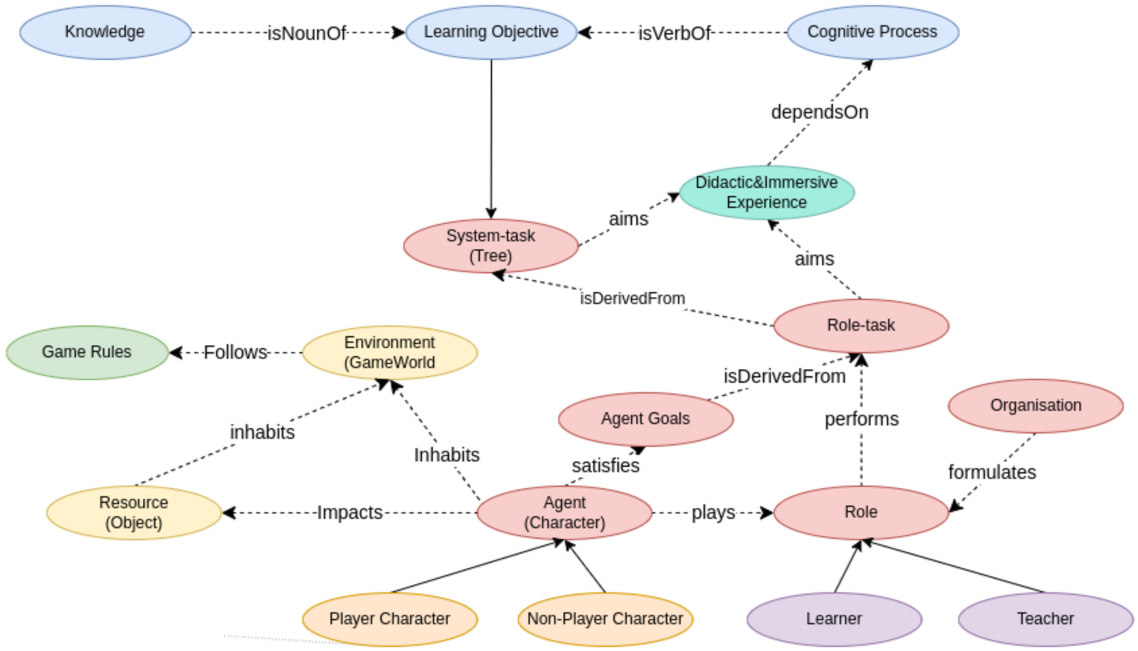

Figure 1: Partial overview of DIG ontology

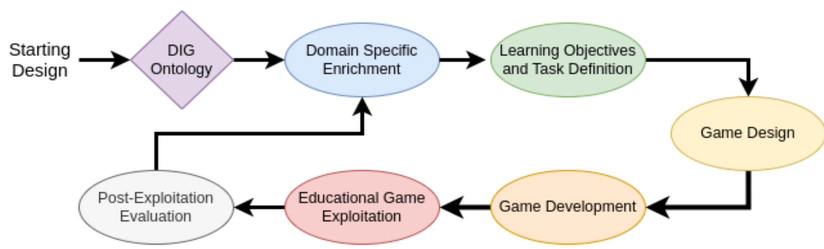

Figure 2: Method of using DIG ontology

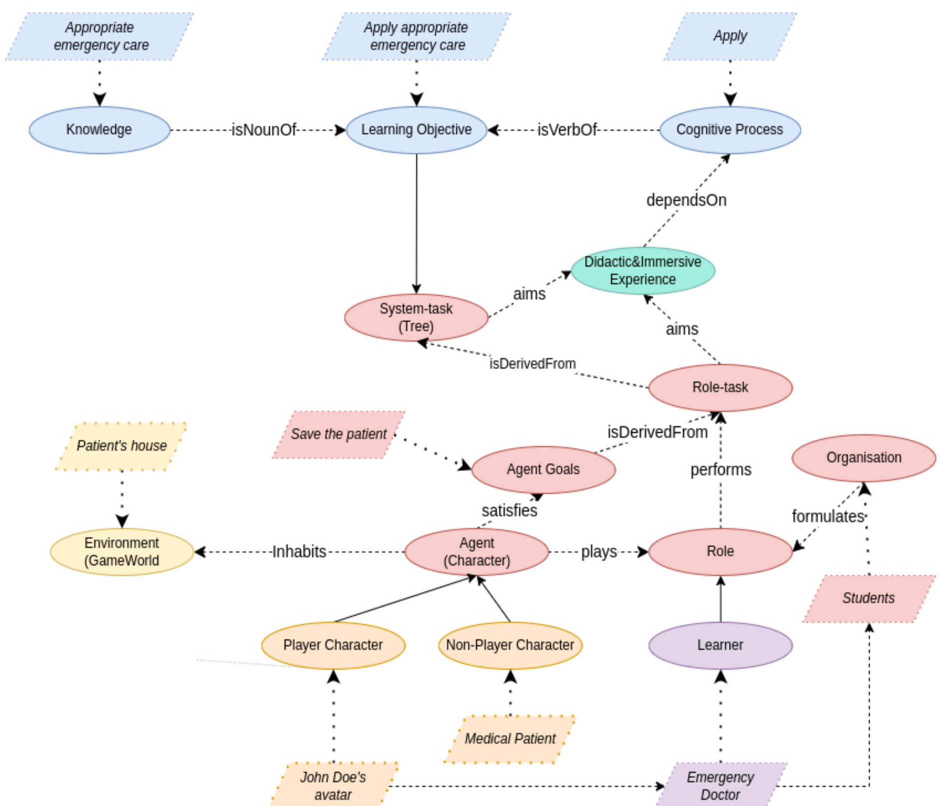

Figure 3: Partial instantiation of UrgSim in DIG ontology