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An Ontology Engineering Approach to Gamify Collaborative Learning Scenarios

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Abstract. The design of collaborative learning (CL) scenarios that increase both students' learning and motivation is a challenge that the CSCL community has been addressing in the past few years. On one hand, CSCL design (i.e. scripts) has been shown to be effective to support meaningful interactions and better learning. On the other hand, scripted collaboration often does not motivate students to participate in the CL process, which makes more difficult the use of group activities over time. To deal with the problem of motivation, researchers and educators are now looking at gamification techniques to engage students. Gamification is an interesting concept that deals with the introduction and use of game design elements in a proper way to satisfy individual motivational needs. The use of gamification in educational settings is a complex task that requires, from instructional designers, knowledge about game elements (such as leaderboards and point systems), game design (e.g. how to combine game elements) and their impact on motivation and learning. Today, to the best of our knowledge, there are no approaches for the formal systematization of the instructional design knowledge about gamification and its application in CL scenarios. Thus, to address this issue, we have applied ontological engineering techniques to develop an Ontology called OntoGaCLeS. In this paper, we present the main concepts and ontological structure used to represent gamified CL scenarios. In this ontology, we formalize the representation of gamification concepts and explain how they affect motivation in the context of collaborative learning. Particularly, we will focus on the definition of player roles and gameplay strategies. Furthermore, to show the utility of our approach, we illustrate how to use our ontology to define a personalized gamification model that is used to gamify a CL scenario based on motivational needs and individual traits of learners in a group.

Keywords: gamification, ontology, collaborative learning.

1 Introduction

In the field of CSCL (Computer-Supported Collaborative Learning), to create effective collaborative learning (CL) scenarios, researchers and practitioners have used learning/instructional theories and best practices to set up well-thought-out

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CSCL scenarios (or CSCL scripts) that increase the occurrence of meaningful interactions [12]. Using well-designed CL scenarios, there is the possibility to increase students' participation and learning during group activities. Despite of these benefits, some researchers have indicated that scripted collaboration may cause, in some situations, demotivation among students, which makes more difficult to use group activities over time [8, 12]. Thus, to support the design of better CL activities, this work intends to combine the design of CL scenarios with a motivational strategy known as ***gamification***.

In the last years, many researchers have contributed to the development of the concept of gamification and its application in education [9, 17]. Deterding and colleagues define gamification as "*the use of game design elements in non-game contexts*" [6]. It aims to increase engagement and motivation through the application of game mechanics, such as point system, social connections and so on, in a situation that normally has other purposes than entertainment. The educational benefits that a learner gets through the use of gamification depend strongly on how well game design elements are connected with pedagogical approaches [17]. Thus, in the CL context, we assert that the chances of increasing motivation and educational benefits happen when game design elements and theoretical concepts from CSCL scenarios are correctly linked.

Nevertheless, such a task is not trivial. Some researchers have indicated that many current uses of gamification are incorrect or poorly designed [24]. One of the main reasons for such poor designs is the assumption that all gamified scenarios can share the same game elements (game mechanics, game dynamics and game aesthetics) in different situations. For example, a point system that rewards all learners with the same quantity of points for each lesson does not make the learning more enjoyable. It is most enjoyable for learners, with the psychological need to demonstrate their mastery, to receive more points than other learners.

To deal with this challenge, this paper will describe the development of an ontology that organizes and adequately links knowledge related to CL design and game elements. This ontology is called **OntoGaCLeS** - an *Ontology to Gamify Collaborative Learning Scenarios*. It has been developed using the Hozo Ontology editor [18], and it is available at *http://labcaed.no-ip.info:8003/ontogacles*. Particularly, in this paper, we will focus on describing the representation of a *gamified CL scenario* and its relationship with game player roles and game mechanics.

The next sections are divided as follows: First, we present the related works and an overview of the representation of CL scenarios using ontologies. Next, we define the concepts of a gamified CL scenario. Then, a personalized gamification model is defined to illustrate the utility of our approach. Using this model, we show how to gamify a CL scenario using individual traits and psychological needs of learners. Finally, we present conclusions and future steps in our research.

2 Overview of the Collaborative Learning Ontology

The CL ontology (Collaborative Learning Ontology) [12] has been developed to formally and explicitly describe CL scenarios based on learning theories. It is based on the understanding of the interrelations among different concepts extracted from

learning theories, such as interaction patterns, group goal, individual goal, learner's role, and others. Currently, the CL Ontology has been successfully applied to support group formation [15], design of CL activities [12], creation of CL scenarios using the interaction patterns [14], and modeling learner's development [11].

To avoid possible misunderstanding, when using a conventional vocabulary, the CL ontology provides a specific terminology to define a CL scenario. The definition of these terms in the ontology is shown in Figure 1 (which illustrates the basic concepts and their relationships), where:

I-goal is the individual goal that represents what a learner (*I*) is expected to acquire, described as a change of a learner's stage of learning.

I-role is the role played by the person in focus (*I*).

You-role is the role played by the participant (*You*), who is interacting with the person in focus (*I*).

Y<=I-goal is the learning strategy that represents the strategy used by *I* to interact with another learner (*You*) in order to achieve *I-goal*.

W(L)-goal is the common goal for group members (*group goal*).

W(A)-goal is the goal of the rational arrangement of the group's activity used to achieve *W(L)-goal* and *I-goal*.

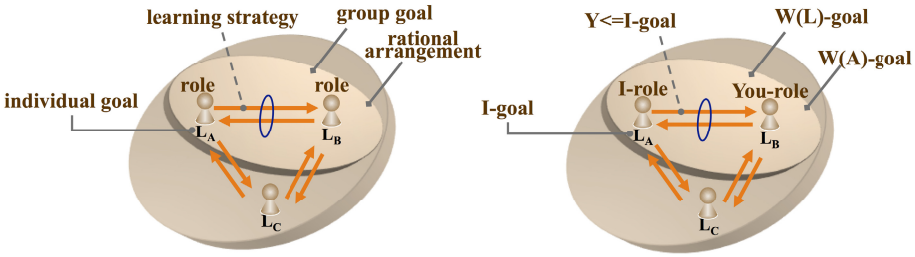

Fig. 1. Concepts and terms defined in the CL Ontology [12]

The learning strategy (*Y<=I-goal*) specifies how a learner (*I-role*) should interact with other members of the group (*You-role*) to achieve an individual goal (*I-goal*). The CL process (*W(A)-goal*) specifies the common goals of process (*W(L)-goal*) and the rational sequence of interactions (interaction pattern) provided by theories. The interaction patterns are represented by necessary and desired interaction activities, among members of a group, as influential Instructional-Learning events [12].

3 Gamifying Collaborative Learning Scenarios

A gamified CL scenario is a CL scenario in which game design elements are applied to make the learning experience more enjoyable and meaningful. In a gamified CL scenario, the learning experience itself intends to be so enjoyable that learners will do the proposed activities, even at great cost, because they are highly motivated, particularly because of the use of different game mechanics (e.g. leaderboards, point system, social connection, etc.). These game mechanics are elements introduced in

CL scenarios that define how these scenarios operate as games. They are the elements that convert specific inputs of a CL scenario into specific outputs (game rewards).

As motivation is the process used to allocate energy and to maximize the satisfaction of needs [21], a circular flow of "needs, behavior and satisfaction" is set in a CL scenario to gamify it, where to fulfill the learner's motivational needs, a learner must be engaged in behaviors that will lead to the satisfaction of those needs using game mechanics. In many cases, the combination of different game mechanics provides the adequate environment to satisfy a person's motivational needs, called human desires by Domínguez et al. [9] and Simões et al. [22]. Thus, to support this fact in CL scenarios, our current formalization of a gamified CL scenario introduces the concepts and terms shown in Figure 2, where:

I-mot goal is the *individual motivation goal* of the person in focus (*I*). Since motivation is circular, at the end of a CL scenario, the needs of a person may change or intensify, and the level of motivation (*motivation stage*) will be increased. Thus, individual motivation goals will be used to represent needs that must be satisfied and motivational stage that will be achieved.

Y<=I-mot goal is the *motivational strategy* that will be used by game mechanics to enhance the learning strategy (*Y<=I-goal*) employed by (*I*). The motivational strategies are guidelines that represent what game design elements are necessary to attain individual motivational goals (*I-mot goal*). Vassileva [23] argues that users can be viewed as agents who act to maximize their utility (payoff) in a world where certain behaviors have payoffs. Thus, to make people behave in a particular way, the motivational strategies will be used to create proper systems of rewards (incentives) for the desirable behaviors.

I-player role is the player role that will be played by the person in focus (*I*). The player role allows a participant to achieve his individual motivational goals through game mechanics define in a gameplay strategy.

You-player role is the player role that will be played by the participant (*You*), who is interacting with the person in focus (*I*).

I-gameplay is the gameplay strategy employed by the person in focus (*I*). The gameplay contains the definition of game mechanics that will be used and the behavior person (*I*) should use when interacting with the run-time using these game mechanics. In this sense, the game mechanics, user rewards and user behaviors are called game dynamics and defined using the guidelines of motivational strategy (*Y<=I-mot goal*). Furthermore, the gameplay (*I-gameplay*) is also used to define the rational arrangement among player roles, motivational strategies and game mechanics.

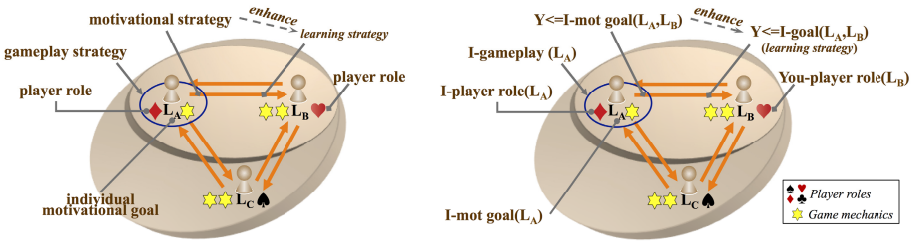

Fig. 2. Concepts and terms defined in a gamified CL Scenario

In the following subsections, we detail the concepts of a gamified CL scenario, showing how they are defined as ontological structures in Hozo. First, the ontological structures for individual motivational goals and player roles are presented because they are used by other structures. Next, the ontological structures for motivational strategy and gameplay strategy are detailed. Finally, we show the ontological structure used to represent a gamified CL scenario.

3.1 Individual Motivational Goals and Player Roles

Our ontological structure of a gamified CL scenario is based on the idea that "to satisfy a set of psychological needs, a learner will perform learning activities if game design elements introduce in them promise the satisfaction of these needs." Furthermore, as a consequence of satisfactory learning results and pleasure experiences, obtained from game design elements, "a learner will increase his liking for the actual learning activities." We call this fact internalized motivation and it consists in the change of the current motivational stage.

In our current version of OntoGaCLeS, employing self-determination theory [5] and Pink Dan Pink's theory [20], we define four psychological needs shown in Figure 3 (a), which are: autonomy, relatedness, purpose and mastery. According to self-determination theory, the motivation stages, shown in Figure 3 (b), include six stages: amotivation, external regulation, introprojected regulation, identified regulation, integrated regulation and intrinsic motivation.

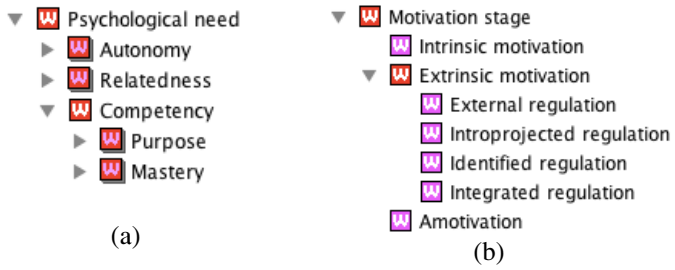

Fig. 3. (a) Psychological needs, and (b) motivation stages

Based on these ideas, Figure 4 shows the ontological structures used to represent the concepts of "satisfaction of need" and "internalization of motivation." These two concepts are individual motivational goals (*I-mot goal*) and they have two parts known as the initial stage and goal stage. In the case of "satisfaction of need", the initial stage is a psychological need and the goal stage is "without need," while the initial and goal stages, for the case of "internalization of motivation," are both motivational stages.

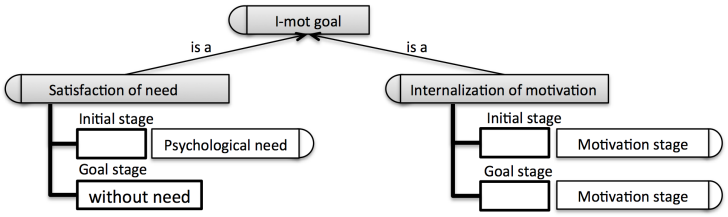

Fig. 4. Ontological structures used to represent individual motivational goals (*I-mot goal*). At the bottom are "satisfaction of need" (left) and "internalization of motivation" (right).

To allow a learner to attain his individual motivational goals, a player role must contains necessary information to define who can play it. This information includes two types of prerequisites defined as necessary and desired conditions. A learner cannot play a player role if he does not fulfill the necessary conditions; and a learner that fulfills the necessary conditions but that does not fulfill the desired conditions, he may play the player role but his individual motivational goals might not be attained.

Figure 5 (a) shows the ontological structure used to represent the concept of player role. In this structure, the current motivational stages and psychological needs are defined as necessary conditions, while the playing styles are defined as the desired conditions. The playing styles represent individual personality traits that define preferences of a learner when he is playing a game. According to Bartle [2], these playing styles represent two preferences: (1) the preference of interacting with other players (*user-orientation*) vs. exploring the game (*system-orientation*); and (2) the preference of unilateral action (*action-orientation*) vs. interaction in the game (*interaction-orientation*). Employing the ontological structure and playing styles, defined by Bartle, Figure 5 (b) shows the definition of two player roles, "Bartle Achiever" and "Bartle Explorer," that illustrate the representation of player roles. For achiever, the necessary condition is the psychological need of "mastery" and the desired conditions are the playing styles "action-orientation" and "system-orientation." For explorer, the necessary condition is the psychological need of "autonomy" and the desired condition are the playing styles "interaction-orientation" and "system-orientation."

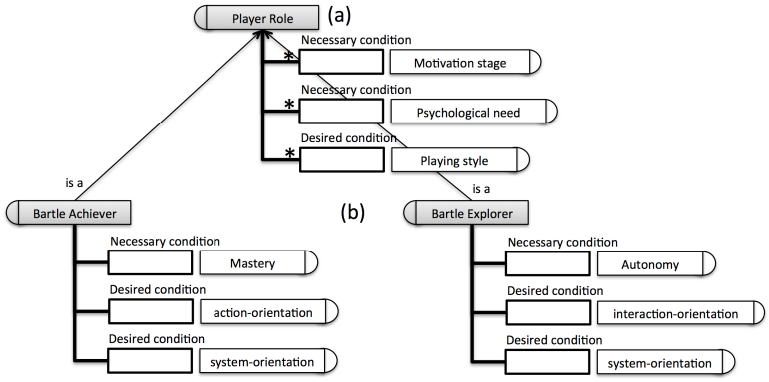

Fig. 5. Ontological structure used to represent player roles (top). At the bottom are the representations for "Bartle Achiever" (left) and "Bartle Explorer" (right).

3.2 Motivational Strategy and Gameplay Strategy

The motivational strategy (*Y<=I-goal*) is a guideline set that defines how a learner can attain his individual motivational goals (*I-mot goal*). In a gamified CL scenario, a game mechanics uses these guidelines to define the proper way of interacting with learners, and this way depends on each player role. For example, if a learner l_a, with player role achiever, and other learner l_b, with player role explorer, are participants of a CL scenario, the learning experience of l_a will be enhanced using a "point system" (game mechanics) when he obtain more points than l_b. At the end of the CL scenario, the learner l_b also obtains points as rewards, but these do not have the purpose of demonstrating mastery. Their purpose can be to unlock some special gift and/or activity in the system to satisfy learner l_b psychological need for autonomy.

Based on this idea, Figure 6 (a) shows the ontological structure used to represent the concept of motivational strategy (*Y<=I-mot goal*). The person in focus (*I*) is playing the player role *I-player role*. The other learner (You), who is interacting with the learner in focus (*I*), plays a role known as *You-player role*. Finally, the motivational strategy benefits, for learner in focus (*I*), are represented in terms of individual motivational goals (*I-mot goals*).

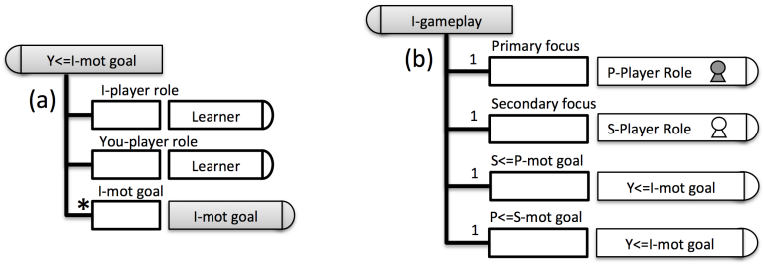

Fig. 6. Ontological structure used to represent motivational strategies (left). Ontological structure used to represent gameplay strategies (right).

As discussed before in the first part of this section, the main goal of a gameplay strategy (*I-gameplay*) is to define the rational arrangement among player roles, motivational strategies and game mechanics. Figure 6 (b) shows the ontological representation used to represent gameplay strategies. The arrangement defined by a gameplay strategy has the purpose of representing how different player roles have the potential to affect each other. Thus, in a particular strategy, the primary focus is a learner (*P*) that plays the primary player role (*P-Player role*), the secondary focus is a learner (*S*) that plays the secondary player role (*S-Player role*), and, for both (*P* and *S*), we define the motivational strategies *S<=P-mot goal* and *P<=S-mot goal*.

3.3 Gamified CL Scenario

Figure 7 (a) shows the ontological structure developed in this work to represent a gamified CL scenario. It extends [12, 13, 16] and consists in the adequate connections of all the concepts presented in the previous subsections. The concept *Gamified CL*

Scenario adds two parts to the concept *CL scenario*, including the motivation strategy and the gameplay strategy. The motivational strategy (*Y<=I-mot goal*) is related to the learning strategy by the relationship "*enhance*" and each player role (*I-player role* and *You-player role*) defined in this strategy is related with the concept of *Player Role*, Figure 7 (b). The concept of gameplay strategy (*I-gameplay*) showed in Figure 7 (c) is included in the gamified CL scenario to define: the proper game mechanics (*what use*) that can be used by learner (*I*). Each game mechanics includes a set of game dynamics (*gameplay*) in terms of game rewards (*rewards*) that will be used during the scenario execution.

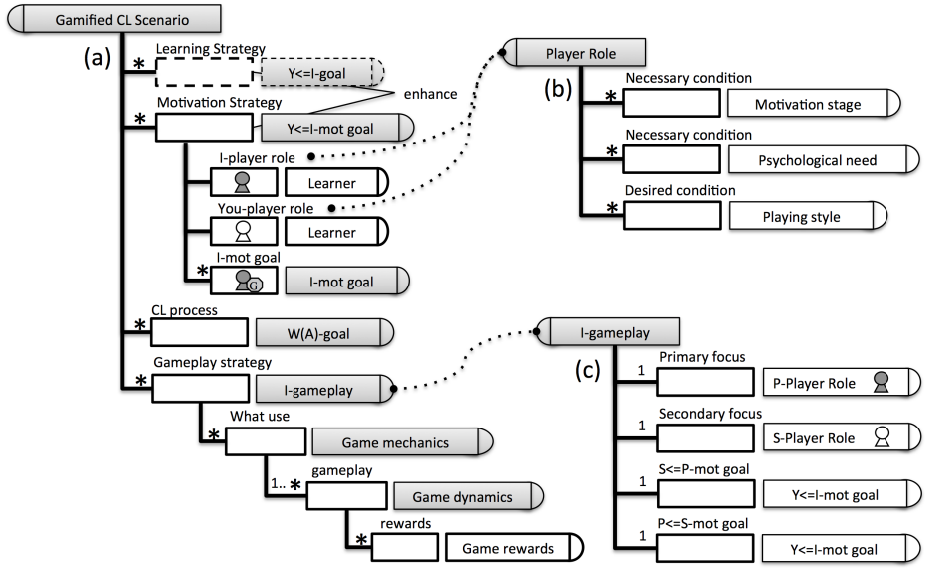

Fig. 7. Ontological structure used to define a gamified CL scenario

4 Illustration: Define a Personalized Gamification Model

To demonstrate the utility of our approach, the ontological structures, shown in previous sections, are used to define a personalized gamification model based on some ideas extracted from Marczewski's[1] blog. He is a leader and expert in gamification.

We begin defining eight player roles, with the information shown in Table 1. These player roles expand Bartle's player roles (socializer, explorer, achiever, and killer) through the addition of intrinsic motivation stages as a necessary condition to play the roles: socializer, free spirit, achiever, and philanthropist.

[1] Website: `http://marczewski.me.uk`

Table 1. Player roles defined in Marczewski's blog

Player role	Necessary and desired condition		
	Psych. need	**Motivation stage**	**Playing style (ind. trait)**
networker	relatedness		interacting-orientation, users-orientation
socializer		intrinsic motivate	
exploiter	autonomy		interacting-orientation, system-orientation
free-spirit		intrinsic motivate	
consumer	mastery		acting-orientation, system-orientation
achiever		intrinsic motivate	
self-seeker	purpose		acting-orientation, users-orientation
philanthropist		intrinsic motivate	

In our model, for each player role, a motivation strategy and a gameplay strategy are defined, using the information shown in Table 2. The values *You-player role* and *S-Player* are default values that are defined in the ontological structures for motivational strategy (*Y<=I-mot goal*) and gameplay strategy (*I-gameplay*).

Table 2. Motivation and gameplay strategies for Marczewski's player roles

Motivation strategy		**Gameplay strategy**	
I-player role / You-player role	**Motivational goal (*I-mot goal*)**	**P-Player Role / S-Player Role**	**Game mechanics (*what use*)**
Networker role / *You-player role*	satisfaction of relatedness, internalize motivation	Networker / *S-Player*	Social Status, Point System, and Badges System
Socializer role / Socializer role	satisfaction of relatedness	Socializer / Socializer	Social Status, and Social Connections
Exploiter role / *You-player role*	satisfaction of autonomy, internalize motivation	Networker / *S-Player*	Point System, Virtual Goods System, and Badges System
Free-spirit / *You-player role*	satisfaction of autonomy,	Networker / *S-Player*	Unlockable System, and Customization Tool
Consumer / *You-player role*	satisfaction of mastery, internalize motivation	Networker / *S-Player*	Virtual Goods System
Achiever / *You-player role*	satisfaction of mastery	Networker / *S-Player*	Quests System, Point System, and Exclusive Reward System
Self-seeker / *You-player role*	satisfaction of purpose, internalize motivation	Networker / *S-Player*	Leaderboard, Badges System, and Exclusive Reward System.
Philanthropist / *You-player role*	satisfaction of purpose	Networker / *S-Player*	Gifting System

Employing the motivation strategies and the gameplay strategies, shown in Table 2, we defined eight ontological structures to represent the gamified CL scenarios (for networker, socializer, exploiter, free-spirit, consumer, achiever, self-seeker and philanthropist), using the structure shown in Figure 7. For example, Figure 8 (a) shows the ontological structure used to represent a gamified CL scenario for a socializer, where the roles of learner on focus (*I*) and of participant (*You*), who is interacting with the learner (*I*), are Socializer roles, Figure 8 (b). Next, the gameplay strategy (*Socializer gameplay*), shown in Figure 8 (c), is used in the gamified CL scenario for a socializer (Figure 8 (a)) to define, as proper game mechanics, the tools: social status and social connections.

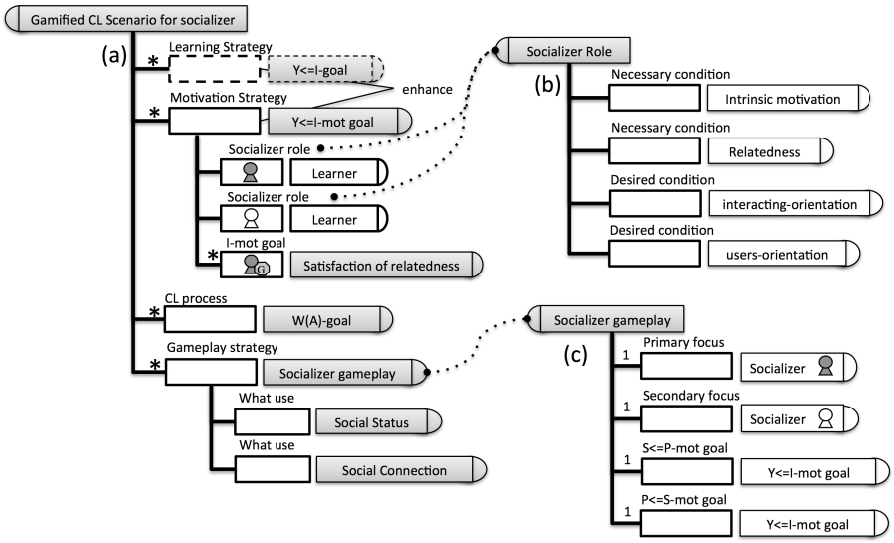

Fig. 8. Ontological structure used to represent a gamified CL scenario for socializers

4.1 Pseudo-algorithm to Define Proper Player Roles and Game Mechanics

Employing a personalized gamified model, the next procedure is defined to identify the proper player roles and game mechanics for all learners in a CL scenario.

1. Match the individual motivational goal, for each learner, by looking at the *I-mot goal* in all gamified CL scenario. The result usually has more than one scenario that can help to internalize motivation and to satisfy basic needs.
2. Check if learners have the necessary conditions to play the game roles for the CL scenarios obtained in step (1).
3. Set the game roles, obtained in the step (2), for each learner according to the priorities calculated using the desired conditions that were satisfied. Learners with all satisfied conditions have high-priority, and learners with only necessary conditions have low-priority.

4. Finally, after the game role definition, set the gameplay for all learners. This task is completed through the selection of proper game mechanics for each learner defined in each gameplay (I-gameplay).

4.2 Gamifying a CL Scenario Using the Personalized Gamification Model

The pseudo-algorithm, defined in the previous subsection, can be used to gamify a CL scenario using the information of individual traits, current motivational stage and motivational psychological needs that is extracted from all learners. Thus, to illustrate how to gamify a CL scenario, the learners' information of a fictional CL scenario, shown in Table 1 is used. In a real scenario, this information can be obtained through a Bartle test [2] and a test of self-determination theory [1].

Table 3. Learners' information in a CL scenario

ID	Gameplay style	Motivation stage	Psychological needs
l1	acting-orientation, system-orientation	Intrinsic	mastery
l2	interacting-orientation, users-orientation	Intrinsic	relatedness
l3	acting-orientation, users-orientation	Amotivation	purpose, relatedness
l4	interacting-orientation, system-orientation	extrinsic (external regulation)	mastery, autonomy
l5	interacting-orientation, system-orientation	extrinsic (identified regulation)	autonomy, purpose
l6	interacting-orientation, users-orientation	extrinsic (external regulation)	relatedness, autonomy

After the execution of the procedural steps, defined in Subsection 4.1, Table 3 is obtained. In step (1), the gamified CL scenarios for socializer and networker can be used by learner *l2* to help him in the satisfaction of relatedness needs, while the gamified CL scenarios for self-seeker and networker can be used by learner *l3* for satisfaction of purpose/relatedness and internalization of motivation (amotivation) needs. In step (2), the player roles for *l2* that satisfy the necessary condition are socializer and networker, and the player roles for *l3* that satisfy the necessary conditions are self-seeker and networker. In step (3), the highest role that can be played by *l2* is socializer because his playing styles are interacting-orientation and users-orientation, while the highest role that can be played by *l3* is acting-orientation and users-orientation. After step (4), the player role for *l2* is not socializer, the player role assigned to him is networker. We cannot define a gamified CL scenario for socializer, because does not exist another learner that can play the socializer role. Finally, after the groups are created, the gameplay is defined and game mechanics are defined for each learner, as shown in Table 4.

Table 4. Player roles and game mechanics for learners in a CL scenario

ID	Player role	Game mechanics
l1	achiever	Quests System, Point System, and Exclusive Reward System
l2	networker	Social Status, Point System, and Badges System
l3	networker	Social Status, Point System, and Badges System
l4	exploiter	Point System, Virtual Goods System, and Badges System
l5	Exploiter	Point System, Virtual Goods System, and Badges System
l6	Networker	Social Status, Point System, and Badges System

5 Related Works

In the literature, there are many gamification frameworks [7, 9, 10, 19, 22, 25] that are applied in different contexts, situations and scenarios. In the education field, Zagal [26] have proposed abstracting and cataloguing patterns in order to provide a set of reusable design elements and a language for discussing them. Furthermore, Domínguez et al. [9] and Simões et al. [22] proposed gamification frameworks that help instructional designers select proper game mechanics based in learners' individual traits. These frameworks were developed employing the relationship between game mechanics and human desire, where each game mechanics satisfies a set of human desires.

Our work extends these achievements by proposing concepts in a formal ontology that can be used by humans and computers as patterns and guidelines to define gamified CL scenarios using player roles, game mechanics, psychological needs and individual traits.

Despite the growing number of studies and applications of gamification in the field of education [4], to the best of our knowledge, this is the first ontology that enables humans and computers to find, share, and combine information related to CL scenarios and game design elements.

6 Conclusions and Future Research

In this paper, we presented an ontological structure that enables the representation of gamified CL Scenarios. This structure allows the development of personalized gamified models. The personalization of this models is archived through the rational arrangement between *motivational strategies* and *player roles*. To demonstrate this personalization, in the Section 4, we performed the organization of the knowledge related to eight scenarios. This knowledge allows the selection of proper game mechanics for each learner based in his psychological needs and individual traits.

We believe that the results of this work are the first steps forward for creating new semantic web authoring tools that can provide assistance for the development of more engaging and motivating CL scenarios. With well-grounded instructional designer knowledge about gamification, our ontology will be used to facilitate the inclusion of game mechanics, through the pseudo-algorithm proposed in Subsection 4.2.

In the current version of our ontology, we did not define the game dynamics that personalize the reward systems for each learner. Thus, our next steps will consider how this game element must be formalized according to our ontology. Furthermore, it is also important to identify what is the association between game mechanics and CL interaction patterns defined in [12, 16]. Future research will also consider the inclusion of optimal flow theory [3] and meaningful gamification [19].

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